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International Association of Research Organisations for the Printing, Information and Communication Industries

Advances in Printing Science and Technology

Volume 30

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of the 30th International Research Conference
of the International Association of Organizations for
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Preface

This volume contains 26 papers presented at the 30th IARIGAI Research Conference, held in Dubrovnik-Cavtat, Croatia, 7 - 10 September 2003. In order to avoid undue delay in publication and to make the proceedings available as soon as possible, the papers are here presented as they were submitted to the conference, with only minor editing regarding typography and layout. The papers have not been reviewed with regard to content, nor have they been linguistically edited.

This volume differs slightly from the material presented at the conference. Those contributions which were available to participants only as power-point presentations or OH-pictures, without any text, are not included.

In addition to the papers presented in the various sessions, the conference concluded with an Open Forum in which a small panel of speakers introduced an open discussion amongst all the conference participants on the topic of The Future of Printing. The comments made in this forum are not, however, documented in this volume.

The conference was enthusiastically and professionally hosted by the Faculty of Graphic Arts in the University of Zagreb, and IARIGAI thanks the members of the faculty and the organising committee for all their efforts to ensure that the conference was a success in both a technical and a social sense. The blue waters of the Adriatic provided a memorable background.

J Anthony Bristow
Technical Secretary

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Facing new challenges

The collapse of the fundamental principles of printing

An essay on the evolution of graphic communications

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Abstract

Many questions have been put forth before those involved in the printing business. There was a coarse step taken in the field of printing some twenty years ago by implementing DTP. Today's innovations with CTP are taken and implemented more soberly. The new questions demanding answers are: Why should the fundamental postulations of printing be changed? How many investments are needed in the further integration with the printing presses, for instance? Are new patents useful or harmful for stable print production? Will today's marginal printing business survive only in specific fields of implementation or is it the very core of dissolution of fundamental postulations of printing? Is hybrid printing necessary in order to comply with market requirements or to survive competition in the market? Do digital systems expand the assortment of graphic products? These questions point out to the fact that traditionalism is beginning to break down. Old-fashioned printers are not used to digital techniques that are being implemented into all segments of graphic art, believing that by some kind of Guttenberg's blessing they are protected from and immune to electronic innovations. On the contrary, it is necessary to unite in business, and be set free from the printing guild. The term *integration* is not discussed here only in the sense of binding organisations and equipment inside the printing presses, but also as accepting all the other systems merging with computer technology. We are talking about the integration of the printing with multimedia applications, e-business, digital kiosks, in order to comprehend that it is the only way to protect and preserve the culture of graphic arts.

1. Introduction

The future of graphic arts includes and insists on implementing XML technology, digital printing, the printing product's individuality, integration of the complete process beginning from prepress, press, postpress and delivery processes. The XML technology is put forth as the number one topic of discussion because it will be the one uniting the alterations made, the development, as well as the future of printing. Computer technology allows individuals to create their own products by using digital printing. Digital printing as a new media is a very powerful motivating means for mass designing of graphic products. In future printing will enter a new area and is not, as was thought, in the decline of it's development, but is in expansion of it's most diverse implementation that could not be even dreamed of without computer technology. The basic principals of conventional printing meaning strict classification of printing technologies, occupational nomenclature, techniques that were incompatible with one another, are shaken by the invasion of digital technologies, allowing multiple printing implementations, manifold integration in all phases of a graphic product's manufacture. Information on planning future printing industry alternations is available through the Internet and they are the initiators of ideas on development paths and patents, having as a goal the expansion of printing methods and technologies. Clarification through polemics on the future of printing is taking place all over the world, dissolving the conventional printing by introducing as it's central core knowledge acquired through other kinds of fundamental research.

2. Computers

Studies of the present state and development of printing are described in many reports as the results of questionnaires answered by people, professionals and speculators on the essence of today's technology providing us with data on the situation now. Investigation should be initiated with thesis on the correlation of variables from two groups: computer science development on one hand and digital technique application in graphics art on the other hand. Regretfully, many reports skip this kind of approach, because until recently printing presses did not depend directly on computers and open types of software. Computer development and it's application have a sufficiently long historical path of development that may be used as a sign for events in the near future. The exponential growth shows a strictly straight line in the logarithmic interpretation. From this point it may be seen that the variable describing the computer speed increases twofold every 31 months. The computer memory increases twofold every 21 months and discs that are double in size increase twofold every 16 months. As these variables have been functioning in such a manner for 25 years now, we must believe that we shall have the same results in future. All activities that have not been included in this trend, graphic arts, for example, are taking part in it now with their specific requirements and are continuing according to their own exponential growth coefficient. By itself this factor is functioning in dissolving the conventional printing processes by founding a new system, whether this is wanted for or not. Let's correlate Internet and wwweb server spreading with this computer development. The two variables have been increasing twofold in the world in the space of just 13 months. For comparison's sake, there will be more servers in 8 years than there are inhabitants on our planet. This shows a completely different relationship of information practice, including graphic art products. There are tasks set before the printing business industry and before the equipment producers not in order for the printing business to survive, but to make people understand how printing is a necessity and is an integral part of the computer science. However, the variables in exponentional value should be in full correlation with computers science and computer technology.

Following this paper let's initiate less restricted deliberations on graphic art future, as we do live in times when wwweb technology alters information systems to their very core. This also alters the essence of the printing industry existence. Regretfully, information science has adapted and tied down computer science to a great extent in schools and in practice. Luckily, the printing industry has embraced computers as its tools, robots, and now even as systems, carrying all production processes. It might be said that JDF has saved the printing business, but I would be braver if I said that the XML technology has allowed for modernisation and the connecting of the printing production into an overall modern information science society. This technology has taken the printing business to a higher level of organisation, production, robotics, and has integrated it fully with the standard information science technologies. This integration carried out by the XML technology is a closed world of an information science network functioning where everyone is needed, the printers as well. Computer technologies have also brought their negative components into the printing business: they are quickly out of date. All computers, even those that are around twenty years old, could be functioning with no servicing, but there are no software or hardware adjustments or additional parts attached to them that could make them work and be competitive with today's computers. The efficient combination of electronics, programs and techniques in the printing press calls for our attention in respect to constant alterations that need to be made as to the printing press's units (quality and quantity). I would like to stress the point that the same as today, neither will there be any possibilities in future of attaching additional parts to our machines, thus making them up-to-date with innovations coming from the CIP4 world.

3. Start with prepress

3. 1 Digital photography has matured for the printing business and has been fully accepted not only in the newspapers industry but also in the demanding commercial printing. The applicability of

commercial digital cameras has been acknowledged, as well as the merging of digital photography and conventional reproduction photography. Photograph and portrait production in photographers' shops as well as web application, have turned to digital photography completely. It is the very moment when there are no objections from the printing industry to these novelties. The developing trend of digital cameras is even faster than computer development, so it is expected that in the very near future digital photography will be fully implemented in the print production. As this powerful trend will continue, there should be discussions organised on the fundamental changes in application of photography, archiving, colour management, data bases control and imaging materials research. Despite the fact that conventional reproduction photography has gone through a total downfall, digital imaging is widely accepted only because the quality has proved to be satisfactory enough at a reasonable price.

Colour management has become an important topic when designers from the modern "creative industry" asked for their electronic entries to be printed out and to be realised in various plants, in small editions, then in industrial presses in large editions, and with various machines: trial print, offset print, inkjet, toner printer, sublimation, screen printing. All the listed jobs should be the same as seen on the computer screen by the author of the design. New printing technologies, new materials, new applications are expected in future, and this only means that colour management software will be a topic of growing importance in graphic art. Not only printing, but web design has also gone to areas reserved for graphic art only. It is necessary to cover all visual technologies with the colour management theory, because it is the same people who are performing different jobs: graphic prepress, proof-printing, conventional printing, digital printing, web presentations. The importance of colour management research is not evaluated properly yet, although printers are aware of the need for standardisation.

3. 2 Marketing and design. Managing printing production means taking up the graphic designer with the aim for him to be present at the actual printing time. A very close co-operation is proposed, and a much more open, more cooperative relationship between the printers, product designers and end-users. The production process control is becoming a standard. The on-coming telecommunication will enable remote on-line control of printing as to quality. Monitor calibration will be interactive and adapted to the situation in the printing process. Designers are giving a new life to products: new formats, get up and binding; products are redesigned to be electronic ones. Electronic wwweb art of printing will influence graphic design. The modern reader will expect good typographical designs in other types of media to be applied in printing. This means new arrangements, new typography, a new way of reading books. The electronic media flexibility is breaking up old graphic rules. New design is encouraged by contemporary instruments: digital printing, digital cameras, software with stochastic elements, a rich variety of filters to simulate actual visual phenomenon, the creating of new values in the field of visual art. Digital printing allows market experimenting, research of the reaction to new products, printing of editions that will not ruin the publisher. Simulation of publishing, printing and product placement with old prints offers a more substantial proof of success and risk test than theoretical market research.

3. 3 Telecommunications and the XML technology will provide two new features in prepress: Client/Server computation and workgroup applications and sharing across the network. Firstly, prepress departments will have on-line accessibility to world wide relation image bases and lay-outs for standardised processing. Processed material will be extracted from the image archive, adjusted to the parameters of the printing presses. Furthermore, the major part of complex reproduction photography solutions will take place in a remote manner in big *host* graphic arts computer centres through client/server computing techniques, with renting or leasing computer facilities. This is the pathway to standardisation in print production. Together with the request for final adjustment of a printed product, data on parameters and printing machines will be sent, so as to form optimal CTP and other CIP4 system entries in the printing press. Today's usual communication speed with printers amounts to one Mbit/sec. If we determine to enter an interactive remote adjustment, available is also the dedicated T3 internet connectivity at 45 Mbit/s.

4. Printing machines and investments

Printers have become nervous in respect to investments needed to implement new technologies. They are first considering how to attach new electronic components to the existing installations. They understand that it is inevitable to alter the plate production technology, and they are purchasing CTP units on a large scale. After ten years of suspiciousness in respect to digital printing, printers have finally accepted the fact that they must have such new units in order to comply with specific requirements: individualization, proof copies, application of new prints as for instance printing large-format matter, printing with non-standard materials, etc.

Printers are very slow in considering the need to make investments. Their cautiousness is seen from their low-based criteria. Firstly, they are considering to improve their existing machines by enhancing automation and adding attachments for special printing. Further on, after noticing how successful their neighbor's CTP-s are, they are purchasing CTP-s of their own. Thirdly, after a very successful era of computed prepress with application of many colors, printers are equipping themselves with multicolor presses. Contrary to these modest investments, a much braver step would be to comprehend that new equipment will be successful only if it has a well defined relationship with the XML technology.

At the beginning of the digital printing era new development programs were put forth by large printing press producers in a most aggressive manner. As a result today one may read millions of reports on how successful the "Big 3" are.

1. Heidelberg digital print solutions named best products of the year by BERTL , The Heidelberg Digimaster 9150i print system was named the best high-end monochrome CRD device - following in the footsteps of the Digimaster 9110 system, which won the award in 2002.

   The Heidelberg Digimaster 9110m system for Magnetic Ink Character Recognition (MICR) printing and the Hole Puncher 9110 were recognized for outstanding innovation and design, high-end CRD devices - and both cited by BERTL as being "revolutionary."

   (http://members.whattheythink.com/allsearch/article.cfm?id=12147)

   Digimaster 9110m Network Imaging System features magnetic ink character recognition (MICR) toner and special fonts and characters for a variety of applications, including printing checks, rebates, coupons and other financial documents.

2. New Komori has developed a true digital workflow, with the press at the center of the digital network. Komori understands that such a network requires two elements: an open architecture that can expedite the smooth integration of new technologies, and support for a workflow that facilitates interactive communications, rather than just passing prepress printing data and the job ticket to the press. Komori's Digital Open Architecture Network, or DoNet, encompasses these two elements.

   (http://www.komori.com/contents_com/product/p_top.htm)

3. We print on any material. Whether selfadhesive film for advertising and construction site signs, labels, translucent films for neon advertising, films with a non-slip protective laminate for floor advertising, fabric for flags and advertising banners - digital printing guarantees printed quality of lasting light-fastness.

   http://www.roland-werbung.de/english/digitalprint.html

   By collaborating with Xeikon N.V., Mortsel, a leading manufacturer of digital printing systems, MAN Roland Druckmaschinen Group has made a significant move towards digital printing. This partnership enables faster development of a strong sales and service organisation for digital printing in the market. In the sense of customer satisfaction, Xeikon-Machines supplements with its facilities for print variable data, the newly developed DICOweb, which was exhibited in drupa 2000.

   (http://www.man-roland.com/en/p0097/p0103/p0105/p0047/p0047.jsp)

   DICOstream is the intelligent processing and automation system from MAN Roland, which is setting new standards for professional digital printing.

How should one carry on in the midst of these innumerous innovations? Expert consultations are necessary. One should be careful in making large investments into new tools before market research has been completed. The interaction and merging of standards should be studied thoroughly. Changes take place rapidly, the same way as in computer science. It is difficult to go on having the same habit of purchasing printing machines that are supposed to last for a whole generation.

5. XML in print production

The printing business would vanish if it were not adapted to the new era of communication. Most of the printed matter products (books, newspapers, magazines, brochures) would not be competitive because there would be a rapid turn taken towards electronic publishing. In general it may be said that the printing business has survived because it had accepted the JDF/XML solution - the solution for integrating all printing processes.

CIP4 (*The International Cooperation for the Integration of Processes in Prepress, Press, and Postpress*) has published its JDF.1 (*Job Definition Format*) specification, based on XML (*eXtensible Markup Language)*. The most significant capabilities of JDF1.1 are its ability to specify and complete every part of a print job and job workflow from start to finish. Production printing machines are integrated with workflow in order to create a digital workflow comprising prepress, press and postpress. JDF has the aim to comprise all the printing business aspects independent of their type, power and printing machine capacity, networking of all processes horizontal and vertical.

The "big three" press manufacturers, Heidelberg, MAN Roland and Komori have a joint plan on CIP4 implementation on all levels. They are rapidly developing their own strategy. This means that the trust in the printing business sustainability idea is growing stronger. CIP4 brings together vendors, consultants and end-users in the print communications, graphic arts industry and associated sectors, covering a variety of equipment, software, peripherals, and processes. Members participate in focused working groups to define future versions of JDF, to study user requirements, and to design the JDF SDK (www.cip4.org/press info/2003/2003juno5e.pdf)

CIP4/JDF and XML are the strongest factors in building the path of interoperability between the printers, publishers and end-users. (On the other hand one should not forget the existence of strong interoperability between wwweb and XML technology). There is the idea that an "industrial standard XML-based format" is being created. It is too early for this since the XML technology has spread much wider and comprises: wwweb, the Internet, data basis with growing significance having input and output possibilities, all program languages, taking over of instrumental data. By implementing strict standardisation in the printing business, this rapid development trend might be slowed down. All of the mentioned XML quality parameters are widely applicable in the printing business. There could be complex discussions organised on "XML printing" only with a project assignment having the following chapters:

1. consultations between the printers at the very moment of trouble-shooting in: production planning, investments, reproduction material purchase, warehouse keeping, relationship with publishers.
2. remote servicing and machine maintenance during their actual production cycle operation time
3. production managing and planning - experience, the problems, new managing software comprising calculation, the job order, dispatch, analysis, statistics.
4. a network system of intranet and internet in the function of rendering instrumental data from the works
5. a network system of intranet and internet in the function of rendering book-keeping and financial data, managing of human resources, strategic management
6. information on the state of art in graphics art at all times, any place
7. expert advice in the actual production time

This is mentioned because the XML technology has offered it's data bases solutions, but is also accepting all the old systems such as: Oracle, Informix, MicrosoftSQL Server, Microsoft Access. XML is fully open to new patents in printing, associated with wwweb oriented data bases.

Numerous JDF products have been offered. The exponential growth of the new product quantity will bring about a situation when there will be programs for every trifle. Printing equipment shows will offer an uncountable variety of new JDF software products. Application will be successful if the JDF/XML philosophy is understood, if there are continuous seminars, promotions, permanent education, active transferof ideas and knowledge, but all of this should take place by using multimedia techniques, and by independent discoveries, research and testing.

6. Individualization

Individualisation expands the scope of printing and allows flourishing of new ideas in respect to jobs that are completely new and the application of which was not possible with the old printing systems. Working out individualised printing (IP) will alter the printing of many products such as catalogues, brochures, specialised literature, scientific literature, especially countries in having a low population number. IP will have to do a lot in the field of layout automation. Libraries of successful layouts are being collected with efforts being made to include standardisation, and this is the opposite to individualisation. Libraries containing layout rules are being made spontaneously, they are multiplied, modified, and they are seeking automatic solutions so as to increase the utilisation of machine and human recourses. Web explorers offer ready solutions according to the "most successful" algorithms, the ones in demand, the ones that are *in*. The same way as fashionable garments, there is fashion in the design of individual printing. The discussions in respect to individualised printing (IP) reminds us first of all about its great success, a *hit*: in making documents IP has made it possible to have digital photographs that are impossible to erase and replace. Individualised printing is a phenomenon that has, together with Xeikon, for example, made way for a new chapter in *graphic arts*. Regretfully, printers are not ready to take over such jobs without relying on the help of computer programmers, who are making a big deal out of it. New printing firms oriented fully to digital printing are somewhat more skilful in taking over such jobs, although only some are capable of organising complex projects, such as, for instance, large scale games of chance or B2B catalogues.

Individualised printing is identified with *on demand* printing, and with one-copy printing performed through *digital Kiosk*. The second type of printed matter is linked with the Internet where the major quantity of printed matter is printed from data bases: e-newspapers, e-books, e-magazines. There will be a rising increase of individual, single printed matter such as department store catalogues, catalogues made for high-class products. All of this is allowed by computerised customer follow-up. It may be expected that special agencies will be founded producing individualised newspapers that will be supplied to dedicated customers. Such customers will subscribe to material of personal interest only, such as, for instance, art criticism from all daily newspapers of that day, because they are not interested in anything else. Individuals could subscribe to sport surveys, stock exchange reports, Middle East politics or many other topics with a level of extension to be programmed for each individual separately. The times have come when the customer's and the seller's personalities will be recognised through well organised rational data-bases. The XML movement has appeared just in time to get the end buyer to actually come to the printing press virtually. The end buyer is a dynamic transaction about who all those in the successful sales, offer, and direct production chain must take care of. Many individualisation themes will be solved through the Internet only. The industry of graphic arts must not miss the opportunity to conquer new markets of individualised printing as the XML technology has been implemented on all levels - from instrumental data in the printing process up to the most sensitive market area. The XML technology is becoming the essential agitator of the printing industry's mass adaptation to the contemporary environment. Computer technology allows

individuals to create their own products by using digital printing and gives them the chance to have their own creations. Digital printing and the new media are a strong motivation means for mass conception of new graphic products. Printing industry is entering a new area and is not at it's decline, as was considered, but is in expansion, having the most diverse application.

7. Automation in printing

There are two phases of contemporary automation in those printing firms that have altered the many-century rules. The first phase was introducing CIP3/4 and has been in the course of implementation for somewhat less than a decade. The second phase is just about to follow and this is implementation of the XML technology with full application of the wwweb service. The main principle of this wwweb automation is the availability of instrument and commercial data everywhere, anytime, any place. The complete data sequence, production instrumental data, data on printing control inside the printing works, communication with dislocated plants, printing enquiries in places not organised for printing - all this is done through wwweb technology. The joint stock company system will be altered as to owner relationships and the feeling of privacy towards the printing works and printing itself.

One of the possible classifications for global, wwweb oriented printing business is the following:

1. printing of products in plants with big machines, large editions; 2. dislocated printing with specialised plants; 3. printing business for fast reaction to small editions; 4. mobile printing firms and 5. personal printing.

There are fiery discussions in the field of electronic publishing as to author's rights. Printing presses and publishers have the same problem in book production: piracy. Holographic marking of each individual product is being applied. A digital book should be *designed digitally* and this means: animated design, questionnaire, interactive connection with the publisher's data base. The digital edition design should initiate the desire to buy many printed books from the same publisher. This kind of approach would expand the publishing business and cause a rise of interest for printed books. Marketing is faced with many options how to invent tricks in keeping a reader's attention: it has the tools coming from digital design and digital graphics on one hand. On the other hand, there is experience in printing design using the advantages of new patents: digital printing, individualisation and new materials, new printing machines sizes, new approaches in colour use. The third advantage is the wwweb and customer data bases, where information on customers' preferences and needs are contained. The conclusion would be as follows: these are the times when books must be read in their digital as well as printed forms, but each of them should be designed applying maximum advantages.

8. Permanent education

Printing works have entirely abandoned stereotype jobs, changed the occupational nomenclature, fired the workers who were unable to adapt to the new electronic era. This has taken place in prepress, and it is going to happen in the press section as well. The need for change has been announced by CIP3 and printer's are forced to adapt to new standards. The oncoming *global printing press* will be a serious blow for the graphic workers' union, resulting in a total break-down of printing technology teaching and process control. Joining networks and remote prepress processing with the Client/Server computation technology allow great opportunities for printing presses to join the global printing industry, and this requires an adequate graphic worker.

Education in graphics arts in the third millenium means constant active improvement, specialising in specific areas, interdisciplinary profiling of experts having up-to-date technological and printing press knowledge.

The contemporary education centres may be criticised for not being rapid in organising new subjects covering oncoming themes in the printing business. For instance, there is no singled out subject on the XML technology with it's application in the printing business. The knowledge acquired by a master's degrees will be a mere foundation to a 21st century graphic professional for systematic, dynamic knowledge and skill accumulation throughout his working lifetime. Transformation is expected in the multimedia, electronic and virtual transfer of knowledge through software and hardware simulators, as well as in forcing of the Internet. An important role of the 21st century educational system is to be flexible and dynamic in the implementation of knowledge on contemporary printing technologies.

9. Conclusion

The printing industry should create additional values, additional offers for clients, services should expand. New innovative solutions are needed. One may say that only innovative printing works will survive. Electronic media are expanding and there is thought this may lead to the decline of the printing industry's significance. It is necessary to open a new type of business regardless of the Internet oriented communications overproduction. Although information is shown more often on the screen than on paper, graphics and printing still remain as information carriers. Printers will raise the quality of their business by refined printing technologies such as, a high level of individualisation, a greater percentage of digital printing or XML transactions. There will be an integration of traditional printing, digital and computer technology. Printing will expand in the field of digital trade, offering through individualisation of printing expansion of basic technologies and will revive the traditionally good relationship between the buyer and the printed matter. Various printing implementations are being developed with multi-pole solutions. The printing idea must go through a period of revived flourishing in its symbiosis with computer technology. The printing industry is acquiring a "global disguise" because there are experts of various profile taking part in it, and due to their specific individuality there is a need for new solutions, new implementations, new integration, new patents. The massive participation in printing practice requires significant innovations in the following: determining standards, communication, invention of new materials, invention of new digital printing techniques, going through the printing process by applying expert knowledge, data basis control, applying innovations that come with the XML technology.

It was not a practice to collect and analyse production data in printing works. Data bases were organised and directed to commercial enquiries, book-keeping, supply control. There is a necessity now to consider more broadly the cycle comprising the printing business, graphic preparation, picture archives and printed matter contents, press and postpress. The use of all kinds of computer information sources based on very different premises are united by the XML technology. As there are new routines and even complete languages developing daily in the XML environment, standardisation is expected with the goal being that printing should take place everywhere, anywhere, anytime. Ahead of us we have a completely open path to a global printing press.

XML is that very point of the printing systems that changes them more there anything else in the history of printing. Nothing will ever be as it used to be.

Media technology outlook

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Abstract

It has been the scope of this strategic project to identify the core technologies, which have a mayor impact on the diversifying media industry in the time perspective of the next decade, i.e. to the end of 2010. Different possible development tracks of these technologies have been analysed; at the same time their probabilities and penetration times have been estimated.

Technology forecasts performed around the world give a realistic comprehension of the trends in technology. According to them, ICT will remain the driving force for technology and economy for the next decade. After that it will slowly merge deeply into different applications.

Data processing and telecommunication speed increases, costs come down, equipment is miniatyrized, battery power increases and information security is improved. Storage capacity and computer power are doubled every 1.5 years according to Moore's law. Storage capacity will obviously reach its theoretical maximum of 400.000 Gbt/in^2 around 2013. Computer power will reach the level 1000 TF in 2006.

The media industry is on one end an integrated part of the ICT sector, and on another end close to the forest sector. The value chain of electronic media is completely digital up to the end user, and that of printed media up to the multiplying (printing) phase. From this point on it is strongly linked to the forest industry.

However, the final role of the media industry in the content value chain of the future is not determined by the technology development alone. It will depend on the estimated business potentials, ownership structures and preferences, which kind of companies and alliances finally will be established. Theoretically any of the players can integrate the entire sector via virtual value chains. This presentation gives an overview of the most likely development paths, and also evaluates the limits of dematerialisation.

1. Introduction

Today the ICT cluster is the edge of the Finnish[1] economy. It had a total turnover of EUR 34,1 billion in 1999 and employed 146.000 people. Hardware production stands for half of the turnover (16,3 billion EUR) and employs 43.800 persons, while the corresponding figures for software and service are 8,6 billion EUR and 42.000 people. The telecommunication service has a turnover of 3,7 billion EUR and 19.000 employees. The media sector, finally, has a turnover of 5,5 billion EUR, but is still a relatively important employer with 41.000 persons. The figures could be compared to those of the Finnish forest industry, who employs 50.000 people and has an export volume of € 13 billions corresponding to 25 per cent of our total export. The total turnover of the Finnish forest industry is € 35 billions.

The three main components of the media sector are print media, electronic media and recorded media. The share of print media (newspapers, magazines, books and printed advertising materials) is 75 per

[1] The total population of Finland is 5,2 millions, of which 2,3 millions are employed.

cent, electronic media (radio, television and on-line information services) 19 per cent and recorded media (phonograms, videos, CD-roms and DVDs and cinemas) 8 per cent.

The dynamics of the ICT sector is based on an efficient utilisation of digitalisation. Digitalisation has its strongest and most direct impact in branches with immaterial products and services. The media sector is one of these branches. Therefore, the media branch is a pioneer. At the same time, it is also a strongly growing sector during the next decade.

The utilisation of ICT technology leads to structural changes across the traditional boarders of branch and market segments. Some hardware suppliers have already become active content providers, and many more intend to come. For instance Sony possesses entertainment business in Hollywood, Philips produces disc records, and Nokia is strengthening its connections to the media and game industries.

One example of connections across traditional branch boarders is the board seat in General Motors offered to the CEO of Nokia. One examples of international cross ownership is the connections between Alma Media in Finland and TV4 in Sweden.

The media branch is strengthening its service functions and customer administration. E.g. the Sanoma WSOY corporation possesses not only distribution channels for printed products - like Rautakirja (kiosks), Leijonajakelu (morning newspapers delivery), and the Academic Bookstore - but also electronic distribution channels, like Swelcom. Moreover, new players are entering the ICT-field, such as finance houses - combining the banking and the insurance sectors -, energy suppliers developing "electric" telecommunications, and electronic commerce. The most successful item in e-commerce is so far the book itself, which is obviously due to the fact that the book is an internationally standardised product and the buyer knows what he will get.

Digitalisation and new telecommunication technologies are essential factors in the development. Digitalised information can easily be revised, stored, compressed and distributed. Not only the production and the way of action are changed, but also the products and the services themselves. New distribution channels, information carriers and terminals, like digital television channels, mobile services and electronic books, offer the end users a variety of new alternatives. Therefore, globalisation is fastest in branches with digitalised products and services. Examples of these are music and financial services in the media branch. On the other hand, the process also shows paradox features, e.g. the most successful item in eCommerce is the traditional printed book.

The spectrum of technologies developed by the ICT cluster increases continuously. The markets have until now been created by technology push, but market pull is growing in importance. The end user is not interested in what technology for data transmission the channel utilises, or the components of the terminal, if only the services are attractive enough in relation to the price, reliable and easy to use.

According to the alignments recently announced by the Finnish Ministry for Trade and Industry a broad use of ICT technology in the entire society is a central national Challenge for the next few years. The core question is to what an extent the traditional industry, the service sector and the public sector will learn to utilise the new technology. Manufacturers of mobile phones, the furniture industry, biotechnology companies, the welfare sector, the forest industry, the judicial system as well as the food industry can all improve their efficiency and extend their services by utilising the ICT technology. It is only essential to identify the technologies with the highest potential for each branch.

An inventory of the technologies - both existing ones, those under development and those just being planned - as well as a multi-angular analysis of the rapidly changing media sector will help the Technical Research Centre of Finland and its units to identify future opportunities and to evaluate their roles in building new solutions for the industry and the society.

It has been the scope of this strategic project to identify the core technologies - also others than ICT -, which have a mayor impact on the diversifying media industry in the time perspective of the next decade, i.e. to the end of 2010. Different possible development tracks of these technologies have been analysed; at the same time their probabilities and penetration times have been estimated. The results have been crystallised in plans for how to take the selected technologies into possession on the VTT level, which includes both specification of strategy, core competences needed, co-operation and directing of research.

2. Technical trends in the media field

According to Japanese technology forecast studies ICT will remain the driving force for technology and economy for the next decade. After that it will slowly merge deeply into different applications, though it remains all the time present. New areas of technology, like life science, environmental technology and energy will get more gravity scientifically, economically and politically, but they will contain the ICT solutions as important integrated elements. This is illustrated in the diagram in Figure 1. The importance has been expressed by an index.

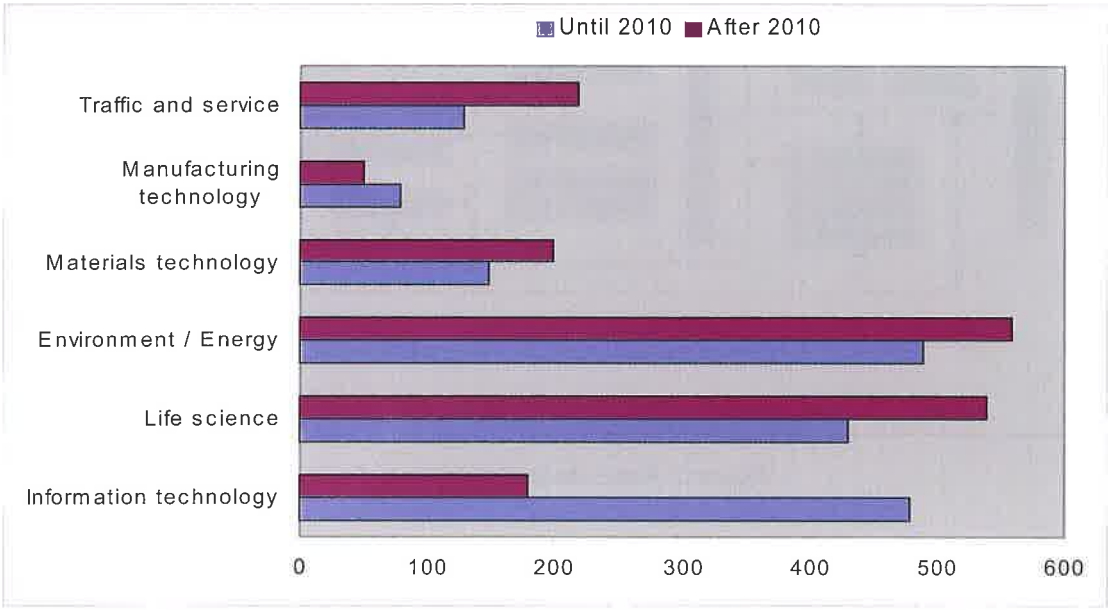

Figure 1: The importance of technologies according to Japanese forecast studies Mamiya (2001)

The two main driving technical forces are the information processing technology and the information transfer technology. In the field of Information Technology (IT), the efficiency has grown rapidly (The Moorean law) at the same time when the prices have been stable, or even declined. The development in the field of Communication Technology (CT) is similar. Development in data transmission technologies, like fibre optics, satellite communication and WLAN, has supported the diffusion of network communication. The technological base behind the progress of Information and Communication Technology (ICT) is the digitalisation of information. Some other development steps, like miniatyrised terminals and durable batteries, have supported the mobility of communication systems.

Data processing and telecommunication speed increases, costs come down, equipment are miniaturized, battery power increases and information security is improved. Storage capacity and computer power is doubled every 1.5 years according to Moore's law. Storage capacity will obviously reach its theoretical maximum of 400.000 Gbt/in^2 around 2013. Computer power will reach the level 1000 TF in 2006.

Content will be created simultaneously for different media and all the content (assets) is in digital format. This is an obvious development trend especially in the large media companies that cover all media channels. In spite of the fact that all different media platforms and information carriers set different requirements for the content visualisation and layout the cost efficiency requires rationalised content production. This is realised by multi-channel editorial offices and new technological tools that support highly digital, multimedia workflow.

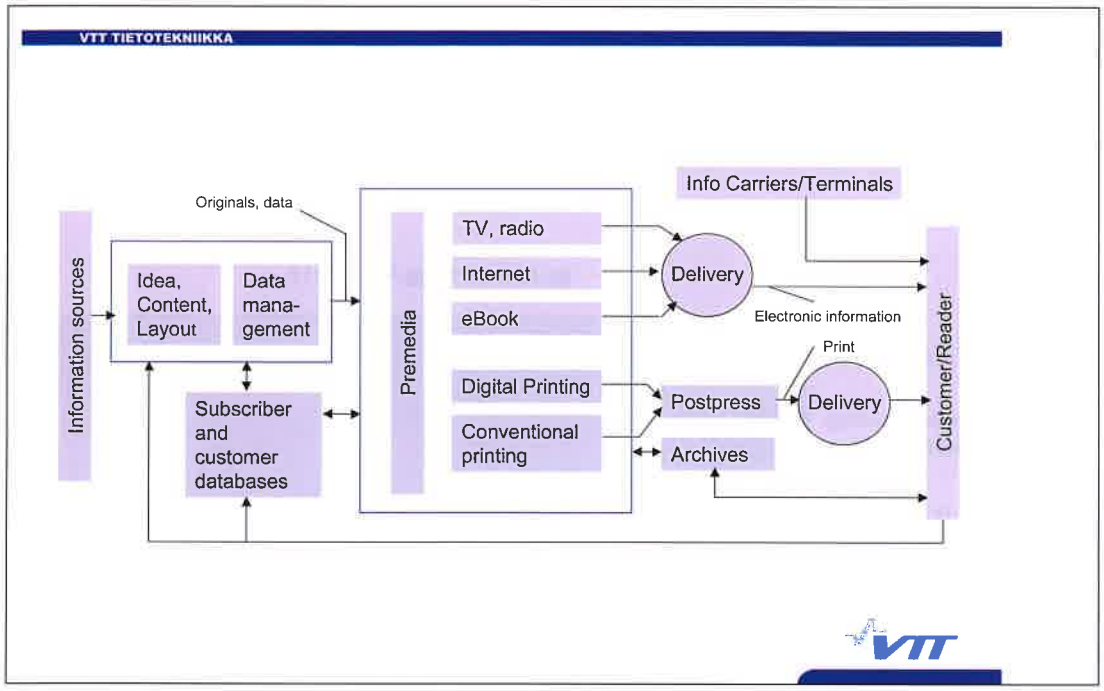

Figure 2: Value chain of multiple media

The workflow will be managed by JDF. The print job will be managed by the web-based systems. Content and digital asset management is based on databases and the reproduction will be completely digital. Automatic colour management gains ground but skilled operators are still required especially in the production of high value products. In certain product types (some digitally printed products, newspapers) the whole production chain up to the printing will be completely automatic.

The printing production chain will be distributed so that premedia processes take place in networked environments supported by intelligent software and the printing itself will be done as near to the end user as possible. Only the mass production will be printed in centralised printing centres, but their number will noticeably decrease.

The only stages that remain physical are printing and finishing processes. High productivity is of utmost importance and sophisticated control systems will be needed to manage these operations which are becoming more and more complex. The demand for shorter runs and targeted, customised products sets high requirements both for the machinery and the materials and methods used. The target values for the productivity and efficiency are taken by benchmarking the best possible companies, which will not necessarily be media companies.

Digitalisation, networking and wireless communications enable the production of new types of electronic publications. For example, most of the daily newspapers in the United States have electronic versions. The layout of printed newspapers has changed to resemble more the Internet version, as an example frames in printed edition. On the other hand, an increasing number of newspaper also introduce e-Newspapers (visually identical to their printed versions), among them The Times in U.K., Keskisuomalainen and Helsingin Sanomat in Finland. Many special magazines, like trade journals, are delivered only by the Internet. Also the archives of libraries are rapidly becoming digitised.

At the moment, most of the electronic publications are read on the CRT screen of a PC, but the developing display and computer technologies enable the manufacture of light, portable information carriers. PDA's, tablet-PC's and mobile digital TV's are examples of new end-user terminals. Programs have also been developed to read electronic books with palmtop and laptop computer.

New technologies are being developed for the production of flexible, thin displays for electronic books and newspapers. The most attractive aspect of these new displays is that they can be manufactured cheaply from low-priced materials. Some of them are called electronic paper, because they aim to have the same convenience, lightness, readability (angle-independent readability), whiteness and contrast as conventional paper, and even a similar touch and look. The other advantage of electronic paper is that it is also a memory display using very little electricity.

The ultimate goal is to develop books or newspapers, which look like traditional publications, but can be erased and re-written. An electronic newspaper could be re-written at night, and you could take it with you in the morning. New technical solutions are needed for electronic books to produce the same reading enjoyment as traditional books do. The many financial benefits for publishers, consumers and writers will promote the development.

The most important digital printing methods are electrophotography and ink jet. The basic principles of these methods were invented over a hundred years ago, but the final breakthrough came in the computerised office environment. In conventional printing, basically, all the copies contain the same information. In digital printing the image is generated without an original, straight from a computer. The benefit of this is that every printed sheet can be different. There are several applications, which can only be executed by using digital printing:

1. Short runs are economically viable.
2. Printed products can be customised, personalised and coded individually.
3. On demand production is feasible.
4. Distributed printing is possible but expensive at the moment.
5. Easy updates can be produced.

It took thirty years to develop a digital printing press based on ink jet principles - the first model was commercially released in summer 2001. Ink jet printing is the only non-contact printing method and because of this, it is the most ideal of all the printing methods. As an example a 360-page book can be printed in 8 seconds (year 2002). Also, multicolour printing can easily be carried out as the different process colours can be ejected directly onto the printing surface.

Table I: The present level of DP technologies

Printing method	Maximum speed	Resolution
Electrophotography	4000 double sided A4 sheets/h (0.17 m/s)	800 dpi
Continuous ink jet (CIJ) technology	2200 pages per minute (9 m/s)	300 dpi
Drop-on-demand (DOD) ink jet	1 m/s	600 dpi

At the moment, more than 10 % of all printed products and less than 20 % of books are produced by using digital printing. It has been predicted that digital book production will reach 30 % share of total production in 2003. Moreover, it has also been forecasted that more than half of all printing will be digital globally in 2015. The main reason for the slow increase in market share is that the printing costs of electrophotographic digital printing are much higher than in conventional printing.

The printing costs of high-speed ink jet printing are only one tenth of electrophotographic printing, and this cost ratio may even increase in future. It can be assumed that ink jet printing will replace electrophotographic printing, when the technology reaches the same image quality level - and this will happen in the near future. Drop-on-demand ink jet printing has already become the most dominant technology in high quality low end printing, so it can be predicted that ink jet systems are the technology of the future, especially in high-speed digital colour printing applications.

3. Restructuring in the media sector

3.1 The future media products and services

Media is our interface to the society. Its social, cultural and educational importance is strong. Nowadays the media industry is on one end an integrated part of the ICT sector and on the other close to the forest sector. The value chain of electronic media is completely digital up to the end customer and for printed media up to the multiplying (printing) phase. The proportion of electronic communications in mass media is increasing slowly but surely. Printed media will anyway dominate the market economically (though not in terms of time spent by consumers) still for a long time. The audience will be fragmented and the number of products and services will be increased and more and more targeted. Advertising is a very important source of finances now and in the future.

The new value chain enables multiple use of the content on a variety of "information carriers" after storing in a generic and structured form, processing and delivery. The media convergence also enables the integrated use of different media (hybrid media) to the consumer, and an optimisation of the media choice according to content, target group and consuming situation. The Internet has been the core of the integration.

Printers have to develop their products and services in order to serve the customers better by integrating themselves into customers' value chain. This can include database services for the customer's content and asset management, interactive services connected to the printed product and services concerning logistics. Value can also be added by developing new characteristics and features of the printed products themselves. The total quality of a printed product is a far more complex question than technical quality.

"Traditional" media products - be it a print product, a television program, or a movie theatre film - are non-interactive in the sense that the user (reader/watcher) cannot influence their content or appearance. Web-based services - on the contrary - are by their nature interactive, because the user is all the time actively selecting the content.

Supplying traditional media products with web extensions can create a clear additional value. Almost every print newspaper has nowadays a web site, which offers the web version of the daily newspaper. Up-to-date online news is also very common. In addition, the web site may provide access to archived issues or articles of the newspaper as well as to the content that has not been published in print. Big newspapers, like Aftonbladet in Sweden, also offer audio and video clips. Voting about news related issues is also common as well as catalogue services covering e.g. housing and cars. Discussion forums are not so common on the newspaper side.

Newspaper and television journalism is expected to become closer to each other as their web extensions grow in importance. However, the two forms of journalism will retain their distinct characteristics, since print and television appeal to different human needs.

As a result of the development in video capturing and multimedia editing and the web development it is probable, that broadcasts in audio and video over Internet will become more common during the coming years. The great spread of webcams is an example of this. Events like junior plays in ice hockey can be broadcast over the net, even if the potential audience can be counted in tens, because the costs are low enough.

Digital television is currently mostly one-way, because the return channel over the phone line or cable is by the rule missing. This is true even if the two-directional technology has been with us for years, primarily in satellite and cable broadcasts. The missing return channel has made it impossible to offer Internet services over television. Over all, it is an open question, how interactive a television watcher wants to be - television is after all "lay back" medium, whereas the interactive PC is a "lean forward" medium.

The media landscape has changed a lot during the last ten years. Developments will result in new applications in media technology, such as mobile multimedia services, including mobile television, integrated media products and services, digitally printed tailored newspapers, manufacturing of electronics using printing technology, intelligent systems for production and distribution of newspapers and other printed products and systems for colour management and quality automation.

Technology for creating, storing, editing and distribution of content and managing languages will open new possibilities for innovative new media products and service forms to reach a global market in a short time period. On the other hand, it will be harder to be observed in the information overflow of the new Attention Economy. What is needed, is sophisticated services and attractive content to all the consumer groups and subgroups, and elegant wraps for communication systems. The growing demand of attractive content means that the importance of the media industry will increase.

3.2 Restructuring of the media company

The most critical challenges to the media industry today are the demand on rapid structural change, over-capacity in the printing sector, ability to create new business models and increase the efficiency of the business processes and the ability to develop new, attractive products and services. This requires significant investments in research and development, but also in training and education. Without these investments there is the threat that the media companies will have a lack of technical and strategic knowledge, and will be completely dependent on extern suppliers.

Outsourcing is ideal solution to combine the brand of big company, and the flexibility of small companies. The shipbuilding industry e.g. has long time followed this strategy. The small subcontractors are very effective and flexible utilising the work force. The car industry has great and established brands, but as a matter of fact, most of the car factories are assembly plants. The components are produced in specialised factories outside the big car factories.

In the media industry publishers have outsourced the production processes for a long time already. In the printing industry outsourcing is increasing as well. For instance, in some printing factories service and maintenance is outsourced, as well as some special operations like finishing. There are also firms, which take care of digital asset management and file transmission. Small subcontractor companies are really excellent buffers against conjunctures. However, the dynamics of product architecture and value chain structure is by no means a one way or an irreversible process. Professor Fine at MIT has studied the dynamics and found the structure of the product to develop between modular and integrated, and

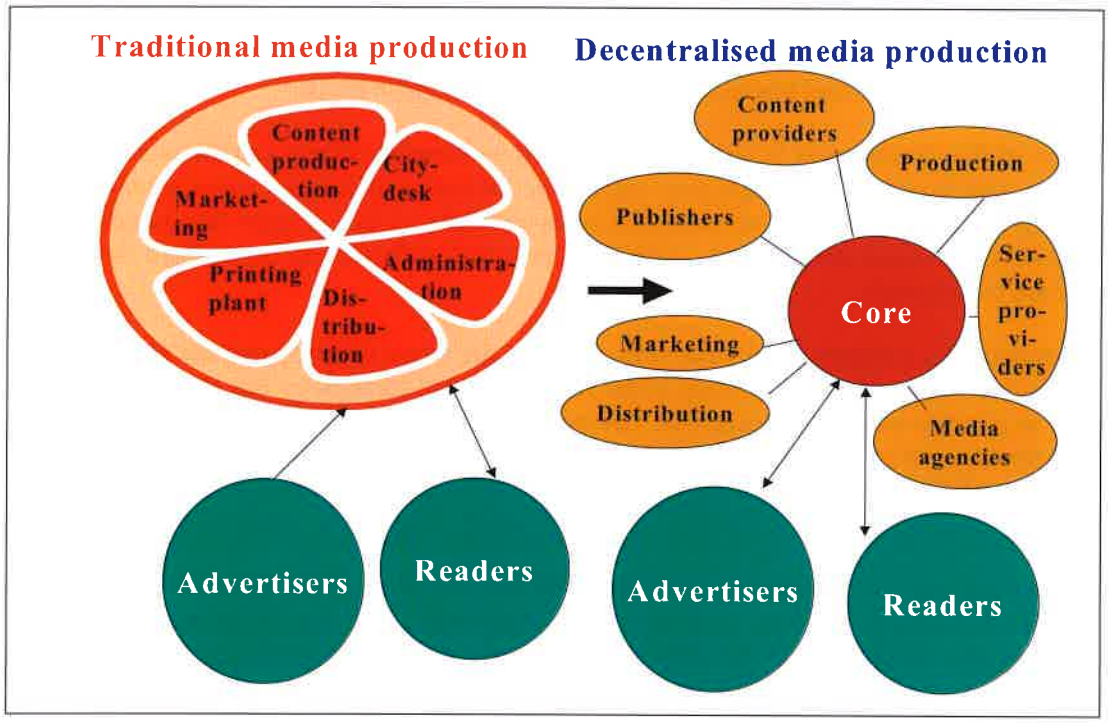

Figure 3: Will media production in the future be totally outsourced? Who will take the core business?

the structure of the companies to vary between horizontal and vertical with time. This is caused by pressure to integrate and to disintegrate in order to reach better flexibility and independence from suppliers. An example of his findings is given for the wireless marketplace in Figure 4.

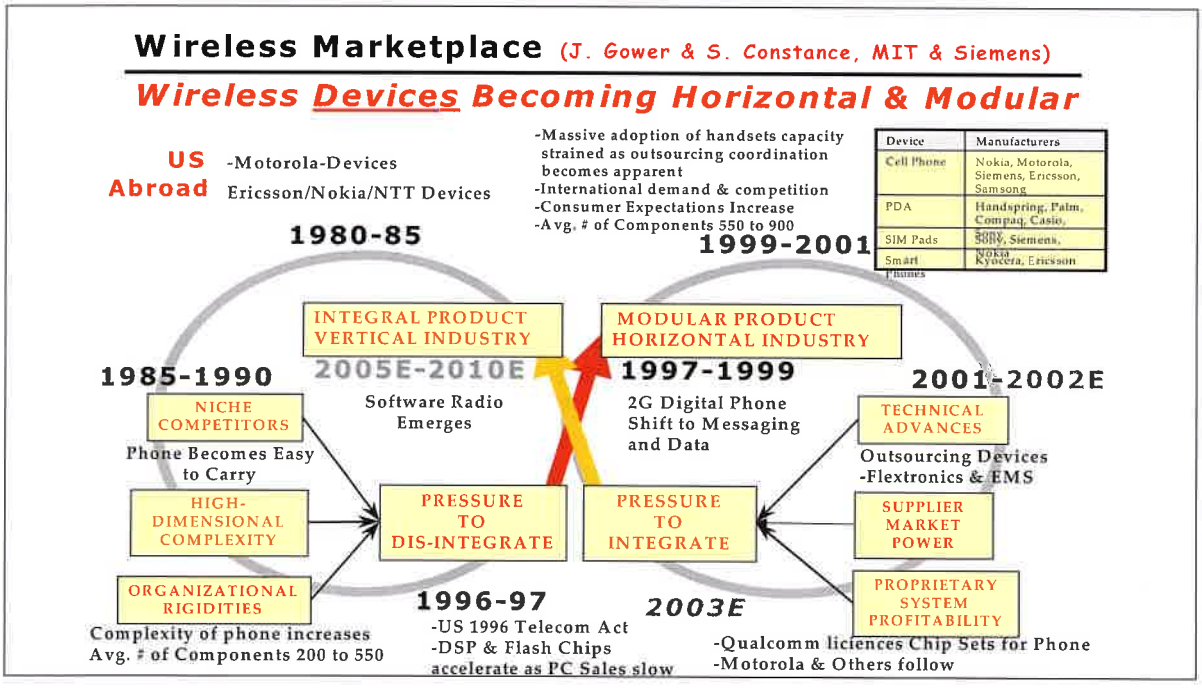

Fig. 4: The dynamics of product and industry structure in the wireless devices according to Ch. Fine (2001). The structure develops as a double helix.

The merging between media is an international phenomenon. Leading media companies search to offer a complete and all-round multiple media service, covering printed media, electronic media and their combinations. A prerequisite is that the merged company possesses distribution chains with enough capacity. The merge between content providers and leading broadcasting companies is a complex process, that is not necessary irreversible. The established media giant may face cultural, traditional, historical and even human obstacles, which may split the giant back into smaller companies.

The media business - especially the electronic and premedia processes - has become an integrated part of the ICT sector as a consequence of the technical development. It follows, that the whole ICT market space is changed, as the new players search for their role and the old players want to expand their position. The ICT space can be presented in a three-node-graph where content, service and hardware are the nodes. The electronics suppliers, the network operators and the content providers (publishers) all have their own corners in the diagram, but also the printers and the electronic media providers match in it.

Each player aims at expanding his market, to find new contact areas to new customer groups, but at the same time also to offer new forms of service to the customer. The development of additional service is, in fact, a prerequisite for each player to survive.

The technical prerequisites for an integration of the content chain to form new brands of multiple media, but also for a convergence of the whole ICT industry already exist. The final structure of the global ICT sector and the position of the value chain of the content industry are still open. It depends on the estimated business potentials, ownership structures and preferences, which kind of companies and alliances finally will be established. Theoretically any of the players can integrate the entire sector via virtual value chains.

3.3 e-Commerce and media

The integration of e-commerce into media is a key question not only for the future of the media sector, but also for the electronic economy. This requires that both security and copyright issues can be solved on both a legal and technical level.

In the new e-Ecomomy the products and services can be divided into three main categories depending on the share of the information value:

- Traditional manufacturing, where e-Business has a strong impact on marketing, selling and customer service, but only a marginal one on the delivery itself,
- New forms of business, where the product or service itself is available in digital form, and where e-Business has a strong impact on the entire industry structure.
- Between these extremes we find a form of e-Business, where the goods are still in material form, but where the new economy has a clear impact also on the delivery structure - like health care, energy sell, selling of books and retailing goods, travelling, etc.

The impact of e-Business on the restructuring of the industry is schematically presented in Figure 5. The dematerialisation and materialisation processes become critical in this third form of e-Business. In this form, customer service - including marketing, selling, ordering, product specification and verification of order performs virtually on web. Nevertheless, the material goods are delivered by traditional logistics.

The immaterialisation has been considered as one of the biggest advantages in e-commerce and in the Information Society. The change of the production, marketing and distribution processes into a non-material form is often more environmental friendly, efficient and economic.

Figure 5: How e-Business forces industry restructuring

However, every value chain contains a critical point, where the bits are turned back into atoms. Independent of how advanced the e-business chain is, the logistics of the physical delivery must be functioning perfectly.

4. Roadmaps for the media industry

Science and technology roadmaps are used in industry, government and academia to portray the structural relationships among science, technology, and applications. Roadmaps are employed as decision aids to improve co-ordination of activities and resources in increasingly complex and uncertain environments. A roadmap is an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of change in that field. A science and technology roadmap provides a consensus view or vision of the future science and technology landscape available to decision-makers. Generically, a "road map" is a layout of paths or routes that exists (or could exist) in some particular geographical space. The practise of roadmapping typically involves social mechanisms, and is both a learning experience as well as a communication tool for roadmap participants. To be most effective, roadmapping and other management decision aids need to be fully integrated into the strategic planning and business operations of the organisation *Kostoff*, (2001).

In the following we present a roadmap for media technologies in a time perspective toward 2010+ using the same technology (Table II). The roadmap has been developed for nine selected strategic core competence areas of the media research field. These fields are all considered being strategically important. However, they represent a priority in our planning, and shall, therefore, be seen only as examples.

Table II: Roadmap over media technologies

Technology	2002	2004	2006	2010+
Personalised, context sensitive multiple media	Electronic identification Web-services using customer profiles Location based services	Profile-driven services with learning features Wearable embedded sensors	Trusted biometric identification Personalised context-driven services Personal navigation guides (enhanced reality)	Digital me Awareness of social context
Broadcast systems	Digi-TV Mobile TV in pilot phase	MHP break-through IP television is commercially emerging	Analog radio spectrum is released for digital use Mobile TV (TV-Anywhere)	3D-television in pilot phase IP-television established
Community media and media production	XML based systems available, but in isolated environments	Semantic web and web services emerging in commercial applications	Integrated XML based applications	Semantic web based integrated applications in use
Print media production	Rationalisation of printing companies	Tracking and job ordering via web logistics	Automated workflow	Virtual factories
Colour management for print media	On-line density measuring devices	Closed loop density control Colour mana-gement systems integrated	Closed loop control for printing process Integration with premedia	Closed loop control in every press
DP/Ink-Jet	< 10% Small editions of ads and books	10% Small editions of ads and books	15% Personalised Print on Demand, Smart logistics	25% Intelligent high quality PoD, Tailored newspapers
Printed electronics	First experiments	Strong R&D activities in conducting polymers	First commercial products	Most common mass manufacturing method
Paper web mana-gement	R&D activities	R&D activities, some features (IQT) in use	First prototypes	First closed-loop systems in use
Distribution and logistics	Prototype for electronic newspaper delivery book RF-ID used in special industrial cases	First systems in practical use Coding/RF-ID tracking taken into use for logistics	Intelligent and adaptive delivery book RF-ID also in consumer goods	Real time intelligent tracking and optimising Real time intelligent management of logistics

One focus represents personalised, context sensitive media services, broadcast systems and community media and media production. Enabling technologies are vital for the test and pilot system development that is our main way to proceed towards product development. Personalisation will develop from the user profiles to automatic diagnosis of the environment and awareness of the social context. In broadcasting systems interactive and mobile TV are interesting developments we will be actively supporting. Ontologies and semantic web will be widely taken into use also in practise until 2010.

Print media production will be done in networked companies (virtual factories) where many functions have been outsourced. Most print products will be mass personalised giving higher value to the customer. Closed loop control of colour management of print media will be realised. Colour management of electronic media can be solved by adaptive displays. The role of distribution and logistics is emphasised and intelligent, real time systems will be developed also for media industry during next eight years period.

Ink-jet printing gains ground in many areas from publishing to printed electronics. Tailored newspapers will be cost effective in 2010 and intelligent packages with printed sensors and tags will be in general use also in low cost consumer products. Electronic paper will be used also in the publishing products. Printing will be the most common method to produce low cost electronics. Data management of the whole production chain will be in everyday use and the closed loop control of paper web management of printing presses will be launched.

5. Summary

It has been the scope of this strategic project to identify the core technologies, which have a mayor impact on the diversifying media industry in the time perspective of the next decade, i.e. until 2010+. Digitalisation and new telecommunication technologies are essential factors in the development. Digitalised information can easily be revised, stored, compressed and distributed. Not only the production and the way of action are changed, but also the products and the services themselves. New distribution channels, information carriers and terminals offer the end users a variety of new alternatives, like digital television channels, mobile media and electronic books.

The utilisation of ICT technology leads to structural changes across the traditional boarders of branch and market segments. Some hardware suppliers have already become active content providers, and many more intend to come. The spectrum of technologies utilised and further developed by the ICT cluster increases continuously. The markets have until now been created by technology push, but market pull is growing in importance. The end user is not interested in what technology for data transmission the channel utilises, or the components of the terminal, if only the services are attractive enough in relation to the price, reliable and easy to use.

ICT will remain the driving force for technology and economy for the next decade. After that it will slowly merge deeply into different applications. Therefore, it is important to identify new solutions in the field of basic industry, services and administration. The most critical challenges to the media industry today are the demand on rapid structural change, overcapacity in the printing sector, ability to increase the efficiency of the business processes and the ability to develop new, attractive products and services. This requires significant investments in research and development, but also in training and education.

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The authors want to express their gratitude to the management of the Technical Research Centre of Finland for the financial support to the project, and to the Steering Committee under supervision of Area Director *Pekka Silvennoinen* for their support, remarks and advise to the performance. We are also indebted to our colleagues, Group Managers *Caj Södergård*, *Olli Nurmi* and *Hannu Linna* for their contribution as experts.

References

1. Fine, Ch., Mapping the telecom value chain: A roadmap for communications networks. MIT Sloan School of Management, Cambridge, Massachusetts, May 2001.
2. Juhola, H., Lindqvist, U., Siivonen, T., Media Technology Outlook. VTT Information Technology, Research Report TTE4-2002-27. Espoo, 2003.
3. Kostoff, R.N., Schaller, R.R., Science and technology roadmaps. IEEE Transactions on engineering management 48(2001)2, p.132-143.

4. Lindqvist, U., Siivonen, T., Integration and convergence in the media field. 29th IARIGAI Conference, Lake of Lucerne, Switzerland, September 8-11, 2002. 22 p.
5. Lindqvist, U., Siivonen, T., ICT-rakennemuutokset ja edunvalvonta. Sähköalojen ammattiliitto, Viestintäalan ammattiliitto. Helsinki 2002, 77 p. (In Finnish)
6. Lindqvist, U., Siivonen, T., Södergård, C., Mistä innovaatiot syntyvät? Vai tuoko haikara innovaatiot? GT-lehti 2/2002. p. 28-29. (In Finnish)
7. Lindqvist, U., Siivonen, T., Södergård, C., Innovaatioita metsästämässä - media valinkauhassa. TEKES Teknologiakatsaus 139/2003. Helsinki, 2003, 45 p. (In Finnish)
8. Lindqvist, U., Rouvinen, P., Siivonen, T., Ylä-Anttila, P., Digitaalisen median teknologiaohjelmat 1996-1999. TEKES Teknologiaraportti 21/2000. Helsinki 2000, 45 p. (In Finnish)
9. Mamiya, K., The Seventh Technology Forecast. Future Technology in Japan toward the Year 2030. NISTEP Report No. 71. July 2001. 586 p.
10. Pletscher, W., Industrial future research at IBM. Presentation after the 29th IARIGAI Conference, Switzerland, on September 11, 2002.
11. Södergård, C., Juhola, H., Context aware collaborative environment for next generation business networks (COCONET). EU/IST-2001-3746 Research Project. The roadmap will be published in Autumn 2003.

Appendix

Calculation of the Index for technology importance, according to Mamiya (2001)

$$\mathbf{I = (100\ H + 50\ M + 25\ L + 0\ U) / (H + M + L + U)}$$

where:

I	is the importance index
H	is the number of persons ranking the technology to be of utmost importance to Japan
M	is the number of persons ranking the technology to be important for Japan
L	is the number of persons ranking the technology to be of some importance to Japan
U	is the number of persons ranking the technology to be non-important to Japan

The new role of paper in the new digital communication age

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Abstract

The relation between digital technologies paper and printing is much more complex than the printing industry is really realising. Often it seems that the new technologies shift the point at which paper and printing is used rather than replacing its use altogether. To understand why it is so and how the printing industry has to react to support some kinds of human activities better than digital alternatives do, was the goal of a research project at VFG.

This paper is dealing with the basic research results of human behaviour to take a new view to see paper and printing not as a problem in organisational life but as a new way of understanding the work that people do and the reasons they do it that way. An essential problem for survival of paper and print is to change attitudes completely to fulfil the needs for a functioning new communication society.

1. Introduction

The relation between digital technologies and paper in the daily life is much more complex than one might think. In most cases, it seems that the new technologies shift the point at which paper is used rather than replacing its use altogether. We see ist shift from pure photocopying to digital printing and how the point at which the printing takes place is altered normally before distribution and more and more after it. In both cases paper will be still consumed. Also new technologies can radically alter the world of printed Words and pictures:the digital technologies do away with the need for paper,but on the other hand they create more demand for it.

To understand why this is so, we need a better grasp of the reasons that paper supports some kind of Human activities better than the digital alternatives do. We need to understand what it is about, how work practices have evolved along with paper in such a way that paper is an integral part of work. To some extent people will be provided with better technological alternatives, but it also is being sensitive to existing work practices, so that we can know what their requirements might be and how change can be introduced.

Notice

Paper is not a problem in organizational life but it is a way of understanding the work that people are looking at organizational work. In other words, it is to view paper as a way of understanding the work that people do an the reason for doing it that way.

To understand the new philosophy on paper and mainly its use, we employ a concept called "affordances". The notion of affordances can be traced back to the ecological psychologist J. J Gibson in his seminal book *"The ecological Approach to Visual Perception"*. Gibsons theory was that people "pick up" information about their environment and the objects in it largely by attending to what those objects afford. An affordance refers to the fact that the physical properties of an object make possible different functions for the person perceiving or using that object.

2. Mission statements

The ART of innovation - is bringing your ideas to life, not just to production of paper and printed materials.

In our globalized economy, market pressure is growing on every field of communication and information technology to improve its ability for developing and implementing product innovations, because are the only sustainable way of securing future success.

At the same time this global pressure is forcing many companies to scale back their R&D budgets due to the lack of financial resources. As a result of this pressure and rather limited R&D funds marketing specialists are trying to ensure a product success as paper by extrapolating market research data into future markets. Because almost every industry and communication segment is pursuing this method, this standard procedure leads to standard products for standard clients in standard markets. This method is minimizing the risk but also minimizing a future success for the use of paper in a global oriented communication mass market.

Another way for creating real innovations is to work on a truly utopian blueprint for tomorrow's society and derive new product solutions for the use of paper and printing from that utopian view by "extrapolating" a utopian vision back to tomorrow markets. This will be the method of **"maximizing the chances".**

So the key issue for the future of paper and printing after investigating the market and interviewing key persons in industry and society about the feeling for a new vision: **How people wish to live and what will be the their needs for this future world in the field of modern communication technologies. We see a great lack in answering these questions especially in a very conservative an holding back paper and printing industry.**

3. Important Questions for survival strategies

1. Where are the utopian views of the printing and paper industry?
2. Where are the risky visions, which are not based only on solid research data?
3. Where is a future lab for the paper and printing industry?
4. Where are the visions of organisations like TAGA and iarigai about the demolishing of the paper and printing market?

Statement:

In a future lab especially young researchers have to work on their personal utopias (the big challenge of organisations like MIT and Frauenhofer).

But what does "utopia" mean for the printing and paper industry? By definition utopia is, when imagination surpasses the limits, permitted by institutions of culture, one speak of Utopia.

Developing utopias demands:

1. *The courage to radically call into question everything that has been done until now*
2. *To think the unthinkable rather than to orient oneself towards existing realities and the dormant possibilities.*
3. *To anticipate the future in the exploration of one`s consciousness.*

4. *The wisdom to identify the important from the unimportant, possible from impossible and recognition of the necessary.*

5. *The strength to identify what is right and important despite all resistance of a very traditional and conservative research community and not to sing only the old song in a new key, but also with an entirely new melody:* ***go against the grain.***

Is paper and printing a lost world?

Change through digitalization

1) Winner (Electronic)

2) Looser (Paper and Print)

The new mobility in society

Face to face communication		**New Media**
Spoken	=	Technical stage
Listen	=	Market stage
Understood	=	Market diffusion
Done	=	Use of media

Stages of diffusion by Konrad Lorenz

Base technology

Base Technology	1995 Percent of Sites	2003 Percent of Sites
ANALOG Analog cameras, prepress, printing equipment	60%	20%
DIGITAL - ANALOG Workstations, software, digital in-and Output, storage, content creation, page mastering, film imaging	50%	90%
NETWORK DIGITAL Modems, networks, servers, network authoring, prepress, printing, digital libraries, electronic data interchange, workflow, just in time	30%	70%
INTERACTIVE DIGI Cross-media authoring and multi-purposing, www-site authoring andmaintanance, multimedia input, output, interactive content distribution, information commerce	10%	50%

4. Changes and Trends

The basic message from looking in our investigation at paper industry trends is that the new technologies from PC to Internet to portable pen-based computing, have so far not been able to have the predicted effect on paper consumption. To be sure, there has been remarkable changes in technology development in the past three decades. However it is clear that some of these developments have changed people's inclination to print. There are two significant technological trends we can point out:

Trend 1 The first trend is that advances in interconnectivity mean that we have access to much more information than before. More and more workplaces are now fully networked; more and more people are linked up to the Internet, not only in the workplace but also in their home.Recent claims are that Internet traffic doubles every nine month and society is not far from **1 Billion Internet users worldwide**. Nevertheless in a survey of 100 companies in Austria, information technology managers reported that introducing networked access to the Internet and to the companies Intranet caused a noticeable increase in the amount of printing but mainly from desktop and work group printers.The availability of e-mail also means that people get more messages than they ever received when the used paper mail.

Trend 2 **A second major trend is the advancement of print technology itself. In the past twenty years or so, there has been quite substantial changes in the way documents get printed and what they consist of. One substantial change was the of order from** print and then distributed to distribute and then print. **Printing is now not only digital but on-demand. Whereas before, production printing was often done through large commercial offset printers who would mainly print predefined print runs, new networked digital printers allow to print as when they need it. Large corporations are not the only one who are changing. There are many changes, too, in the way work group and personal printing gets done. Improved publishing software, e-services, and printing architectures let people design what the want and print only what the need. Finally all is cheaper, better in quality than before and color is now commonplace also in home printing.**

Coevolution of paper and work practices

Paper and work practices have coevolved over the years, and changing these long standing work patterns within social, technologica, and cultural infrastructures is difficult.

Dispel the myths- the idea that there are always benefits going paperless is one myth.

The need for better design of digital alternatives

Many digital alternatives to paper are inadequately designed for the tasks at hand and for accomplishing the goals people are trying to achieve. Thus, paper often does the job better and enables people to work around the problems posed by technological alternatives (many of them are originally designed to replace paper).

Information ecologies is a term for the way different forms of information are made useful by their interdependence with other forms of information.

The affordances of paper

Paper has particular affordances that make it the best choice for some tasks at hand and that will likely continue to make it the preferred medium for certain work tasks in the foreseeable future.

Designing the future is very complex task and paper is often a fall-back when new technologies are going wrong;paper can provide a quick fix or can prove to be the better tool. An paper is also a Design Resource.

The future of paper

New technologies will continue to be developed and will find their own niches in the communication society in the future

There are three kinds of reasons hat people stick with paper despite the growth of digital devices inflating the media world

1. **The coevolution of paper and work practies**
2. **The need for better design of digital alternatives**
3. **The affordances of paper**

5. Conclusion

Where Paper Will Find Its Place

Key properties:

- *A single sheet is light and physically flexible;*
- *It is porous, it is markable;*
- *It is a tangible, physical object;*
- *It is immediately responsive to executed actions.*

The design of digital tools may eventually be capable of supporting these knowledge work much Better than the currently do. Until such time, paper will maintain its importance in the kinds of roles we have investigated in this paper. In other words, it will continue to predominate in activities that involve knowledge work, including browsing through information, reading to make sense of information, organizing, structuring and reminding of ideas, information integration in support of authoring, and activities that involve beauty and feeling and discussion help for face to face meetings.

Digital technologies on the other hand, will increasingly take over more of the activities for which electronic media are better suited - those activities in a supporting role for large scale search and retrieval of information, analysis of data, document production.

All the changes are not implying the disappearance of paper but some fundamental changes of the role of paper and printing. We can also see that as digital technologies begin to increasingly inhabit our homes, so too will printing in the home be on the increase an the role of printing and paper industry will shift also from production to teach people how to handle and use paper in a proper way.

Literature

Sellen Abigail J., Harper Richard H. R., The myth of the paperless office, The MIT Press, Cambridge, Massachusetts, London, England, 2001

Sobotka W., Innovative Drucktechnologien, WIFI, Wien 2001

Sobotka W., Umwelthandbuch für das graphische Gewerbe, WIFI Wien 1998

Latzer Michael, Mediamatikpolitik für die ditale Ökonomie, Studienverlag, Wien-München 2000

Rubin Michael, A guide to digital film and video editing, Triad Publishing Company, Gainsville, Florida, 1995

Tapscott Don, Ticoll David, Lowy Alex, Digital Capital, Campus Verlag Frankfurt-New York 2001

Structural changes in the graphic arts and media sector - new concepts, new tasks, new people?

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Abstract

Structural changes in the graphic arts and media sector strongly affect the skills characteristics and competence requirements of existing employees and personnel that are to be recruited in graphic arts and media enterprises. In particular, personnel in the sector are asked to perform new tasks, develop new skills and gain new competence. This applies not only to employees but affects managers, owners of companies and entrepreneurs as well.

In addition, new management structures and concepts as well as learning in various forms are appearing and are being applied in the company environment affecting the employment structure of companies. Such concepts are, for example, new human resources and management policies, and further training. Other concepts in the environment of the sector are its image, recruitment and competence evaluation and certification.

The concepts above are thus discussed in this paper. Investigation is taking place in some of these new concepts, in particular, regarding their determination as elements of a strategy of human capital development which is specifically oriented towards the graphic arts and media sector.

One significant factor concerning the definition of elements of a human capital development strategy is the opinions and considerations of trade unions, employers' federations and entrepreneurs as well as experts belonging to the European graphic arts and media sector.

This study is based on a structured questionnaire and on extensive discussions with trade unions and employers' federations organizations in European countries.

1. Introduction

1.1 Structural changes in the graphic arts and media sector

Structural changes in the graphic arts and media sector, considerably influence the skills characteristics and competence requirements of existing employees as well as personnel that are to be recruited into graphic arts and media enterprises. In particular, employees are asked to perform new tasks, develop new skills and gain new competence. This applies not only to employees but also affects managers, owners of companies and entrepreneurs.

In addition, developments mainly regarding new management structures in the company environment, the structure of employment, and the role of new learning environments are appearing in the sector. These developments are further addressed as possible (potential) elements which constitute a strategy of human capital development oriented towards the graphic arts and media sector.

1.2 The human capital development strategy

The hypothesis for the formation of a "strategy of human capital development" is based on the convergence of different elements such as recruitment, education and training, and the integration of new human resource management concepts.

Some of these elements have been developed for big companies whereas others are applied in a general manner (for example as general reforms in education). In most of the cases these concepts are applied separately without any relation or interaction between them.

Finally, such concepts do not take into consideration the specific characteristics of an industrial sector and the specific needs and requirements regarding the development of personnel in this sector.

The main objective of a strategy for the development of human capital, as it is proposed here, is to integrate all different (however strongly related concepts) under a common platform. In addition, a strategy needs to be formulated taking into consideration the specific characteristics of an industrial sector – in this case the graphic arts and media sector. The reason for this is that these specific characteristics affect the formation of the strategy. Furthermore, any concept of human capital development seems to be influenced by the specific characteristics of the particular industrial sector. This approach on the strategy has the potential benefit of taking into consideration all the new elements affecting the development of personnel within an industrial sector.

These elements can be further defined and classified into those oriented towards the specific characteristics of the graphic arts and media sector (such as the image of the sector, recruitment policies, sector-specific job profiles, and upskilling), education and training (such as on-the-job training, continuous learning and upskilling), new human capital management policies (such as emotional intelligence and company social responsibility) and new structures of employment and working environments (such as distance and flexible work).

In addition, elements such as competence evaluation, certification and validation are examined.

2. Research questions and objectives

Changes in the graphic arts and media sector lead us to see the development of the people involved under a more "global" or transnational point of view. One research objective, therefore, is to explore elements that could possibly be components of a suggested strategy of human capital development.

The principal objective is to investigate the considerations of trade unions, employers' federations and entrepreneurs as well as experts in the European graphic arts and media sector on the components of a suggested human capital development strategy.

3. Research methodology

3.1 Literature study

Literature study was based principally on surveys indicating the structural changes in the graphic arts and media sector as well as developments in new management applications at company level. In addition, the literature study was oriented towards finding evidence on new human resource management and its degree of application and importance for the graphic arts and media sector.

3.2 Survey

In order to extract data on the considerations and opinions of organizations in the graphic arts and media sector on a proposed strategy of human capital development and its components a questionnaire was developed. The objective of the questionnaire was to investigate the elements of a strategy of human capital as employed in whatever form in the graphic arts and media sector in European countries.

The questionnaire consisted of a set of questions divided into three main categories. The first deals with the formation of a proposed strategy for the development of human capital as employed in whatever form in the graphic arts and media sector in European countries.

The second examines the suitability of the various components of the strategy. The third and final category is oriented towards the possibility of the establishment of a strategy in the European graphic arts and media sector and the participation of organizations in its application.

In order to obtain reliable results, the decision was made to receive answers from trade unions and employers' federations organizations from the 15 European Union countries plus Iceland, Norway and Switzerland. Moreover, the questionnaire was directed towards certain industry experts as well. The criteria for the selection of the experts was their experience with the industry and their involvement with issues regarding human capital development.

The questionnaire was distributed either directly or through the European confederation of trade unions (UNI-Europa Graphical) and the federation of employers (Intergraf) of the graphic arts and media industry. Following this methodology, 38 questionnaires were distributed among trade unions and employers' federations organizations in the 18 countries and the two confederations.

Based on the questionnaire, extensive discussions and interviews took place between October 2002 and March 2003 with trade unions and employers' federations organizations in European countries. At least 14 interviews were taken through personal contact. In addition, 9 questionnaires were directed towards industry experts. Questionnaires were sent out three or four times (mostly by e-mail). This made a total of 46 questionnaires.

The ideal result would have been to receive an equal number of responses from each country and at least from 2 organizations, so great effort was made to achieve this objective. One principal problem regarding the distribution of the questionnaire was to find the appropriate person, officer of the organization, authorized to answer the questionnaire.

In addition, the lack of answers from some countries or organizations was probably the result of the indirect contact with these organizations or the lack of translation into the proper language (e.g., the Italian trade unions or Spanish federation of employers). The questionnaire was translated from English into the Greek, French and Spanish languages.

Despite this, the response rate was considered quite satisfactory: 30 responses were received from 15 countries having the following structure:

- 11 responses from trade unions
- 11 responses from employers' federations
- 8 out of 9 questionnaires from experts

In Table I the responses arranged by country and organization or expert are illustrated:

Table I: Responses received from trade unions, employers' federations and industry experts

Country	Trade unions	Employers' Federations	Experts
Austria	-	-	-
Belgium	-	1	-
Denmark	-	1	-
Finland	1	1	1
France	-	-	-
Germany	1	-	1
Greece	2	2	1
Iceland	-	-	-
Ireland	1	-	-
Italy	-	1	-
Luxemburg	1	-	-
Norway	1	1	-
Portugal	1	-	-
Spain	1	-	1
Sweden	-	1	2
Switzerland	-	1	-
The Netherlands	1	1	1
UK	1	1	1
Total	11	11	8

The results of the survey were further analyzed and combined with the findings of research from the literature in order to obtain the final conclusions.

4. Background - developments in the graphic arts and media sector

4.1 Structural changes in the graphic arts and media sector

Substantial technological developments have been taking place, primarily in the last decade of the 20th century, within the graphic arts and media sector, especially with innovations and improvements in pre-press and printing which affect the existing structure of production workflows, the technological processes applied, and the working environment.

Re-organization strategies have been widely applied as steps for adaptation of the sector to the new conditions. The first step was characterized by investments in new equipment and systems, followed by significant changes in production workflows (Pira, 1999). A second step included organizational and administrative structural changes and application of marketing strategies and activities at company level. These actions were aiming at a new position and orientation in the rapidly changing market of the information and communication industry (Comprint, 1998). The latter are still in development in relation to the wider field of the media industry.

Further progress in the graphic arts and media sector is also dependent on parallel developments in other sectors and conditions that have an indirect relationship to and probably affect the sector. As such developments can be mentioned the competition of the print and electronic media and the resulting consequences for the future of printed products. Therefore, any development strategy for the sector as a whole or for specific parts should take into consideration these parallel developments and their implications (Hancock, 1998).

As stated in the Comprint study the entire sector of communications, information, entertainment, and knowledge acquisition is undergoing a time of deep and drastic changes. New markets and new market forms are arising as a result. As a rule they all have one thing in common: the discovery of a possible market opening is "supplied" almost simultaneously with a forecast of virtually unlimited rapid growth and booming market volumes. In addition, new technical possibilities in media integration and telecommunications are opening up new forms of communication and information dissemination.

The effect on the graphic arts and media sector resembles one of being squarely "in the line of fire". New market structures are being formed the development dynamics of which recognize no obstacles. New performance factors are emerging in the context of the media upheaval alongside the classic competitive factors - sometimes even making them irrelevant. Still, changes bring with them opportunities: the media markets of the future bring with them enormous possibilities for growth and the printing/media economy will be part of this process! (Comprint, 2002).

4.2 Drivers of change

According to an IPTS study, the main drivers of change in the media and communications industry relate to:

- Industrial restructuring around the search for economies of scope and scale - related to features such as globalization, industry concentration and mergers, liberalization and convergence.
- Cost reduction of the production process in the mass media because of digitization.
- Technological change reducing entry costs for net presence and thus leading to new media, especially Internet-based; the emergence of online versions of existing media or new media linking communities (the e-zones); new forms of media based on Wireless Applications Protocol Technology and aimed at fast and short information delivery, all resulting in the creation of new companies and occupations.
- New types of content creation across a wide variety of sectors (from health care and museums to local governments) promoting new forms of electronic democracy emerging from the convergence of multimedia.
- Changes in demand patterns specifically related to factors such as increases in income, rising educational achievements, demographic growth amongst the active elderly, and a greater differentiation of tastes and changing lifestyles such as the growth of single person households (IPTS, 2000).

According to the study the overall implication is a ***strong and diversified demand for new skills and an associated growth of new occupations.***

4.3 Restructuring policies for the sector

Regarding the previously defined new graphic arts and media environment, it is important to mention that the traditional graphic arts sector worldwide faced technological developments along similar lines. As Hancock points out developments are the same and in most cases reactions and reform strategies are the same as well (Hancock, 1998). Following this, technological developments caused the need to restructure traditional graphic arts and media companies and their rapid adaptation, as far as their internal structure is concerned, to the new production workflows, and changes of position and orientation towards the new market conditions (Ullmann, 1995).

As regards the graphic arts and media sector, it can be concluded that the traditional media are challenged to re-orient their strategies and functions in order to secure and further develop their position within a future media market. It seems necessary for the sector as a whole to continue its pace towards integration into new business markets and business environments and adaptation to new customer needs.

4.4 The structure of the new graphic arts and media sector

Based on conclusions from the Comprint study, we can speak ***not of an "old" and "new" economy*** but rather of a ***"real" economy***. New performance factors are emerging in the context of the media upheaval alongside the classic competitive factors - and still, changes bring with them opportunities: the media markets of the future bring with them enormous opportunities for growth and the printing/media economy will be part of this process! (Comprint, 2002).

Furthermore, the findings of the Comprint study on human resources clearly indicate that the complexity of the types of business activities involved and thus pressures to innovate are increasing for graphic arts and media companies. Because of the ready availability of technologies, the growing competition within and between companies, and the blurring of dividing lines between industries, strategic business planning and the ability to innovate are beginning to play a crucial role in strengthening the competitiveness of graphic arts and media companies. Personnel are expected to play an essential role in this development as well.

This is related to evidence provided by the IPTS study where it is stated that the overall implication of the changes in the media industry is a ***strong and diversified demand for new skills and an associated growth of new occupations*** (IPTS, 2000).

Regarding the potential elements of a strategy of human capital development in the graphic arts and media sector, research has revealed that the image of the sector is a major problem, principally concerning the perception of the sector by outsiders (customers and the general public). The image of the sector is considered problematic (even bad) even by the people involved in the sector and needs to be revised. Research has revealed that recruitment policies are affected by this image, requiring more effort to attract young people for employment mainly in printing and finishing.

In addition, new forms of learning seem to be present in a wide variety and diversity in the sector, complementing the formal national education and training systems (which are subjected to reforms as well). Such learning applications are on-the-job training, e-learning and continuous/further training.

The structure of employment is expected to be affected by new forms of work such as temporary, distance and flexible work. It seems that the graphic arts and media sector are more subjected to such new employment forms because of their specific characteristics. Furthermore, new human resource management policies such as emotional intelligence and company social responsibility, which are increasingly applied at company level, will probably find their position in the graphic arts and media sector chiefly in medium and large companies (Cedefop, 1995), (Brugge, 2002).

5. Results

As can be derived from the questionnaires and interviews conducted, a principal result is that the vast majority of social partners' representatives and experts from the 15 countries consider that the suggested elements can be included as components in a human capital development strategy for the graphic arts and media sector.

5.1 Image of the sector and recruitment policies

Referring to the first question such elements as sector image and recruitment, job profile description, forms of learning and competence evaluation and certification - cover to a satisfactory level the strategy (equally 82% of the trade unions and employers' federations representatives and 67% of the experts). The remaining responses were positive, adding elements that they considered important to be parts of the strategy. Elements suggested include issues of skills gaps and shortages, recruitment policies for young people, career progression within the industry and a policy for motivating people by providing useful information about the companies' goals and other incentives (in other words a professional orientation policy).

One interesting viewpoint was presented by the German expert. He stated that in Germany the development of human capital is strongly linked to vocational education in the so-called dual system (education at company and school), leading to a profession which is essential for the development of the personality of young people and consequently this being the basis of all strategies of human capital development in Germany. According to his statement: ***"this is a constitutive element of human development. And it is more than HCD. People who do not have a basic qualification must have the right to achieve it and this fact has to be added in the listing".***

One problem that was mentioned was the updating of the elements of the strategy, such as job profile description, since there is continuous change in the sector.

Responses to whether a policy of presenting the sector to other sectors, customers and users should be developed at European level were about 80% positive (yes and probably yes). Respondents commented that this policy (or element) should be used for recruitment and as a promotional tool as well. Negative responses mainly pointed to the presentation of the traditional skills and expertise in the sector, which were not considered adequate. Following these viewpoints the modern description of the sector should be used instead.

5.2 IT skills and their relation to graphic arts and media job profiles, education and training

With reference to the importance of IT (Information Technology) skills for the graphic arts and media employees, the relationship of IT skills to graphic/media job profiles and the relation of IT to graphic/media education and training; responses were requested to the question whether graphic arts and media job profiles should be described independently and whether they should be clearly distinguished from IT job profiles. In addition, respondents were asked whether graphic media education and training should be transferred to schools or universities of the IT sector or offered by graphic/media departments and schools.

Regarding both questions almost equal responses were reported by trade unions and employers' federation representatives: graphic arts job profiles should be described independently (equally 64% yes - probably yes by social partners) and education and training should be definitely offered by graphic arts and media schools (91% and 82% respectively). Experts have the same opinion with the social partners regarding job profiles. However, on the issue of education and training 22% responded that graphic arts education and training should be transferred to IT schools/universities.

Comments by the interviewed organizations regarding job profiles included the consideration that IT-ICT elements/skills should be an integral part of job profiles. In addition, some job profiles/tasks relate closely and some interchange with the IT sector.

5.3 Importance of non technical - "social" skills

The vast majority of the answers consider important all "non-technical" - social skills such as organizational and management skills, the ability to understand continuous change as part of the working environment, ability to understand and analyze complex tasks within the media industry, teamwork and communication capability, management skills and life-long learning capability. Respondents additionally reported that further clarification is required as all the socials skills seem important, tough not equally important to all employees in the sector; some are more important at management level.

Language skills, teamwork and communication capability, and ability to work within an international environment were suggested as well. An opposite opinion was reported by one of the two Greek trade unions. According to this opinion, these skills are probably important but are overloading the employee with more and more tasks and responsibilities. There should be a limit to new skills and the amount of continuous training and learning that employees are forced to participate in.

5.4 Flexible and distance working environments

With regards to the application of new working environments and employment structures in the sector such as flexible and distance work, the perception of trade unions and employers' federations representatives is that the sector cannot avoid the application of these forms of employment, but regulations towards proper employment must be agreed upon (82% and 73% respectively). The same direction is prevalent in the responses of experts (88%).

One important comment came from an employers' federation representative. He states that: ***"the sector should incorporate new and different employment structures as a positive tool alongside "old" structures, not through regulations but through agreements based on wide and broad guidelines"***. On the same line is another comment from the employers side where: ***"flexible working hours, project oriented employment and to some extent distance work are an integral part of the future working environment.*** *They* ***complement*** *the basic work schedule so that a company can react flexibly to changes in customers expectations and needs".*

Finally, according to the opinion of a trade union officer these matters are part of a continuous dialogue which is taking place among social partners and they need to be re-considered each time such a subject appears.

5.5 New concepts of human resource management

Furthermore, as far as the application of new concepts of human resource management such as Company Social Responsibility, Emotional Intelligence and Family Friendly Company and their contribution to the benefit of the employees in the graphic arts and media sector is concerned, the majority of trade unions, employers' federations and experts gave a positive answer, however, these concepts need to be further examined regarding their real benefits for employees and companies (equally 64% of trade unions and employers' federations and 80% of experts).

Nevertheless, according to comments by employers' federations representatives, these policies should not be applied following a top-down approach, but should be a matter of freedom of management within each company. Moreover, the main issue is to understand human nature and to respect every individual's value and personality. These policies tend to lose their real substance if - as it often happens - they are followed as a company policy because people have to do so, and not because they want to do so, or because they accept the idea behind the concept. One trade union officer also responded positively but pointed out that very few companies implement such policies.

5.6 Application of an "Investment in people" policy - budget to be spent

Responses to the question of the application of an "Investment in people" policy for graphic arts and media companies in Europe, and the estimation of a percentage to be spent on the development of people involved made the results quite diverse. For those representatives who provided a number (50% of the total number of responses) percentages ranged from 5 to 100%.

In many answers it was stated that it is difficult or impossible to estimate such a percentage. Another answer from some responses was that such an estimation needs to be further investigated, cannot be generalized and should be dependent on the company, the country and the policy available. The main issue was that the management understands the need to invest in human capital as a tool for a company's continuous success and development.

In one response it was stated that the amount to be spent on the development of personnel can be a percentage of the investment in machinery and equipment. In another response by a trade union officer it was stated that many companies claim that their employees are their most valuable asset, but whether they really mean it is open to doubt since they are negative to an "investment in people" concept in real life. Last but not least, there was a significant percentage of responses with no answer at all (20%). This indicates the degree of difficulty in gaining proper answers for this subject.

5.7 Life-long learning

Regarding life-long learning there were two questions leading most of the respondents to separate their answers. Concerning the first part of the question on the application of life-long learning as part of daily business activities, there was a clear divergence among social partners: 91% of the trade unions responded that life-long learning activities should be formally included in the daily practice of graphic arts and media companies, whereas only 54% of the employers' federations representatives gave a positive answer (responses yes and possibly yes). Experts responded positively and included comments on how this could be done properly.

Furthermore, to the question whether respondents agreed that the time spent by employees on life-long learning in a company should be considered as part of their official working hours, differences were obvious among social partners: 100% of trade union representatives agreed, whereas only 45% employers' federations representatives gave a positive answer. Experts were positive as well (100% yes and possibly yes).

There were, however, several opinions on the subject as reported by all respondents. According to the employers' federations opinions, relevant courses of immediate benefit for both parties would probably be considered as part of the official working hours and in some countries collective agreements include such stipulations. In another negative answer it was stated that: this should be determined case by case, since learning is also an investment in an individual's personal competence and thus increases his/her abilities. According to this opinion it should not be part of the official working hours.

5.8 Description of job profiles and the usefulness of curricula guidelines

Furthermore, the description of Job profiles and the usefulness of curricula guidelines at European level for the sector was examined. Regarding the question of whether an initiative for job profiles description and whether curricula guidelines related to the sector's job profiles should be taken into account and used for the design of education and training modules, both social partners and experts gave a positive answer (91% responses by social partners and 88% by experts). The trade union officer from Germany stated that such policies are already in existance in Germany.

5.9 Competence evaluation and certification at European level

With reference to the necessity of developing a competence evaluation system and the application of a sector-driven system for the certification of competence at European level, both social partners and experts gave a positive answer (100% and 91% by trade unions, 91% and 73% by employers' federations and 88% by experts for the two questions respectively).

There were comments by respondents mainly pointing out the relationship to a formal educational system (as stated by the German-speaking countries). The issue of standardization of the process was mentioned by both social partners as well as the consideration by Intergraf that competence evaluation and certification should involve training institutes and authorities plus social partners.

Concerning the trade unions' perspective, representatives pointed out that there are national standards regarding the entry level for higher education but not the work itself. Further, in collective agreements the necessary competence for someone to be ready for employment is stated. Moreover, it was reported that the sector should orientate more towards how people get their competencies.

5.10 Considerations of the social partners and experts on the establishment of a human capital development strategy

On the final consideration whether the questioned social partners' representatives and experts find necesary the establishment of an initiative or organization in Europe concerning a strategy on human capital development for the graphic arts and media sector, there were positive answers by the majority of respondents (91% of the trade union representatives, 73% of the employers' federations representatives and 88% of the experts). Some representatives from the employers' federations doubted the need for the development of such a strategy or they possibly thought that the strategy could be better developed at national level. One expert had the same opinion as well.

Regarding the question of participation by organizations in developing the strategy and the establishment of common actions within the sector at European level, again social partners' representatives and experts provided positive answers (82% of the trade union representatives, 73% of the employers' federations representatives and 88% of the experts).

When further examining the answers, the final question was whether the organizations were ready to participate in the design of such strategies; the majority of responses were positive, but there were different opinions regarding the degree of maturity for moving forward in this direction. In Table II the classification of the positive answers is presented:

Table II: Classification of responses by trade unions and employers' federations representative to the question whether organizations are ready to participate in the design of a HCD strategy

Answers to the question whether organizations are ready to participate in the design of a HCD strategy:	Trade union representatives	Employers' federations representatives
Positive responses:	82,0%	73,0%
They could participate immediately*:	22,2%*	12,5%*
They need to be better prepared	33,3%*	50,0%*
They need to be more thoroughly informed by those undertaking the responsibility of this initiative.	44,5%*	12,5%*
They were not ready to give an answer.	-	25,0%*
Total:	100,0%	100.0%

**percentage on the number of positive answers*

6. Discussion and conclusions

Generally speaking, the contribution of social partners' representatives was quite satisfactory and provided a lot of valuable input for further discussion. However, in some cases, the orientation towards national policies was stronger by some respondents. In addition, in some cases, political issues arose in areas concerning official working hours as well as the official implementation of learning during working hours.

If questions affecting political issues or similar subjects are excluded, a finding of the research is that there are no significant differences between trade unions and employers' federations on the formation of a strategy of human capital development and its components. This shows an increasing degree of maturity of social partners to cooperate on many issues for the further development of the sector.

A principal outcome of the research conducted is that the suggested elements can be included as components of a human capital development strategy in the graphic arts and media sector.

An important finding of the interviews and questionnaires is that ***all the above mentioned elements are strongly related and cannot be treated separately***. The image of the sector affects recruitment and the shortage of skills is related to the age of employees. Upskilling is required and the different forms of learning need to be coordinated and managed under a more global view at sector level. As far as the promotion of the sector is concerned, it is necessary to combine existing traditional knowledge and expertise with modern elements.

Furthermore, it can be concluded that new learning forms have to be combined with formal education and training systems. However, further discussion is required on the subject of the application of an "Investment in people" policy as this matter affects political issues. This question could possibly be formulated in a better way by including various investment areas in order to receive more comprehensive responses.

Despite this, responses to this question indicated that further discussion is required concerning the subject of "Investment in People". It is interesting to compare this question to the Comprint study where findings resulted from the question to print/media entrepreneurs and market observers "about how they would spend an available budget for the next five years". According to this study, print/media entrepreneurs would spend only 17,2% and market observers 19,5% (Comprint, 2002).

The conclusion is that "Investment in People" is a concept that cannot be generalized and it should be applied depending on the company, the country or the policy available. As such it cannot be considered as an element of a human capital development strategy.

The combination of findings from the questionnaire and literature research on issues concerning education and training, job profiles, curricula development and competence evaluation and certification justifies the fact that these issues can be considered as components of a HCD strategy. In addition, despite the close interaction and relations of the graphic arts and media sector with other sectors such as information technology (IT), the conclusion is that the identity of the sector must be further developed and must also be kept separate.

As a final conclusion of the research conducted, the elements that can be suggested as components or sub-strategies of a HCD strategy are the following:

- The image of the sector
- Development of professional orientation - recruitment policies
- Descriptions and definitions of job profiles, qualifications, tasks and competence characteristics

- Definitions of qualifications, tasks and competencies for the graphic arts and media sector
- Development of curricula guidelines related to job profiles
- Management of various forms of learning
- Competence evaluation
- Competence certification

Potential recommendations on the application of new human resource management policies (such as emotional intelligence, company social responsibility and family friendly company), and new employment structures (such as distance, flexible work and teleworking) can also be part of the strategy.

9. Further research

Additional research is required to further define the relations and interactions among the elements of the suggested HCD and the willingness of the existing authorities and organizations such as social partners, educational organizations and decision-making bodies to participate and become involved both at national and European levels in the formation of the strategy.

Acknowledgements

I would like to thank Ms Yvonni Inglessi and Ms Anna-Maria Chimariou for the translation of the questionnaire into the French language; My brother Georgios Politis for his invaluable help in processing and classifying the collected data from the questionnaires.

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References

(Brugge, 2002)
Brugge, H.: "Future qualifications and employee upskilling", EGIN seminar on upskilling, Dublin, Ireland, 7 November 2002

(Cedefop, 1995)
"A sectoral approach to training in the printing industry and the hospital sector", Synthesis report of a study in five European countries, Cedefop, Luxemburg, 1995

(Comprint, 1998)
"Navigating in the future media markets", Comprint international conference, Intergraf, Edinburgh, 1998

(Comprint, 2002)
"The horizon of print and publishing opportunities in the Media economy", Comprint International report, IBI, Duesseldorf, in cooperation with the University of Wuppertal, Intergraf, Belgium, 2002

(Hancock, 1998)
Hancock Michael, "Technology in a state of change in the graphical sector", Paper presented at the EGF-AFETT international seminar, "New technologies, work organization and collective bargaining in the European Graphical Industry", Florence, 3 June, 1998

(IPTS, 2000)
Employment outlook and occupational change in the media content industries 2000 - 2005, Scenarios and background note, K. Ducatel, J-C Burgelman, M. Bogdanowicz., IPTS, JRC, Seville, Spain, 2000

(Pira, 1999)
"Into the Millennium - Catalysts for change in the printing and publishing Industry", Pira International Technology forecasting, 1999, Pira Ltd, Journal of pre-press and printing technology, pp. 21-43, vol. 5, March, 1999

(Ullmann, 1995)
Ullmann Dieter, 1995: "Mit verhaltenem Optimisums", Article published in the W&V magazine, vol 18, 1995, pp. 32-33, Germany

2

Advances in printing

Influence of lithographic offset blanket characteristics on print quality

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Abstract

The aim of examination was to determine the influence of micro hardness (IRHD) of offset litho blankets, compressibility of blanket (daN/cm^2) and hardness of blanket and packing (Shore), micro roughness of the surface (Ra, μm) and other characteristics of blanket, packing and print substrate on the print quality. During practical experiment we choose various printing blankets with soft and hard packing, different printing papers (coated and bulky uncoated) and regular inks on GTO printing press. We set up the printing pressure and correct blankets height using standards and manufacturers recommendations. We defined surface and other characteristics of blankets, packing and substrate before printing. Evaluation of results is based on densitometric measurements and image analysis of prints.

We established, that hardness of packing and blanket has almost no influence on print quality, the major influence on print quality has micro hardness and roughness of the blanket surface and compressibility of the blanket. Blankets with soft surface give us better results in dot gain and mottling. Printing press manufacturers recommendations and standards for pressure set up are not valid for modern compressible blankets, where we need more packing material to achieve standard print quality, especially when using bulky paper.

1. Introduction

Characteristics of offset blanket and packing has important influence on pressure in printing nip. Every manufacturer of printing presses provides for each model of a press a technical requirements and recommendations for pressure adjustment when we use conventional or compressible blankets, underblankets and several types of packing materials. In handbooks and textbooks we can find schematic drawings showing adjustments of printing pressure depending on plate and blanket cylinder undercut, thickness of plate and blanket with packing, thickness of printing paper or board and gap between the bearers.

In literature we can find conclusions:

- Blanket Shore A hardness has almost no influence on print quality (Marchner, 1982).
- Compressible blankets can not be graded by Shore hardness numbers (Sun Chemical, 1991), similar recommendations were given from blankets manufacturers for the past 40 years.
- It is important to measure according to DIN 53521 separately on 6 mm thick sample of upper rubber layer to get Shore A hardness or to measure directly on the blanket and get micro hardness (Spöring, 2000).
- In textbooks there are explanations, that soft packing is good only for simple less quality jobs (Aull, 1995).

The aim of the examination was to determine the influence of hardness, micro hardness, compressibility of blanket, hardness of packing, micro roughness of surface of the blanket and other characteristics of blanket, paper and print substrate on the print quality.

2. Methods

During examinations we were using blankets, packing materials, print substrates, inks and other materials available on the market. For printing we used common printing machine and for measurements we used standards and some internal methods and equipment.

2.1 Influence of blanket hardness with hard and soft packing on print quality

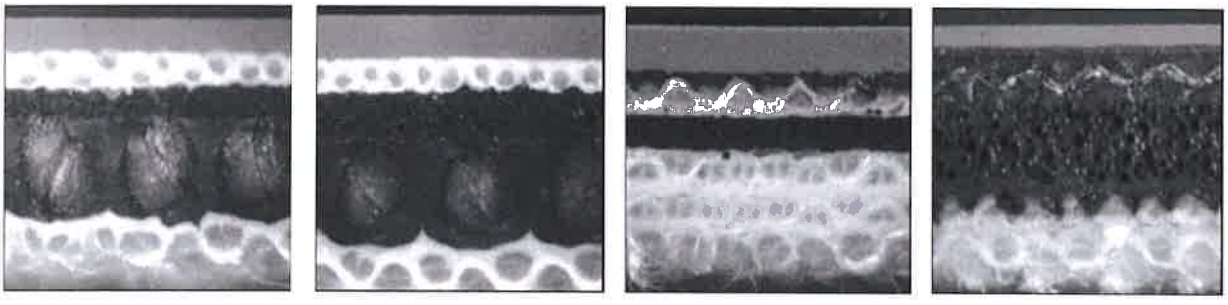
Printing press: Single colour presses Heidelberg GTO52 with Varn Compac dampening system. Printing pressure was set up using manufacturer documentation. To adjust pressure between blanket and print cylinder we started at zero pressure (kissprint) and after that we increased pressure by machine adjustment to achieve perfect smooth impression on the paper. Values are shown in Table I.

Table I: Achieved blanket thickness and squeeze on printing press at first test

	Sample 1		Sample 2		Sample 3		Sample 4	
Packing	Soft	Hard	Soft	Hard	Soft	Hard	Soft	Hard
Blanket and packing thickness (mm)	3.03	3.02	3.03	2.99	3.02	3.01	3.05	3.00
Thickness reduction after 2000 impressions (mm)	0.02	0.02	0.02	0.02	0.05	0.03	0.04	0.01
Blanket squeeze in plate cylinder nip (mm)	0.12	0.12	0.13	0.11	0.09	0.11	0.13	0.11
Blanket squeeze in print cylinder (paper) nip (mm)	0.17	0.17	0.25	0.20	-	0.24	0.20	0.20

Sample 3 blanket with soft packing gave us no good impression without additional increase of packing.

Blankets: Images of four samples are shown on Figure 1. Table II shows blankets characteristics used for first test. All Shore A hardness were measured directly on the blanket surface, not under standard conditions. Micro hardness was measured by DIN 53519. The compressibility module was measured using internal method of blanket manufacturer Sava, based on pressure needed for known indentation depth of 0.15, 0.30, 0.45 and 0.69 mm on triple blanket sample, where higher value means less compressible blanket.



Sample 1 Sample 2 Sample 3 Sample 4

Figure 1: Microscopic images of four samples, where different structure and thickness of layers is visible

Table II: Characteristics of blankets at first test

	Sample 1	Sample 2	Sample 3	Sample 4
Blanket thickness (mm)	1.70	1.97	1.99	1.95
Face layer thickness (mm)	0.23	0.30	0.36	0.28
Compressible layer thickness (mm)	0.21	0.33	0.33	0.58
Compressibility module (daN/cm^2)	15	10	7	13
Roughness R_a (µm):	0.57	0.59	0.64	0.93
Hardness on the blanket (Shore A)	85	80	79	81
Hardness in the press, soft packing (Shore A)	86	81	82	84
Hardness in the press, hard packing (Shore A)	87	83	83	85
Micro hardness (IRHD)	74	67	66	78

Packing: For soft packing we used underblanket 1.0 mm and some soft printing papers to achieve proper thickness/pressure. For hard packing we used 6 to 8 hard plastic foils and calibrated manila paper to achieve proper thickness/pressure.

Print substrate: Gloss coated paper 135 g/m^2.

Ink: Sakata Inx Azul Master +.

Densitometer: Macbeth RD 1242, Status E, with polarisation filter.

Results: Characteristics diagrams, compared to Fogra specification (Fogra, 2001).

2.2 Influence of blanket face layer micro hardness on print quality

Printing press: Single colour presses Heidelberg GTO52. We used same adjustment procedure as for the first test. We used underblanket and manila paper packing for both blankets. Pressure for bulky paper was increased using additional manila papers under blankets. Values are shown in Table III.

Table III: Achieved blanket thickness and squeeze on printing press at first test

	Sample 5		Sample 6	
Paper	Coated	Bulky	Coated	Bulky
Blanket and packing thickness (mm)	3.03	3.18	3.02	3.12
Thickness reduction after 2000 impressions (mm)	0.01	0.04	0.02	0.05
Blanket squeeze in plate cylinder nip (mm)	0.14	0.24	0.12	0.17
Blanket squeeze in print cylinder (paper) nip (mm)	0.21	0.45	0.22	0.40

Print substrate: Gloss coated paper and bulky uncoated paper was used. Characteristics of both papers are shown in Table IV.

Table IV: Characteristics of print substrates for second test

	Biogloss (gloss coated paper)	Aurora (bulky uncoated paper)
Grammage (g/m^2)	134	90
Specific volume (cm^3/g)	0.75	2.01
Roughness R_a lenghtwise (μm)A/B	0.47/0.44	4.81/4.55
Roughness R_a cross direction (μm)A/B	0.47/0.56	5.16/4.88

Blankets: Table V shows blankets characteristics used for second test. Measurement methods were the same as on first test.

Table V: Characteristics of blankets at first test

	Sample 5: Sava Ratio	Sample 6: Sava Advantage New
Blanket thickness (mm)	1.97	1.96
Face layer thickness (mm)	0.28	0.28
Compressible layer thickness (mm)	0.38	0.37
Compressibility module (daN/cm^2)	8	8
Roughness R_a (μm)	0.60	0.60
Hardness on the blanket (°Shore A)	83	80
Hardness in the press, soft packing (Shore A)	84	82
Micro hardness (IRHD)	74	68

Ink: Sakata Inx Azul Master +.

Densitometer: Macbeth RD 1242, Status E, with polarisation filter.

Results: Characteristic diagram, compared to Fogra specification.

3. Results

3.1 Influence of packing hardness on print quality

Characteristic dot area diagrams on Figure 2 (Sample 1, 2, 3, 4) shows results of first test for four blanket samples with hard and soft packing. There are only small differences between four tested samples with hard and soft packing, no more than 1 or 2 %, near precision and repeatibility of measurements. The apparent dot gain is in all cases under Fogra specification. In ¾ tones the difference is good visible.

3.2 Influence of micro hardness (IRHD) of blanket face layer on print quality

Results are shown in Figure 3 (Hard and soft blanket - coated and bulky paper). On gloss coated paper we obtained dot gain similar to Fogra specification, but dot gain by using blanket with soft micro hardness was smaller comparing to blanket with the same characteristics except for harder face layer. On rough bulky paper dot gain was high over Fogra specification, but results using blanket with soft face layer (IRHD micro hardness) were better.

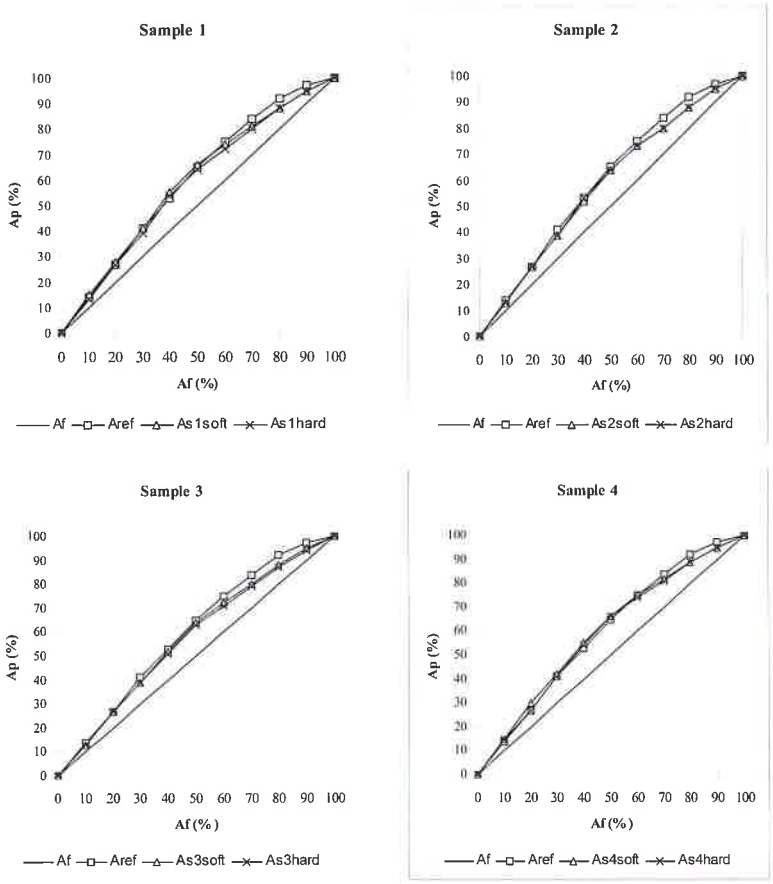


*Figure 2 (Sample 1, Sample 2, Sample 3, Sample 4): Apparent dot area (*A *on gloss coated paper compared to Fogra recommendations (*Aref*)*

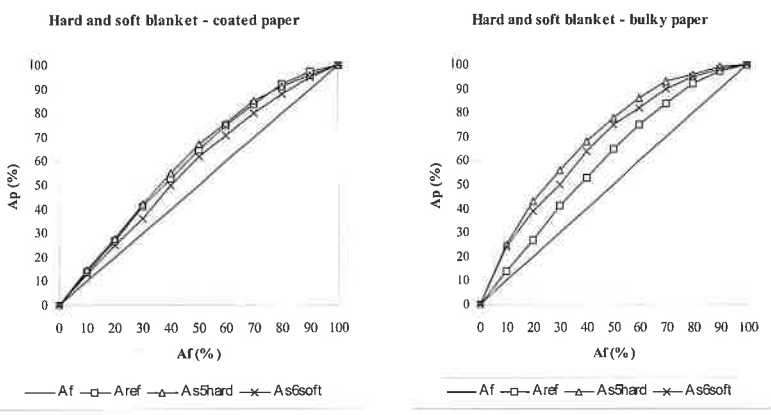


*Figure 3 (Hard and soft blanket - coated paper, Hard and soft blanket - bulky paper): Apparent dot area (*A*) on gloss coated paper and bulky paper compared to Fogra recommendation (*Aref*)*

4. Conclusions

During the first test we found that all four tested offset litho blankets gave us very good results comparing to Fogra specification. Hardness of packing was found having no influence on print quality observed through dot gain.

We did not perform tests with extremely soft packing based on soft cloth or cork, which were not available on the market any more and in practical use for quality lithographic offset printing. We also did not perform tests on four colours machine and in big format. We believe, that our results are valuable for printers having interest to perform additional tests under their specific conditions.

During the second test we found, that the only important parameter of blanket is micro hardness of face layer measured in IRHD. Blankets with soft face layer gave us better (smaller) dot gain on gloss coated paper and on very rough uncoated bulky paper.

Compression module of the blanket is also important to achieve proper printing pressure (200 to 300 N/cm^2). General instructions for adjustment of printing press should be corrected. Adjusted pressure depends on characteristics of blanket and print substrate, not only on thickness of blanket with packing and distance between rollers. The printing pressure must be set separately between plate and blanket cylinder and blanket and print cylinder.

In further investigations we intend to compare our methods for measurement of micro hardness and compressibility with other standards and specifications (Shore M micro hardness, compressibility ISO 12636) in order to find other characteristics of blankets that have important influence on ink transfer and print quality.

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Literature

Marchner, 1982, *Das System Birkan, Birkner & Kandlbinder Drucktuchvertrieb "Triumph", 80 p.*

Sun Chemical, Marketing Newsletter No. 45*: Litho Blankets for Heatset Printing, 1991.*

Spöring, 2000, *Das Drucktuch: High Tech im Offset, Druck & Medien Magazin, 5/2000, p. 34/35*

Aull, 1995, *Lehr- und Arbeitsbuch Druck: Technologie für Drucker der Fachstufen I und II*

Fogra, 2001, *ProcessStandard Offsetdruck: Wege zu konstanter Qualität von der Vorstufe bis zum Druckprodukt, BVDM, Wiesbaden*

Čuk, 2001, *Vpliv trdote gumijeve prevleke na kakovost rastrske reprodukcije v ofsetnem tisku (diploma)*

Kovač, 2002, *Vpliv mikrotrdote povrhnjice gumijeve napone na kakovost tiska (diploma)*

Prediction of rheological behaviour of paper in coldset web offset printing

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Abstract

Control of paper rheology in web offset printing is a big challenge; runnability is not only break-free run of paper through the printing process. The dimensional changes initiated by the water applied on paper in coldset web offset printing cause problems such as tension losses and fan-out. Instead of running laborious and expensive trials at coldset web offset printing press, the rheological behaviour of printing papers can be evaluated much more reliably with new devices that KCL has developed. KCL AHMA is a flexible pilot machine for measuring tension losses after water application in a wet nip. KCL Vesikko measures the fan-out tendency of papers in laboratory scale.

The advantages of KCL AHMA over ordinary printing trials are clear. For example, the water amount applied on paper can be adjusted accurately on-line. Web strain and tension are measured and controlled throughout the whole machine, which enables controlled experiments with several experimental designs. Delays before and after moisture application are adjustable, which makes it possible to simulate various printing processes.

In this paper, we show that water intake is the key parameter: when water intake is big, tension losses and fan-out are big. Applied water amount controlled the machine directional strain and dynamic tensile stiffness, and cross-machine directional fan-out both in coldset web offset printing and KCL AHMA. Paper properties had only small influence except for the factors that control water intake.

1. Introduction

Runnability is often defined as break-free run of paper through e.g. printing process. A lot of attention has been paid in studying the tensions and web breaks in printing. One must keep in mind that there is more to runnability than just the web breaks. The dimensional changes initiated by the water applied on paper in web offset printing causes problems such as tension losses. Tension losses can induce web fluttering that leads to wrinkles and even web breaks. Fan-out is a common problem in cross-machine direction. Prediction of these problems has been virtually impossible without expensive and time-consuming full-scale trials in printing press. Furthermore, in ordinary printing trials, measurements of web tension and strain are usually inaccurate and not simultaneous. In practice, it is very difficult to measure differences between papers with sufficient accuracy and relate them back to well-defined paper properties such as the tensile stiffness of paper.

The dimensional changes of paper in printing have been studied earlier either in full scale offset printing trials (Trollsås, 1987) or in pilot scale (Trollsås, 1997). Correlating laboratory experiments with full-scale offset printing has not been successful (Hansen, 1995). In this study, we conducted trials in web offset printing press and in pilot scale web characterization device KCL AHMA (Niskanen, 2003). In laboratory, we measured the dynamic dimensional changes of paper with KCL Vesikko (Tattari, 1998 & Tattari, 1999). The primary objective was to verify that KCL AHMA could predict the rheological behaviour of printing papers in coldset web offset printing.

The work presented in this paper is a part of the web rheology studies carried out at KCL. The work started by building a new machine for web runnability studies, KCL AHMA (Niskanen, 2003). Currently KCL AHMA is open only for the owners of KCL; other companies can use KCL AHMA when cooperating with the owners. Studies at KCL include thorough modelling of water sorption and the subsequent dimensional changes (Ketoja, 2001) along with experimental work (Kananen, 2003). In this study we build a practical connection from the pilot scale measurements to the phenomena in full-scale coldset web offset printing.

2. Experimental

2.1 Sample material

We used six commercial newsprint papers in the trials. The sample material was selected so that the runnability properties of different mills can be compared. The basic properties of the papers are presented in Appendix 1.

2.2 KCL Vesikko experiments

We measured the dynamic dimensional changes of the papers with KCL Vesikko (Tattari, 1998 & Tattari, 1999). KCL Vesikko is a device for measuring the in-plane dynamic dimensional changes of the paper after application of a water film to the paper surface in a wet nip (Figure 1). Two water application levels, 1.4 and 4.5 g/m^2, were used. Water intake was measured with lithium tracer. The results are presented in Appendix 1.

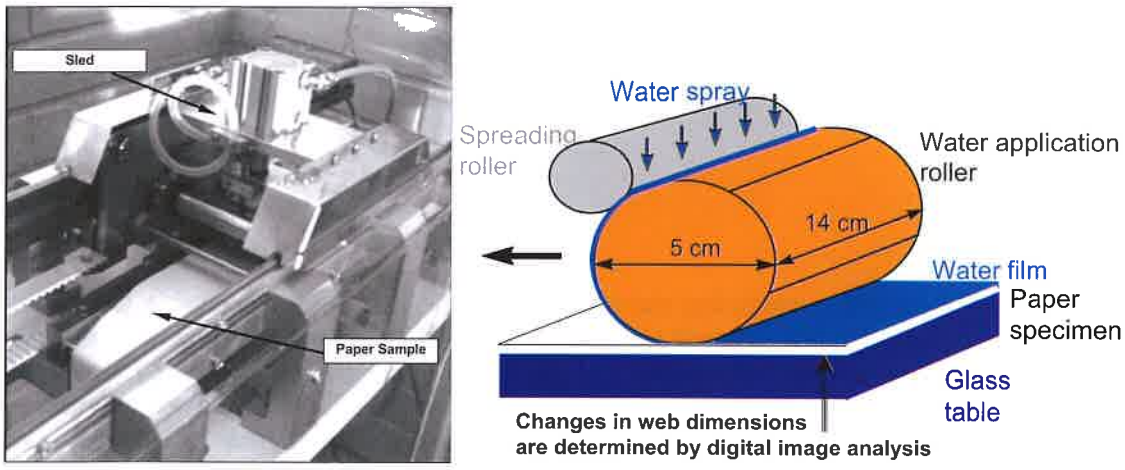

Figure 1: KCL Vesikko: a device for measuring the in-plane dynamic dimensional changes of paper after water application in a wet nip

2.3 Printing trial

The printing trial was implemented in the heatset web offset printing machine at KCL by simulating coldset web offset printing. The printing conditions were kept as normal as possible. We used commercial coldset inks, high amount of fountain solution (3 % Vegra violet and 6 % IPA) and the dryer was not used. IPA was used in the fountain solution to ensure that high enough water amounts (relevant to coldset printing) were transferred to paper with the water supply system of a heatset press. Production speed was 50 000 copies/h (6.2 m/s). Web tension after the four printing units was adjusted

to three different levels (200, 300, and ca. 400 N/m) by changing the speed of the folder unit. Infeed web tension was constant 200 N/m. In the beginning of the run of each paper we adjusted the print density to a constant value and fountain solution feed to normal level. The two other water intake levels used (low and high) were achieved simply by changing the fountain solution feed. Generally, we had no difficulties in running the papers in the printing press even though the changes made in printing conditions were quite big. Neither breaks nor other significant runnability problems occurred.

Web speed in the printing trial was measured with wheels that were pressed against the running paper web. With two of these measuring sensors, one in the infeed and the other after the chill rollers (see Figure 2 for illustration), we were able to measure the strain of the paper web. The measured value is the actual strain of the paper; not an estimated value based on the speed difference settings of the driving motors of the printing press. Web tension after the printing units was also measured.

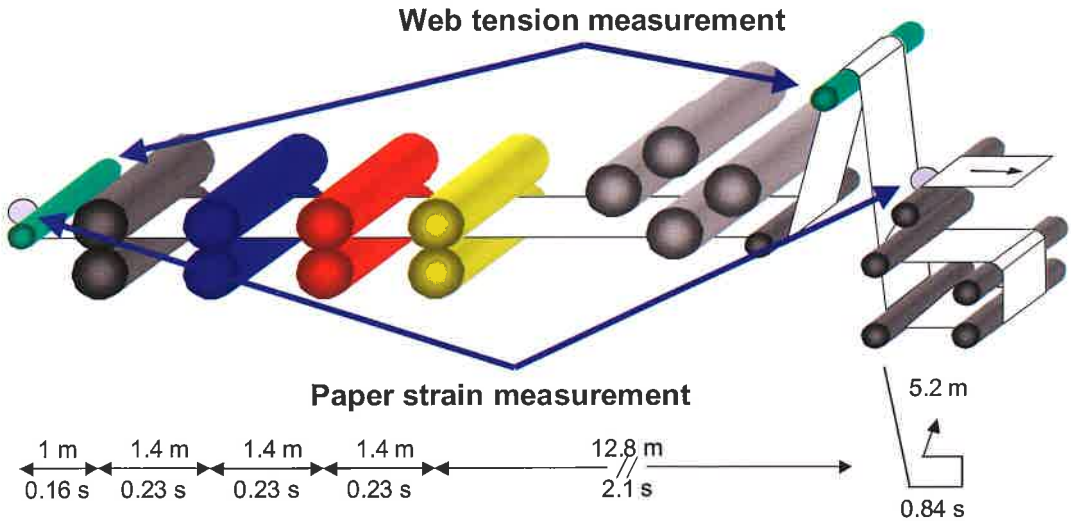

Figure 2: The set-up of the printing trial. The distances and delays (with the printing speed at 6.2 m/s) between different measurement points are presented in the figure. Chill rolls were bypassed in the trial

We determined the dynamic tensile stiffness of the web after moistening in the printing units by fitting a trend line to the stress-strain data. We use the concept of dynamic tensile stiffness here to separate the measurements made on the running paper web from laboratory measurements. The page lay-out consisted of cross-machine directional bars; part of them were full-colour fields and part one-colour fields on both sides of the paper. The page lay-out had also unprinted areas on both sides of the paper. Fan-out was measured with the aid of special scales that were printed near the edges on both sides of the web. The measurement was not possible with the yellow colour and so the fan-out was measured between black and magenta, the 1st and 3rd printing units, on the upper side of the paper.

2.4 KCL AHMA trials

KCL AHMA is a unique pilot scale test machine for general studies of the web rheology of running paper and board webs (Niskanen, 2003). Dynamic stress-strain characteristics of dry, moistened, and wet webs can be determined easily and affordably. The paper web runs at a speed of up to 1000 m/min through moistening units and open draws. Web tension and strain data is measured from several locations along the paper path. In the end the paper goes through a special test draw section for dynamic stress-strain testing. We can also change the moisture application "on the fly", in order to map out how the moisture intake of paper changes, and how the paper reacts to these changes.

Figure 3 displays the layout of KCL AHMA. The paper web moves from right to left in the figure. After the unwinder, the paper passes first a notching device, then two moistening units and a storage path, dancer roller that stabilizes the web, and finally the special test draw section between a brake nip and a pulling nip. After the pulling nip paper goes into a pipeline that leads to a waste paper compactor. The construction of the water application unit of KCL AHMA resembles that in offset printing. The water is transferred onto the paper in a wet nip with a rubber roller.

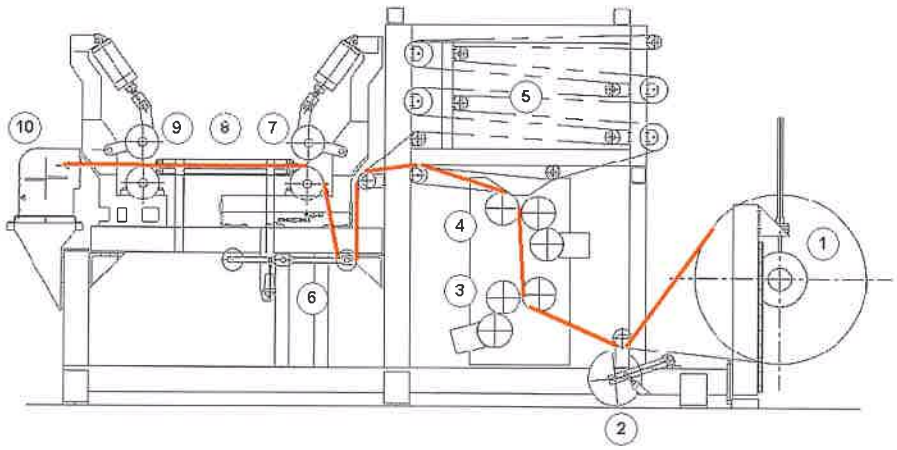

Figure 3: Web passage in KCL AHMA (Niskanen, 2003). The main components of KCL AHMA are: unwinder (1), device for making notches (2), lower moistening unit (3), upper moistening unit (4), storage path for delay control (5), dancer roller (6), brake nip (7), special test draw section for stress-strain measurements (8), pulling nip (9), and a shredding unit (10)

The KCL AHMA experiments were performed at constant web tension, without induced web breaks. The water amounts were 1.0, 1.5, 2.4, 4.0 and 8.0 g/m^2. The fountain solution contained 1 % of IPA. The transferred water amount was measured by weighing the water container on-line. The water intake (g/m^2) could be calculated since the running speed of KCL AHMA was known. The method allows accurate on-line adjustment of water intake. The water intake levels 1.0, 1.5, and 2.4 g/m^2 correspond to the average transferred water amounts in the printing trial.

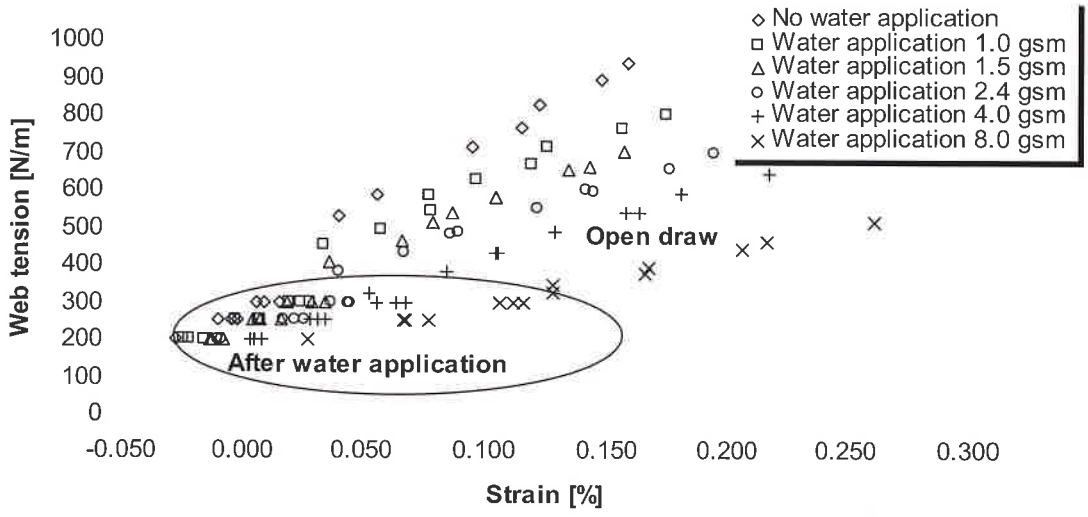

Figure 4: Example of KCL AHMA results with five water application levels and dry paper (no water application) were used in the trial. For each of these, the data points correspond to three web tension levels after the moistening unit and three speed differences. Water intake was measured using on-line weighing

Running speed was 4 m/s and delay from the moistening to the open draw was 0.5 seconds. We used three settings for the pre-tension after the moistening unit (200, 250, and 300 N/m, between numbers 4 and 7 in Figure 3) and three speed differences in the open draw (0.05, 0.10 and 0.15 %, number 8 in Figure 3). The purpose of using three pre-tensions and three speed differences in the open draw was to calculate the dynamic tensile stiffness of the running paper web; an example is presented in Figure 4.

3. Results

3.1 Printing trial results

The results of the printing trial are presented in Appendix 2. Water intake in the printing trial was measured both by lithium tracer (image and non-image areas) and weighing methods (non-image area). Water intake was higher for image areas than for non-image areas (Figure 5a). This has been detected also by other researchers (Lim, 1996 & Hansen, 1995). An average over the image and non-image areas (lithium tracer measurements) was calculated to obtain a single value for the water intake (Figure 5b). The average water amounts were 1.0, 1.6, and 2.3 g/m^2 for the low, normal, and high fountain solution feed levels, respectively. These values for water intake are used in this paper. The lithium measurement represents the total amount of water transferred into the paper in the printing nips, whereas weighing represents the moisture content of the web after folding. The results show that at least half of the water transferred to the paper in the printing nips evaporates during the printing machine. The addition of IPA to the fountain solution presumably accelerated evaporation. The "effective water amount" is somewhere between these two values. This means that some of the water transferred into the paper evaporates before it actually softens the paper or causes hydroexpansion.

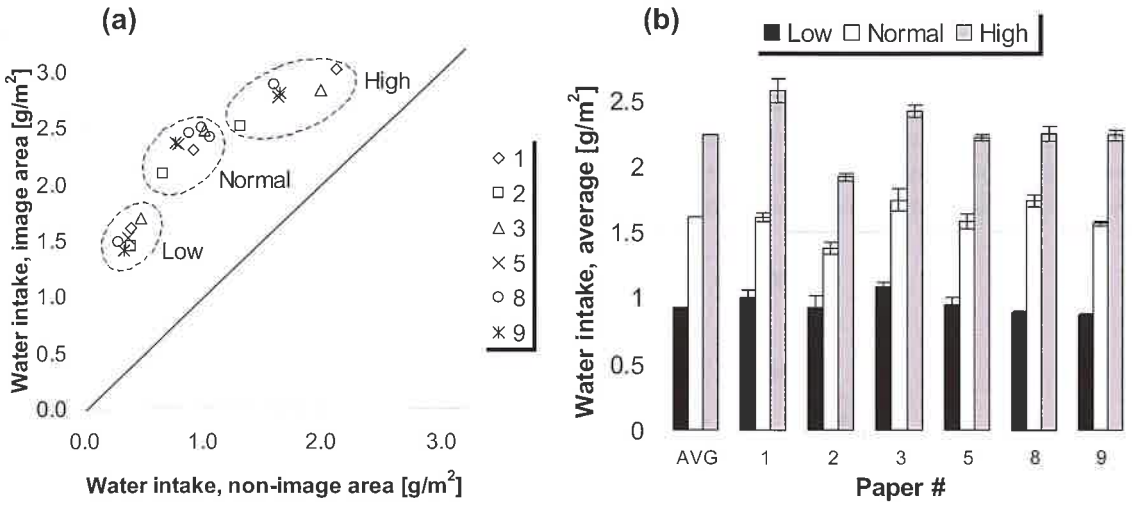

Figure 5: (a) Comparison of water intake on image and non-image areas in offset printing and (b) average water intakes. Three fountain solution feed levels were used and water intake was measured with lithium tracer

Water intake had a clear effect on paper strain in printing. An example of this is presented in Figure 6a for a web tension of 300 N/m, but the same was seen also for higher and lower web tensions. The stress-strain curves move to the right (i.e. in the direction of higher strain) when the fountain solution feed is increased, and at the same time, the slope (i.e. dynamic tensile stiffness) decreases. Anyhow, this effect is not that obvious (Figure 6b). For paper #8, the dynamic tensile stiffness decreases systematically with higher water intake. Papers #1 and #5 behaved exceptionally, as the dynamic tensile stiffness was highest at the normal fountain solution feed level. This behaviour was surprising

because the trial and measurements of these papers were successful. In the case of paper #2 the dynamic tensile stiffness did not change with higher fountain solution feed. These results demonstrate that dynamic tensile stiffness values measured in a printing trial are not highly reliable.

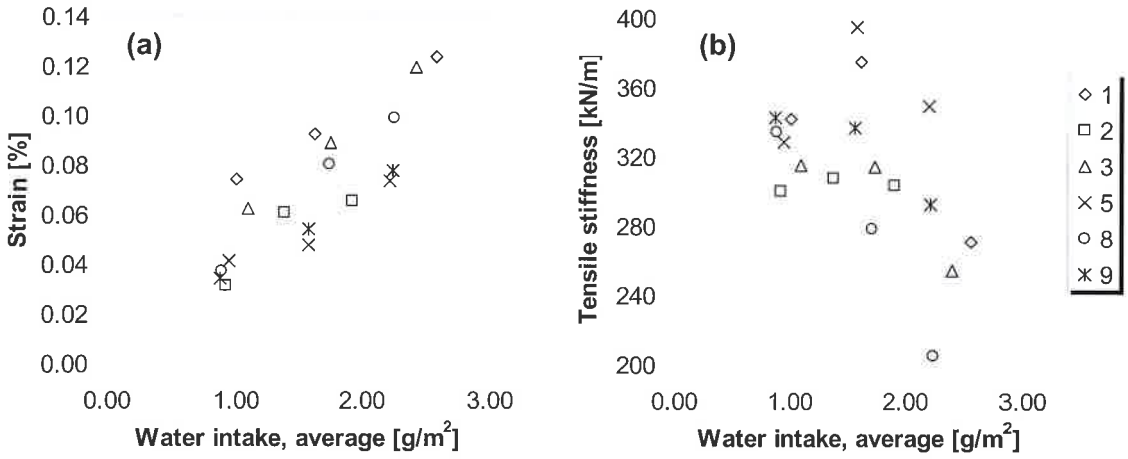

Figure 6: The effect of fountain solution feed on (a) paper strain at web tension 300 N/m and (b) dynamic tensile stiffness after printing units in four-colour coldset web offset printing. Three fountain solution feed levels were used. Water intake was an average of non-image and image areas and was measured with lithium tracer

Water intake controls the cross-machine directional expansion, i.e. fan-out, in web offset printing (Figure 7). Fan-out is higher with higher fountain solution feed. As fan-out was measured from black to magenta (1st and 3rd printing units) only the water applied in the black and cyan printing units (1st and 2nd printing units) affected it. The total water intake was therefore divided by two. The amounts of water applied in the different printing units were not equal, but the best approximation for the effective water intake was one half of the total amount. These water quantities are presented in Figure 7. Changes in web tension did not affect fan-out. This was tested using paper #1. Generally, register errors should not exceed 0.20 mm in printing (Thalén, 1994). This corresponds to 0.0125% with a 160 cm wide web. Fan-out of this order of magnitude was detected for all papers in this trial.

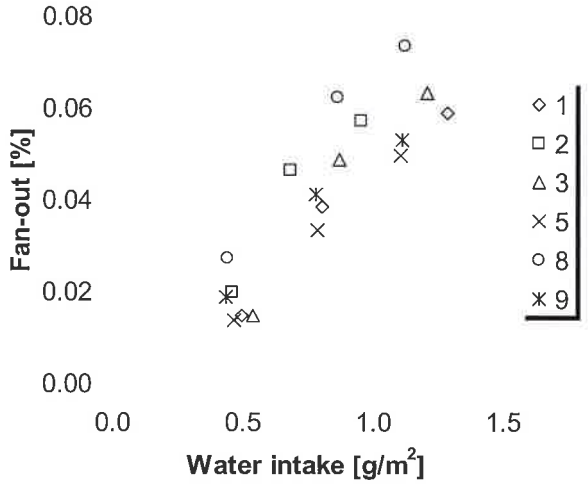

Figure 7: Fan-out as a function of water intake in coldset web offset printing. Water intake was varied by fountain solution feed. Fan-out was measured between black and magenta, and the corresponding water intake is shown. Water intake was an average of non-image and image areas and was measured with lithium tracer. Web tension 300 N/m

3.2 KCL AHMA results

The KCL AHMA results are presented in Appendix 2. Paper strain increases systematically with higher water intake (Figure 8a). The same was observed in the printing trial (Figure 6a), but the behaviour was less systematic than with KCL AHMA. Some papers strained more than others, which is not necessarily seen in the values of dynamic tensile stiffness (Figure 8b). It is obvious that the tensile stiffness of paper decreases with water application. The decrease in tensile stiffness is much more systematic than what was observed in the printing trial (Figure 6b). The dynamic tensile stiffness values for dry papers after the moistening units were in the order of 200 to 300 kN/m for most of the papers and therefore not realistic and not comparable to those of dry paper measurements in the laboratory. Generally, we have noted that the values for the dynamic tensile stiffness are smaller than the ones measured in laboratory. This was also seen in the printing trial. The dynamic tensile stiffnesses measured in the open draw were close to those measured in the printing trial (Figure 6b).

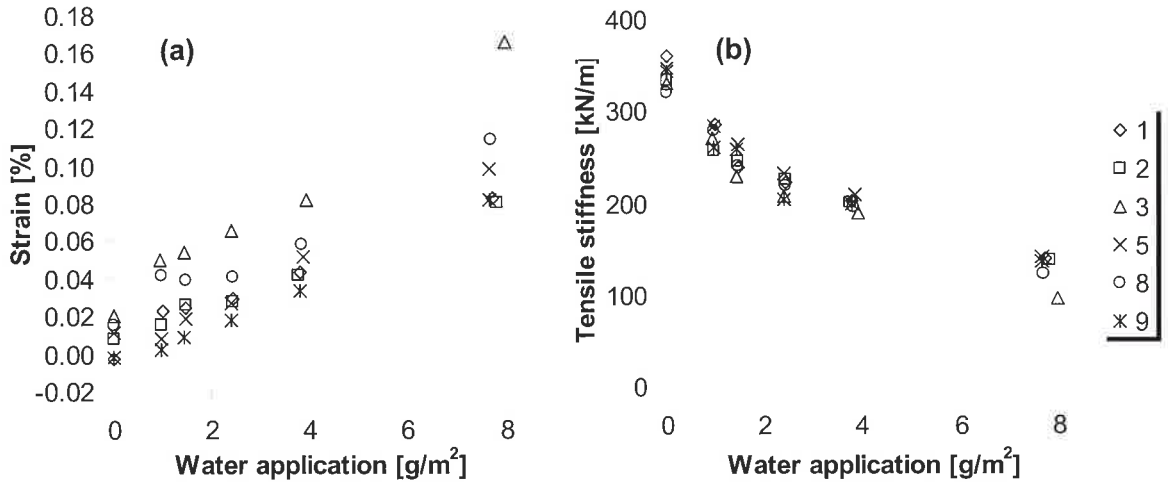

Figure 8: (a) Paper strain measured after the moistening unit in KCL AHMA. Paper strain is an average over all the trial points (web tensions) at each water application level. (b) Dynamic tensile stiffness in KCL AHMA after 0.5 seconds delay in the open draw. Water intake was measured using the on-line weighing method

4. Comparison of KCL AHMA and printing

It is reasonable to use the dynamic tensile stiffness values measured in the open draw (number 8 in Figure 3) for comparing the results to those of the printing trial because the values are close to the values measured in the printing trial. Another strong argument is that there was a delay from moistening to measurement. There was also a delay between printing units and measurements in the printing trial. One must keep in mind that the delays are not the same in the two processes.

Figure 9 shows the dynamic tensile stiffnesses at low and high fountain solution feed in printing and the corresponding KCL AHMA measurements. Paper #5 had an exceptionally high dynamic tensile stiffness in printing at high fountain solution feed (Figure 6b); if this is really correct, KCL AHMA cannot predict it. At low water application, KCL AHMA ranks the papers in the same order as the printing trial. The differences in the dynamic tensile stiffnesses with normal and high water levels were smaller in the KCL AHMA than in printing.

Generally, the dynamic tensile stiffnesses measured in KCL AHMA were smaller than those measured in the printing trial. This was most probably due to the different delays, the effect of nip compression, and creep caused by the high tensions used in the KCL AHMA. The relative importance of these

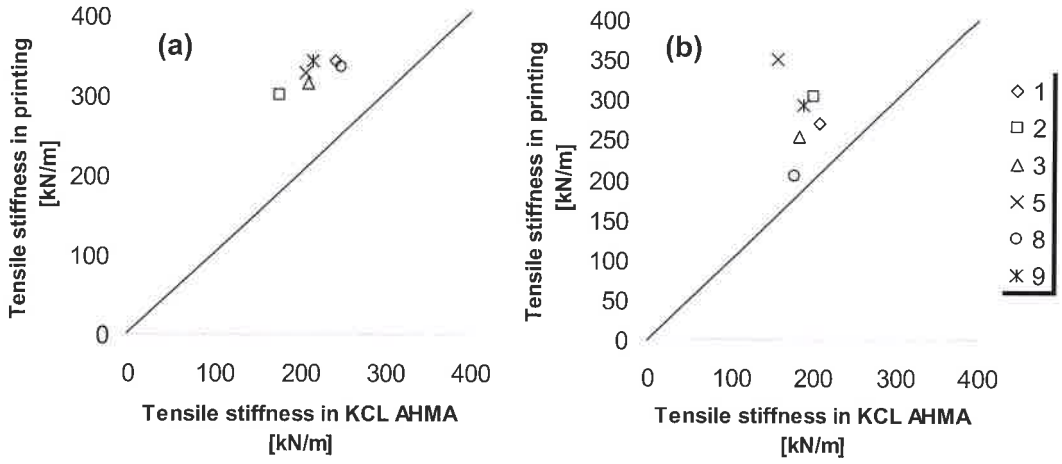

Figure 9: Comparison of the dynamic tensile stiffness in the printing trial and in the KCL AHMA. (a) at low water application and (b) at high water application. The water intake was equal in the two processes

mechanisms should be clarified in the future. The comparison of paper strain measured in KCL AHMA and in the printing trial shows the effect of delay clearly: the strain values measured in KCL AHMA were generally smaller than in printing. However, the increase in strain at higher water levels was seen in both processes even though the differences were smaller in KCL AHMA. After all, the results from KCL AHMA and printing are very well comparable.

5. Comparison of KCL Vesikko and printing

The papers reacted differently to the water applied to them in KCL Vesikko. The relationship between water intake and CD expansion was not obvious. Fan-out in printing was measured between black and magenta. The water applied in the black unit had 0.46 seconds to absorb into the paper and the water from the cyan unit had 0.23 seconds. Values for comparing the KCL Vesikko measurements with fan-out measurements were taken at 0.35 seconds after water application. This was the average of the two absorption times.

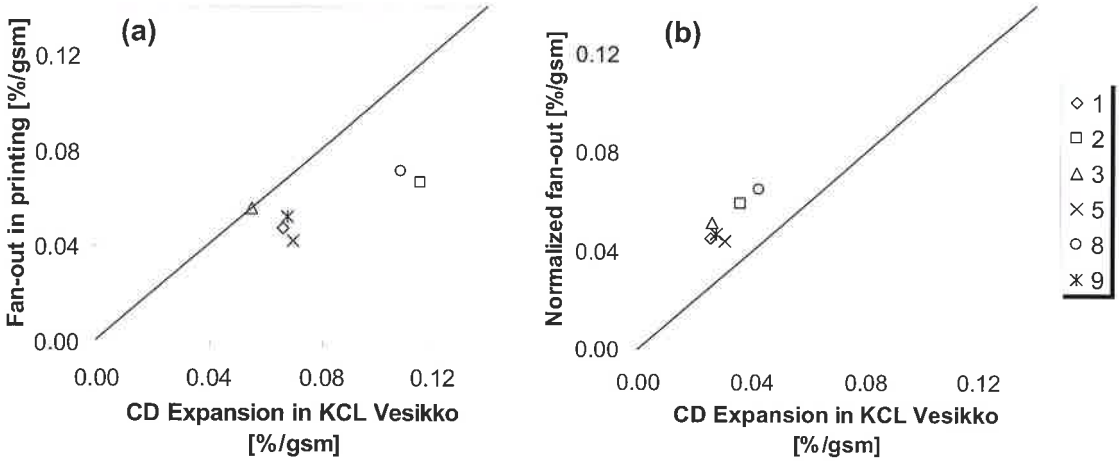

Figure 10: Normalized fan-out in printing against normalized CD expansion in KCL Vesikko. Normalization means that the expansion (or fan-out) is divided by water intake. (a) Normal fountain solution feed in printing (1.6 g/m^2) and low water intake in KCL Vesikko (1.3 g/m^2). (b) High fountain solution feed in printing (2.3 g/m^2) and high water intake in KCL Vesikko (4.5 g/m^2)

Direct comparison of KCL Vesikko measurements with fan-out in printing does not take into account the differences in water intake. The normalized CD expansion has to be calculated in order to predict fan-out based on KCL Vesikko measurements (Figure 10). Normalization means that the expansion (or fan-out) is divided by water intake. These normalized values were almost the same in the two cases. Values at high water intake were lower than at low water intake. Water is much more "efficient" at causing expansion when the water intake is low. The papers could be divided into two groups: papers #1, #3, #5, and #9 were clearly better than papers #2 and #8. These groups can be separated in the KCL Vesikko experiments.

6. Conclusions

In order to predict the tension losses caused by water application in coldset web offset printing we performed trials with six commercial newsprint papers in web offset printing and pilot scale machine, KCL AHMA. We measured the dynamic tensile stiffness of the running paper web. In addition, to evaluate the fan-out tendency of papers we measured the cross-machine directional expansion in printing and in KCL Vesikko.

Our trials showed that the amount of water applied in coldset web offset printing controls the machine directional tension losses and cross-machine directional fan-out: the higher the applied water amount, the greater are the harmful effects. Hence, the most effective way of minimizing dimensional changes is to minimize the amount of transferred water. The governing effect of water intake has also been verified by theoretical models developed in KCL (Ketoja 2001).

KCL AHMA can predict the tension behaviour of different papers in coldset web offset printing. The behaviour is much more systematic with water application than in coldset web offset printing. Furthermore, dynamic tensile stiffness correlates with the corresponding measurements in coldset web offset printing. The advantage of KCL AHMA is that paper strain and tension are measured in the same open draw. The basic rheological properties of paper can therefore be determined. This is not possible in printing trials where strain and tension measurements are not taken at the same place. The strain and tension values are complicated composites of many open draws and web transfers around rolls. The results are hence, strictly speaking, valid only for the machine configuration used. In addition, in KCL AHMA the applied water amount is adjusted exactly to the desired level, which allows systematic evaluation of paper performance.

Prediction of the tension behaviour of paper in any printing process is, in principle, possible if the dynamic tensile stiffness is known. KCL AHMA measurements are very flexible allowing simulation of the printing application at hand. Furthermore, one can use the theoretical models of KCL (Ketoja, 2001) to transform the results obtained with KCL AHMA to correspond to any printing process. Thus, KCL AHMA trials offer significant savings both in trial costs and time compared to printing trials.

Savings in product development costs can be achieved by using KCL AHMA in ranking e.g. different mixtures of furnish. Benchmarking is one of the obvious applications. The inexpensive KCL Vesikko experiments are reliable in predicting cross-machine directional fan-out in web offset printing. Fan-out is generally a problem with newsprints containing mainly deinked pulp. Applications of KCL Vesikko in tackling these problems are relevant. For example, different sizing agents or furnish mixtures can be tested reliably and affordably.

Acknowledgements

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References

Hansen A., *Water absorption and dimensional changes of newsprint during offset printing. Advances in printing science and technology: proceedings of the 23rd research conference of IARIGAI, Paris, France, 17-20 September 1995. John Wiley and Sons, 1997. pp. 247 - 267.*

Kananen, J., *Water Transfer and Dimensional Changes of Paper in a Wet Nip. Licentiate thesis. Helsinki University of Technology. 2003. 177 p.*

Ketoja, J.A., Kananen, J., Niskanen, K.J. & Tattari, H., *Sorption and web expansion mechanisms. The science of papermaking, 12th Fundamental Research Symposium, Oxford, UK, 17-21, September 2001, The Pulp and Paper Fundamental Research Society, Bury, UK, 2001, vol. 2, pp 1357-1370.*

Lim, P.Y.W., Daniels, C.J & Sandholzer, R.E., *Determination of the fountain solution picked up by the paper and ink in offset printing. 1996 International Printing and Graphic Arts Conference, Minneapolis, MN, USA, 16-19 September 1996. TAPPI Press, Atlanta, GA, USA, pp 83-*

Niskanen, K., Mäkinen, J., Ketoja, J., Kananen, J. & Wathén, R., *Paper industry invests in better web runnability. Pap. Puu 85(2003):5, pp 274-278.*

Tattari, H. & Niskanen, K., *Dynamic measurement of dimensional changes. International Printing and Graphic Arts Conference, 6-8 October 1998, Quebec. CPPA, TAPPI, pp 117-120.*

Tattari, H. & Niskanen, K., *Influence of web tension and water application on dimensional changes of paper. 4th International symposium on moisture and creep effects on paper, board and containers, Grenoble, France, 18-19 Mar. 1999, pp 234-244.*

Thalén, N., Kolmodin, H. & Glasare, K., *Dimensional changes of newsprint in offset printing. Moisture-Induced Creep Behaviour of Paper and Board, Stockholm, Sweden, 5-7 December 1994. STFI, Stockholm, Sweden, 1995, pp 149-165.*

Trollsås, P.-O. & Larsson, L.O., *Water uptake and dimensional changes of newsprint paper in offset printing (in Swedish). Tidningspappersbrukens Forskningslaboratorium (TFL), Rapport 4:6. Djursholm, 1987. 49 p.*

Trollsås P.-O., *Influence of small amounts of water and small strains on the dimensional changes and tensions in a running paper web. 3rd International symposium on moisture and creep effects on paper, board and containers. 20-21 February 1997, Rotorua, New Zealand. PAPRO 1997. pp. 135-150.*

Appendix 1

The basic properties and results of KCL Vesikko experiments of the papers.

Table I: Basic properties of the papers. Averages and standard deviations are presented in the table

Paper #	1		2		3		5		8		9	
	AVG	DEV	AVG	DEV	AVG	DEV	AVG	DEV	AVG	DEV	AVG	DEV
Grammage, ISO 536:1995, g/m²	48.8		48.4		47.2		51.9		44.7		48.2	
Single sheet thickness, ISO 534:1988, µm	79	0.76	86	1.10	67	0.51	79	1.22	74	1.24	81	1.30
Bulking thickness, ISO 534:1988, µm	74		81		63		76		69		77	
Apparent bulk-density, ISO 534:1988, kg/m³	659		598		749		683		647		626	
Roughness, Print-surf, S10, ISO 8791-4:1992, µm												
Inside	3.65	0.21	3.95	0.18	2.80	0.10	3.75	0.23	3.30	3.3	3.55	0.14
Outside	3.25	0.16	3.65	0.16	2.75	0.07	3.10	0.15	2.80	2.80	3.00	0.09
Roughness, Bendtsen, ISO 8791-2:1990, ml/min												
Inside	115	10	160	17	50	4	102	15	123	123	131	14
Outside	91	6	143	16	48	3	82	11	104	104	108	13
Air permeance, Bendtsen, ISO 5636-3:1992, ml/min	192	16	307	41	168	9	147	21	186	186	158	12
Tensile strength, ISO 1924-2:1994, kN/m												
MD	2.53	0.11	2.65	0.13	2.38	0.23	2.57	0.16	2.68	2.68	2.88	0.06
CD	0.93	0.02	0.89	0.04	0.82	0.02	1.02	0.03	0.76	0.76	0.90	0.03
Tensile index, ISO 1924-2:1994, Nm/g												
MD	51.8		54.7		50.3		49.5		59.9		59.6	
CD	19.1		18.3		17.5		19.7		16.9		18.7	
Stretch, ISO 1924-2:1994, %												
MD	0.90	0.07	0.99	0.08	0.85	0.11	0.92	0.08	1.08	1.08	1.14	0.04
CD	2.67	0.21	2.42	0.19	2.32	0.21	2.77	0.21	2.62	2.62	2.40	0.16
Tensile energy absorption, ISO 1924-2:1994, J/m²												
MD	13.3	1.7	15.5	2.2	11.9	2.7	13.9	2.3	17.1	17.1	19.6	1.3
CD	16.7	1.8	14.0	1.9	13.2	1.7	19.4	2.1	13.1	13.1	14.1	1.5
Tensile stiffness, ISO 1924-2:1994, kN/m												
MD	371.1	3.3	356.5	6.6	364.8	9.2	373.1	10.6	338.4	338.4	355.3	3.8
CD	77.0	2.1	71.3	3.9	81.6	1.3	88.0	4.0	58.1	58.1	71.8	1.3
Ash content, ISO 2144:1997, 900 °C, %	2.79		6.52		8.77		2.36		0.67		1.32	
Contact angle, 0.1 s, °												
With distilled water	81.1		99		81.1		51.8		93.5		91.8	
With fountain solution	57.3		77.7		64.8		46.8		67.6		66.3	

Table II: KCL Vesikko dynamic expansion in a wet nip. The applicator settings of 0 µm were used for high water intake and – 150 µm for low water intake. The other variables were constant: web tension 143 N/m, nip pressure 7.5 kN/m (3 bar), sled speed 0.5 m/s, and measurement frequency 50 images/s (measurement time 10.2 s)

	Expansion averages								95% Confidence intervals								Water intake
	Machine direction				Cross-machine direction				Machine direction				Cross-machine direction				Lithium analysis
Sample	0.2-0.9s %	0.9-1.6s %	1.6-2.5s %	0.3-0.4s %	0.2-0.9s %	0.9-1.6s %	1.6-2.5s %	0.3-0.4s %	0.2-0.9s %	0.9-1.6s %	1.6-2.5s %	0.3-0.4s %	0.2-0.9s %	0.9-1.6s %	1.6-2.5s %	0.3-0.4s %	g/m²
1 High	0.036	0.054	0.070	0.035	0.140	0.213	0.251	0.116	0.006	0.008	0.008	0.005	0.015	0.023	0.024	0.017	4.62
2 High	0.035	0.051	0.073	0.030	0.162	0.258	0.295	0.135	0.004	0.010	0.012	0.005	0.018	0.033	0.031	0.007	3.77
3 High	0.041	0.072	0.084	0.033	0.146	0.229	0.278	0.147	0.007	0.006	0.007	0.005	0.013	0.023	0.030	0.005	5.70
5 High	0.041	0.063	0.084	0.035	0.169	0.265	0.315	0.167	0.009	0.013	0.015	0.002	0.013	0.029	0.028	0.009	5.54
8 High	0.034	0.047	0.077	0.035	0.143	0.231	0.286	0.150	0.003	0.007	0.007	0.005	0.014	0.024	0.043	0.012	3.54
9 High	0.023	0.028	0.058	0.018	0.113	0.175	0.212	0.105	0.010	0.013	0.021	0.006	0.015	0.018	0.022	0.013	3.82
1 Low	0.024	0.025	0.022	0.022	0.102	0.130	0.137	0.098	0.005	0.006	0.007	0.003	0.008	0.009	0.008	0.009	1.48
2 Low	0.025	0.031	0.029	0.033	0.094	0.124	0.128	0.106	0.004	0.009	0.011	0.009	0.011	0.014	0.012	0.011	0.92
3 Low	0.023	0.025	0.024	0.018	0.090	0.130	0.144	0.097	0.004	0.010	0.008	0.004	0.009	0.010	0.009	0.010	1.77
5 Low	0.027	0.036	0.046	0.026	0.104	0.136	0.152	0.115	0.004	0.005	0.006	0.009	0.015	0.020	0.017	0.007	1.66
8 Low	0.023	0.010	0.003	0.034	0.100	0.136	0.140	0.104	0.006	0.007	0.004	0.010	0.008	0.009	0.008	0.005	0.96
9 Low	0.024	0.017	0.016	0.026	0.104	0.141	0.145	0.093	0.006	0.009	0.007	0.006	0.009	0.012	0.011	0.009	1.38

Appendix 2.

Results of the printing trial and the KCL AHMA trials.

Table I: Results of the printing trial

Paper #	Fountain solution feed level	Web tension level	Water intake, weighing [%] Non-image area	Water intake, lithium tracer [g/m²] Image area	Non-image area	Average over image- and non-image areas	Web tension [N/m]	Strain [%]	Dynamic tensile stiffness [kN/m]	Fan-out [%]
1	Normal	Normal	0.45	2.31	0.92	1.62	313.1	0.093	375	0.038
		High	0.69				342.5	0.103		0.039
		Low	0.89				220.3	0.070		0.042
	Low	Normal	0.43	1.62	0.39	1.00	302.4	0.074	342	0.014
		High	0.22				317.9	0.073		0.010
		Low	0.35				205.9	0.043		0.009
	High	Normal	1.39	3.03	2.12	2.58	306.1	0.123	271	0.059
		High	1.42				341.5	0.143		0.021
		Low	1.36				219.6	0.097		0.023
	Dry	Normal	0.05				312.6	0.097		
2	Normal	Normal	0.26	2.10	0.66	1.38	306.4	0.060	308	0.046
		High	0.00				344.5	0.070		0.010
		Low	0.07				202.2	0.025		0.004
	Low	Normal	0.13	1.46	0.39	0.92	300.7	0.031	300	0.020
		High	0.12				323.6	0.036		0.013
		Low	-0.02				217.8	0.002		0.014
	High	Normal	0.43	2.52	1.32	1.92	314.7	0.065	304	0.057
		High	0.69				349.8	0.082		0.025
		Low	0.86				206.1	0.033		0.020
	Dry	Normal	-0.43				313.3	0.040		
3	Normal	Normal	0.27	2.48	1.01	1.75	300.3	0.089	314	0.049
		High	0.25				315.0	0.091		
		Low	0.30				215.8	0.061		
	Low	Normal	-0.02	1.70	0.48	1.09	297.7	0.062	315	0.014
		High	0.22				296.5	0.061		
		Low	0.13				206.2	0.033		
	High	Normal	0.83	2.84	2.00	2.42	304.4	0.120	254	0.063
		High	0.54				312.8	0.119		
		Low	0.74				201.7	0.077		
	Dry	Normal	-0.24				311.9	0.102		

Paper #	Fountain solution feed level	Web tension level	Water intake, weighing [%] Non-image area	Water intake, lithium tracer [g/m²] Image area	Non-image area	Average over image- and non-image areas	Web tension [N/m]	Strain [%]	Dynamic tensile stiffness (kN/m)	Fan-out [%]
5	Normal	Normal	0.34	2.36	0.79	1.58	300.5	0.048	395	0.033
		High	0.64				324.8	0.058		
		Low	0.65				219.1	0.031		
	Low	Normal	0.33	1.52	0.37	0.94	298.6	0.041	329	0.014
		High	0.25				305.5	0.040		
		Low	0.39				208.5	0.012		
	High	Normal	0.84	2.78	1.64	2.21	304.4	0.074	349	0.049
		High	0.75				323.1	0.085		
		Low	0.99				214.3	0.053		
	Dry	Normal	0.11				313.3	0.069		
8	Normal	Normal	0.75	2.41	1.06	1.74	302.7	0.080	278	
		High	0.65	2.51	0.99	1.75	341.8	0.090		
		Low	0.40	2.45	0.89	1.67	206.6	0.043		
	Low	Normal	0.11	1.49	0.29	0.89	302.5	0.037	335	0.027
		High	0.23				Failed	Failed		
		Low	0.34				209.0	0.009		
	High	Normal	1.05	2.89	1.61	2.25	310.0	0.099	205	0.073
		High	1.34				336.9	0.124		
		Low	1.38				213.0	0.062		
	Dry	Normal	0.12				311.9	0.066		
9	Normal	Normal	0.44	2.37	0.77	1.57	304.7	0.054	336	0.041
		High	0.31				332.6	0.060		
		Low	0.29				214.0	0.026		
	Low	Normal	0.46	1.42	0.33	0.88	302.4	0.034	342	0.019
		High	0.39				317.1	0.037		
		Low	0.38				209.1	0.006		
	High	Normal	0.96	2.81	1.65	2.23	307.3	0.078	293	0.053
		High	0.96				332.5	0.096		
		Low	1.00				217.4	0.057		
	Dry	Normal	-0.13				300.8	0.054		

Table II: Results of the KCL AHMA trials

Paper #	Water application [g/m²] Weighing	Lithium tracer	Strain (Average of each water application level) [%] After moistening	Open draw	Dynamic tensile stiffness [kN/m] After moistening	Open draw
1	-	-	-0.003	0.097	260	360
	1.00	-	0.023	0.123	238	286
	1.48	-	0.025	0.125	195	239
	2.45	-	0.029	0.129	206	222
	3.82	3.85	0.043	0.137	165	203
	7.73	7.89	0.083	0.183	142	139
2	-	-	0.008	0.108	228	334
	0.99	-	0.015	0.115	173	257
	1.48	-	0.026	0.120	195	245
	2.44	-	0.027	0.127	199	225
	3.79	3.71	0.041	0.141	157	201
	7.81	7.61	0.080	0.180	125	137
3	-	-	0.020	0.120	251	331
	0.95	-	0.050	0.150	207	270
	1.46	-	0.054	0.154	186	229
	2.41	-	0.065	0.165	181	208
	3.95	4.19	0.081	0.181	152	189
	7.95	8.61	0.165	0.265	99	95

Paper #	Water application [g/m²] Weighing	Lithium tracer	Strain (Average of each water application level) [%] After moistening	Open draw	Dynamic tensile stiffness [kN/m] After moistening	Open draw
5	-	-	0.011	0.095	284	347
	0.99	-	0.008	0.108	203	283
	1.47	-	0.019	0.119	209	264
	2.43	-	0.027	0.133	156	233
	3.88	3.81	0.051	0.151	165	209
	7.65	7.76	0.098	0.198	136	141
8	-	-	0.015	0.115	228	321
	0.98	-	0.042	0.142	246	279
	1.47	-	0.039	0.139	179	241
	2.44	-	0.041	0.141	177	219
	3.84	3.77	0.058	0.158	177	195
	7.68	7.69	0.114	0.214	117	123
9	-	-	-0.002	0.105	254	344
	0.97	-	0.002	0.102	212	260
	1.45	-	0.009	0.109	236	258
	2.42	-	0.018	0.118	188	205
	3.81	3.70	0.033	0.133	171	199
	7.66	8.24	0.082	0.182	118	136

Paper surface quality in electrophotographic printing

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Abstract

Printing orientation to digital printing techniques means the use of new valuation methodology of surface properties and interactions between paper surface and printing inks, toners or colours. Interactions are caused by the change of surface charge of the printing substrate, which activates the surface and make it possible to electrostatic bonding of single components from the toners and printing inks.

Mechanisms of the interactions base on surface charge neutralization by adsorption of opposite charged ion from the printing ink or colour. The rate of adsorption and stabilization of the printing ink or colour is determined by the properties as surface charge, capillarity and appropriate penetration ability in to the printing substrate structure.

Research hypothesis is the study of the effect of used raw materials like fibres as well as added auxiliary agents into the paper web that affect the surface charge and surface energy and the study of the printing quality.

1. Introduction

This presentation on digital printing is focused on electrophotographic printing, namely on the influence of raw materials in paper sheet on the surface properties and quality of print.

Due to rapid development of desktop publishing, knowledge of materials and technology in electrophotography enables the user of electrophotographic appliances to determine printing runnability, printability and quality in test printing.

Electrophotography differs from analogous printing techniques in the fact that a new printing form is made by the appliance for each individual print. The image is created by neutralizing a latent image's electrical charge and by applying electrostatically charged toner particles that are fixed on paper by means of temperature and pressure. The basic properties of a printing substrate, namely paper, used in electrophotographical techniques, are therefore good temperature stability, electric resistance and surface properties such as surface energy, roughness, smoothness and optical properties.

Digital printing techniques, especially electrophotography and inkjet printing, determine surface and structural quality of a printing substrate. Raw materials, technological parameters and production process are factors that mainly affect structural quality, whereas surface quality is influenced by the finishing processes such as sizing, coating and calendering.

Since all components of paper are charge carriers that enable transfer and print of ink or toner particles in digital printing techniques, structural properties depend on entering raw materials, fibres, fillers and auxiliary papermaking additives. Electrophotographic print on paper surface depends on electrical surface and structural properties, surface energy, and on the acidic-basic balance between toner and

paper surface and local changes in surface roughness. Electrical properties determine the efficiency of toner transfer to the surface of the printing substrate. With electrophotographic printing techniques, an image is created by neutralizing the charge on printing substrate's surface with toner particles that are fixed on the surface by temperature or/and pressure.

The conditions for good electrification and surface activation are electrical properties such as dielectric constant, dielectric loss and a decrease in dielectric strength. The influential constant is affected by sheet structure, crystallinity of the cellulose molecule, presence of wood components and fibre density and orientation since electric conductivity and surface resistance depend on the possibility of polarization of polymers as composite parts of paper. Dielectric loss is needed for a change in polymerisation, and depends on polar groups in paper and on metal ions in the presence of humidity.

The aim of the research was to determine the influence of raw materials on surface properties of paper and on the quality of an electrophotographic print. Specific properties of paper surface, surface energy, electric resistance and their influence on print quality were analysed on different laboratory-made paper grades.

2. Experimental work

General requirements for electrophotographic paper are determined by standards or by producers of paper and graphic equipment. However, there are some common required properties that need to be taken into consideration: constant grammage and thickness of the paper sheet without mechanical damage or folds; humidity content being a condition not only for printing runnability but also the for electrification ability; electrical properties, surface electric resistance and structural conductivity; roughness, smoothness and optical properties.

An appropriate choice of raw materials in paper enables specific properties. For example, mechanical pulp and high-yield pulp enable high voluminosity and opacity of paper sheet, whereas chemical pulp contributes good mechanical properties, low abrasivity, roughness and good folding endurance.

To record information, electrophotographic appliances use a photosensitive semiconductor. Under the influence of light, an electrostatic charge is formed on. A latent image is formed and the charge is neutralized with toner particles. To fix toner particles on the printing substrate's surface, increased temperature and/or pressure are required. Low-quality or irregular print, as well as poor fixing of toner particles can be caused by a choice of toner, machine defect and/or by inappropriate quality of the printing substrate, namely paper.

The quality of the printing substrate for electrophotographic printing techniques is determined mainly by surface properties, namely by smoothness and roughness that determines a tolerance of actual surface to the geometrical, ideally smooth surface, and to some extent affects the distribution of toner particles on the surface. The surface energy of a printing substrate determines surface wettability by liquid. Namely, it is required that the difference between the liquid's surface tension and the printing substrate's surface energy should be < 10mN/m. Electric resistance of the surface is expressed by the voltage quotient between the electrodes on paper surface and electric current in a particular time of electrification.

The aim of the research was to determine the influence of raw materials, fibre and fillers on the properties that are important for the printing substrate printed by electrophotography. A Hewlet Packard Laser Jet 2100 laser printer was used.

2.1 Laboratory sheet formation

Paper sheets were formed by laboratory scale. We decided for the following raw material compositions:

- 1st series: chemical pulp of hardwood and softwood at a ratio of 60 % to 40 %
- 2nd series: 80 % BCTMP and 20% mixture of chemical pulp (see Table I).

Additives: calcium carbonate with negatively charged particles and calcium carbonate with positively charged particles as filler, AKD sizing agent and a cationic cornstarch derivate. Sheets had been formed on a Rapid Koethen laboratory former in compliance with the SIST ISO standard requirements. Afterwards, they were calendered on a Ramisch laboratory calender at 1 t line pressure without temperature regulation, with the purpose of improving paper surface roughness.

Paper sheets were fully sized without surface treatment because we wanted to monitor the influence of basic fibre and filler, which would otherwise be concealed by surface sizing of paper sheets.

As the comparable printing substrates, the printing papers of the commercial grades and the laser printing film, were used (see Table I).

Table I: Paper samples
- composition and finishing and the comparable printing substrates

Sample	Fibres	Filler	Sizing agent	Finishing	
1	Cellulose fibres	Calcium carbonate (-ZP)	AKD		calendered
2	Cellulose fibres	Calcium carbonate (-ZP)	AKD	--	
3	Cellulose fibres	Calcium carbonate (+ZP)	AKD		calendered
4	Cellulose fibres	Calcium carbonate (+ZP)	AKD	--	
5	BCTMP (80%) Cell. fibres (20%)	Calcium carbonate (+ZP)	AKD		calendered
6	BCTMP (80%) Cell. fibres (20%)	Calcium carbonate (+ZP)	AKD	--	
7	BCTMP (80%) Cell. fibres (20%)	Calcium carbonate (-ZP)	AKD		calendered
8	BCTMP (80%) Cell. fibres (20%)	Calcium carbonate (-ZP)	AKD	--	
ref 9	Commercial product	Calcium carbonate	Neutral sizing		machine calendered
ref 10	Commercial product; 3-plies [1]	Calcium carbonate	Neutral sizing		machine calendered
film	Kimoto Laser Film				

Note: [1] the middle ply is produced of mechanical fibres

2.2 Measuring methods

Paper properties were analysed by surface characterization methods. Thus, roughness was determined than surface energy, electric resistance of surface and gloss.

Roughness of sample surface was measured by a laser profilometer (Perthometer). The measurements were conducted on the printable side of samples, namely on unprinted and printed samples with 100 % covered surfaces. The measuring area was horizontally 5,6 mm and vertically 250 μm. The measurement represents the average aberration of an actual-profile curve from the middle line and thus provides information on altitude tolerance.

Surface energy is an indicator of the paper surface's wettability degree. The liquid wets (is distributed on) the surface of a solid substance if its surface tension γ is lower than the surface energy of the solid substance. In that case, due to activities of interior cohesive forces, the liquid is formed into a drop (its surface energy is then the lowest) with a contact angle that is determined regarding the solid substance surface. This property of liquids in used for measuring the contact angle, which serves as the criterion for the surface energy of solid substances. Contact angle calculation and wetting are expressed by the Young equation (1).

$$\gamma_{SV} - \gamma_{SL} = \gamma_{LV} \cos\theta \tag{1}$$

Research results indicated that surface energy also influences the properties of toner fixing on paper in the process of laser printing. The most suitable toner adhesion is attained when the free surface energy of both toner and paper is the same (6). Surface energy of paper samples was measured by means of a wetting dynamics and sorption tester (DAT; CCD camera that creates 50 images in a second). As liquids water and formamide were applied. Surface energy is defined by an equation (2) with σ being the liquid's surface tension

$$g^s = \sigma + \Sigma\Gamma_i \mu_i \tag{2}$$

The electric resistance of paper surface is expressed as a quotient of electric tension established between the electrodes on paper surface and electric current between the electrodes during electrification (provided that polarization on electrodes is neglected).

A Hewlett Packard appliance for measuring surface and volume resistance of materials with isolating properties was used for measuring the surface electric tension of paper. The appliance comprises a measuring element (resistivity cell Hewlett Packard 16008 A) and resistance meter (Hewlett Packard 4329 A). Charging (electrification) lasted 1 minute, and the tension with which samples were charged amounted to 100 V. Measurements were conducted on printed and unprinted samples under standard conditions (50% relative air humidity and 23°C air temperature).

Print quality was determined by measuring toner adhesivity, gloss, print mottling and line wicking. Toner adhesivity is defined by the degree of strength with which the toner (affected by heat or pressure) is fixed on paper surface in the process of laser printing.

Out of several available methods for measuring adhesivity, we chose a modified method of determining toner adhesivity in compliance with the ENV 12283 standard. All measurements were conducted on the upper side of printed samples (100% covered surface) by means of the IGT A1 appliance and the Gretag D185 densitometer.

Toner adhesivity was calculated according to the following equation (3).

$$T = \frac{D_{IGT}}{D_{100\%}} \tag{3}$$

Gloss was determined by means of the Lehmann measuring appliance with optical measurement geometry of 75°/75° on paper surface (Gs). A print with 100 % covered surface was tested (Gp) and printing gloss (Pg) was calculated according to the following equation (4).

$$\mathrm{Pg}\, Pg = \frac{Gp - Gs}{Gs} + 1; [\%] \tag{4}$$

To determine mottling (non uniformity printing), the 100 % covered prints were scanned by the Hewlett Packard ScanJet 6100C (300 x 300 dpi) scanner and evaluated by image analysis by means of the "Proton Surface" software (ICP internal standard).

Wicking was determined by means of the NIH image software (Scion Image) on the smallest letter E as the compute area percentage.

Print characteristic curve (print gradation) was measured by the GRETAG D185 densitometer. Defined raster fields from 10 to 100 % RTV (Ad) were measured on an ICP printing form for black and white laser printing and recalculated by the Murray-Davies equation (dAd) in order to obtain the percent of half dots of toner increase. If all tones were wholly reproduced during printing (offset, laser), a straight line would be created as a transfer curve. It is therefore wished for that all tones are wholly reproduced and that the RTV increase is as low as possible.

3. Results and discussion

3.1 The paper quality

Print quality depends on parameter types, surface energy of the printing substrate and liquid tension, roughness and electric resistance of the printing substrate surface, determined by the type of fibre, fillers and technological paper manufacture.

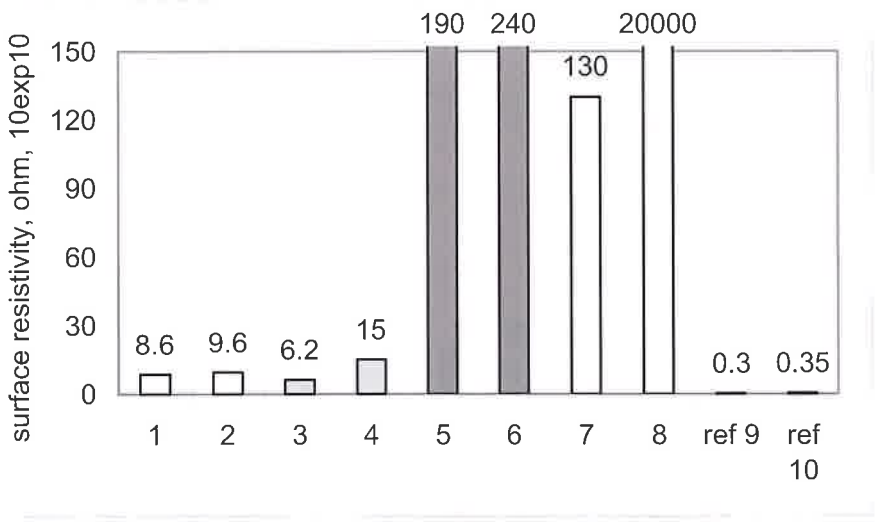

Figure 1: Review of the results of the paper electric surface resistivity

The results of electric properties, mainly surface resistivity show high resistivity of paper samples, made with mechanical fibres, because of the great influence of wood components as well as the lower activity of the fibres and less possibility of polarization of polymers as composite parts of paper, presented in the fibre stock (Figure 1).

The dielectric constant is affected by sheet structure, paper density and fibre orientation. From the Figure 2 the influence of the calendering on paper density and surface resistivity can be seen. Higher density values means lower paper surface electric resistivity.gher density values means lower paper surface electric resistivity.

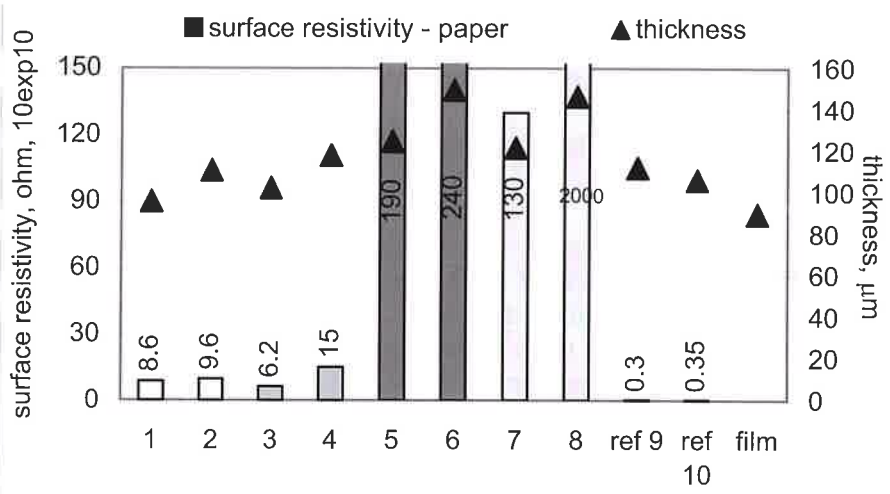

Figure 2: Paper surface resistivity in the comparison with thickness after finishing

The research indicated the effect of surface energy on the properties of toner fixing on the printing substrate surface during laser printing. The most appropriate toner adhesion was attained when surface energy and toner tension were the same. In the Figures 3 and 4 are the results of the surface energy measurements as well as the demonstration of the polar/dispersed part of the surface energy.

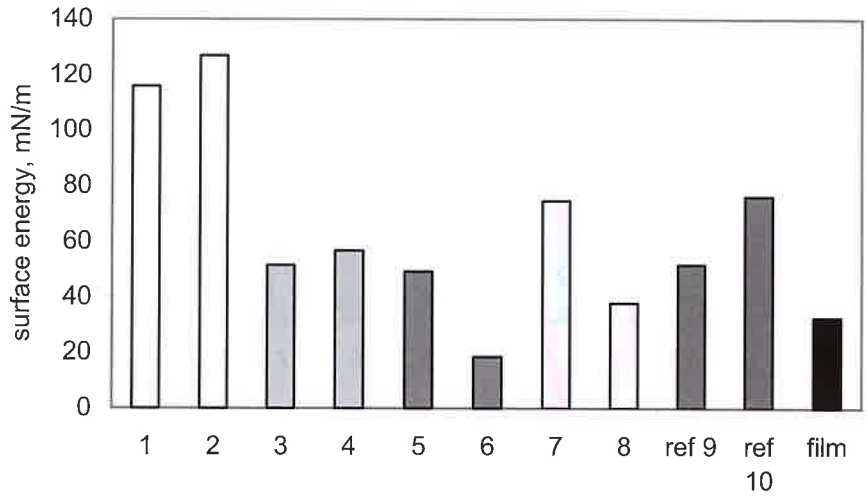

Figure 3: Surface energy is higher on the calendered paper surface, made of cellulose fibres, while the opposite conclusion is in the case of the paper samples, made of mechanical fibres

The comparison of the surface energy values, measured on paper surfaces with the value, measured on referent film, shows higher values on the paper samples. The small polar part is noticed on paper samples, made of mechanical fibres. The influence of the positive charged filler on polar part of the surface energy is noticed. The polar and dispersed part, measured on the film surface, are in the some ration.

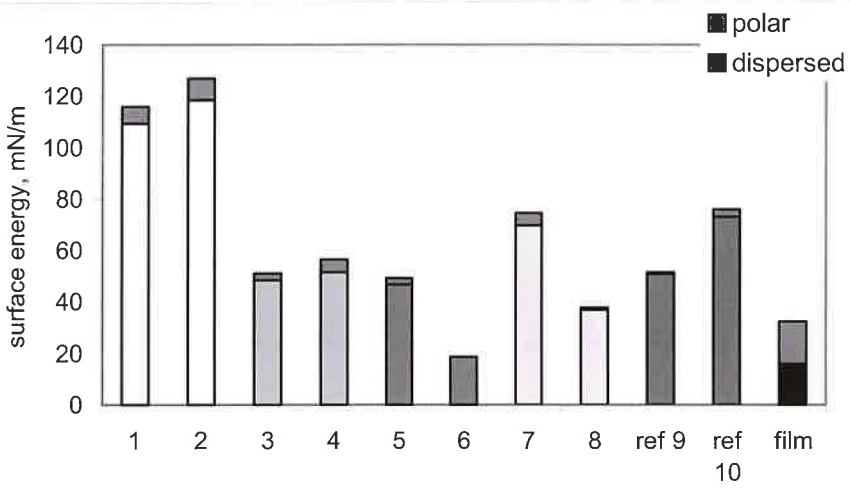

Figure 4: The influence of the raw material selection and the calendering on surface energy mainly polar and dispersed part

The comparison of the surface energy values, measured on paper surfaces with the value, measured on referent film, shows higher values on the paper samples. The small polar part is noticed on paper samples, made of mechanical fibres. The influence of the positive charged filler on polar part of the surface energy is noticed. The polar and dispersed part, measured on the film surface, are in the some ration.

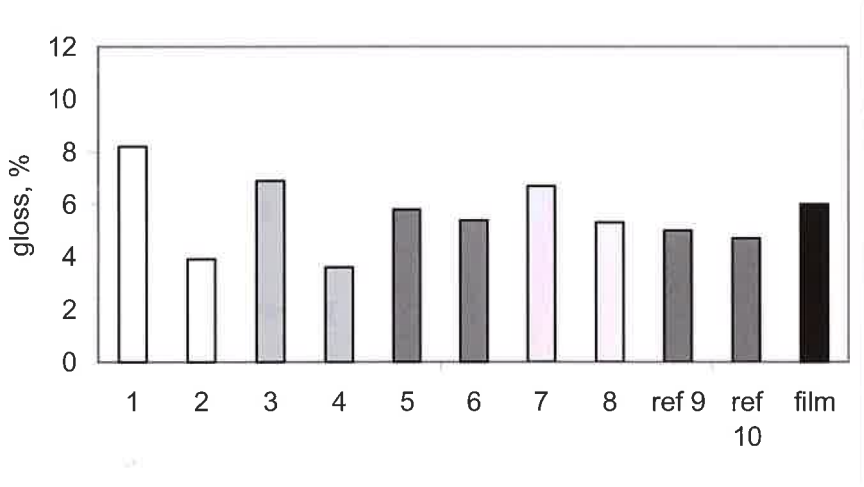

Figure 5: Paper gloss; the influence of the calendering

Calendering process affects the paper smoothness/roughness and the paper gloss. From the Figure 5 the higher gloss values of the calendered surfaces are noticed.

In the Figure 6 are the results of the roughness measurements, determined by laser profilometer. Less flexible mechanical fibres influence, beside mechanical, electrical and chemical properties, the paper surface properties as is the roughness, so the values are higher on the samples, made of mechanical fibres.

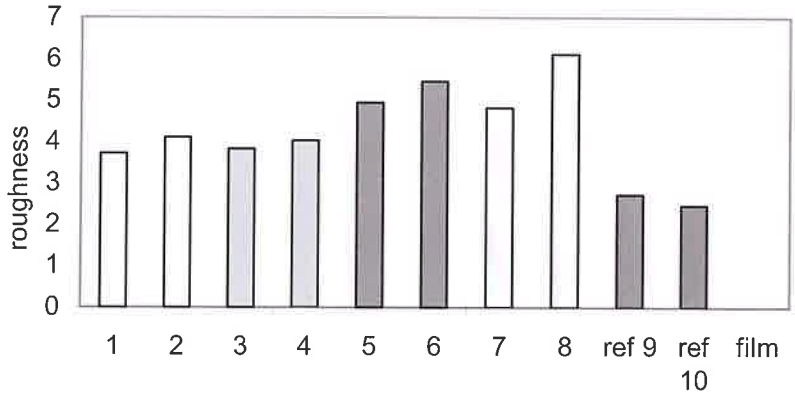

Figure 6: Paper roughness was determined by laser profilometer - Perthometer

3.2 The print quality

Printing quality is defined by the quality of print. Therefore, the influence of the printing substrate's surface roughness on printing gloss was analysed.

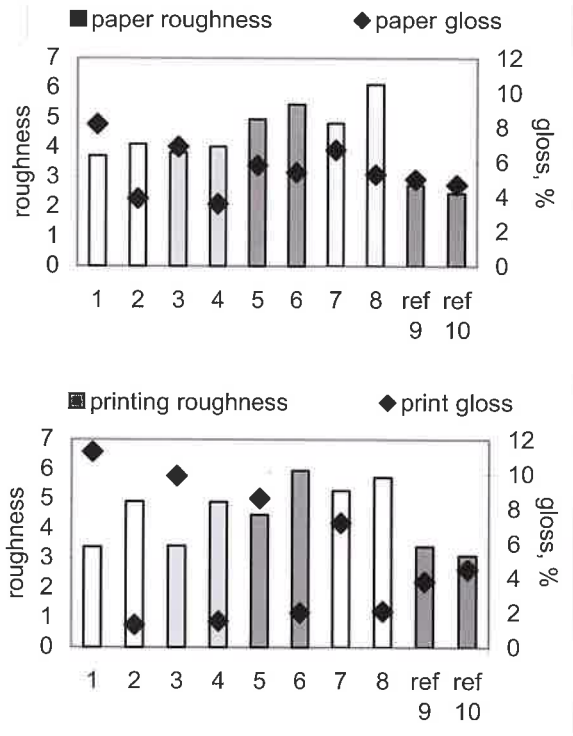

Figure 7:
The influence of paper roughness on print gloss

The results of printing roughness measurements on non-calendered printing substrates showed enlargement of printed surface roughness and consequently the print gloss decrease. Smoother surface of printing substrate enables smoother print image and higher print gloss even on the paper samples, made of mechanical fibres (Figure 7).

A lower roughness value of the printing substrate causes a higher print gloss value, which holds true mainly with papers made of chemical pulp, whereas the use of mechanical pulp in paper for electrophotographic techniques is less appropriate.

Printing gloss was calculated according to the equation (4) and is the measure of the increase or decrease of the gloss, measured on the printed image comparing to the gloss of the base printing substrate (Figure 8).

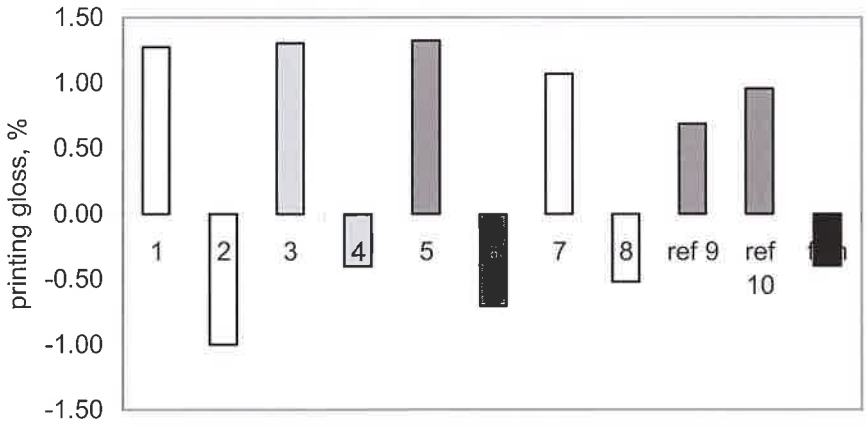

Figure 8: Printing gloss, measured on laboratory paper samples and referent printing substrates

Smoother paper surface influences better printing gloss; means the increase of the gloss of the printed image is higher in the comparison to the gloss of the image, printed on the rough base printing substrate.

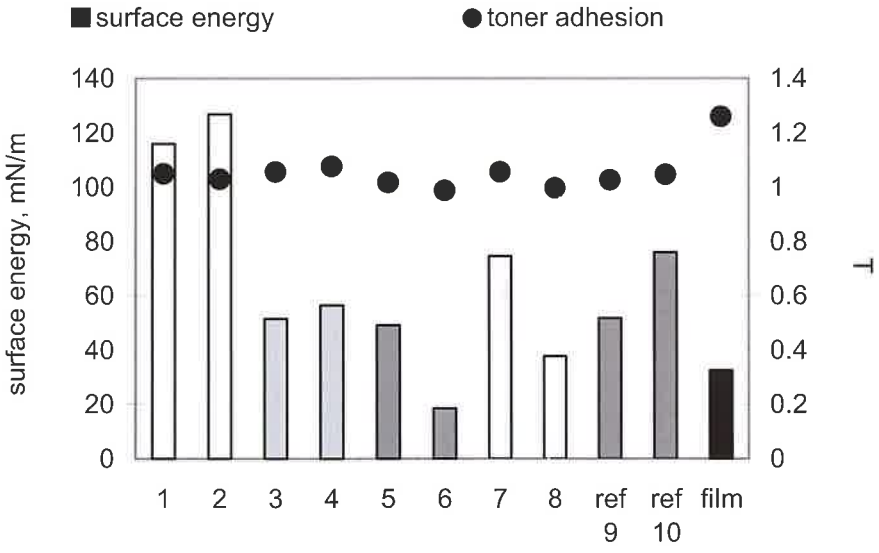

Figure 9: Toner adhesivity in correlation with surface energy

It was determined that higher surface energy causes a better toner adhesivity value, which is true only for a calendered surface of the paper printing substrate. This conclusion is not true for the film as printing substrate (Figure 9). Toner adhesivity value does not give us the real conclusion of the paper substrate quality, because of the influence of the interfiber bonding in the paper substrate.

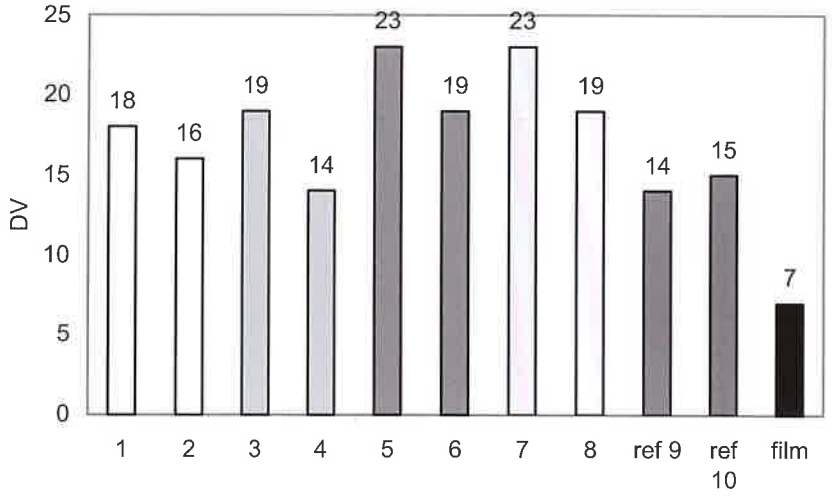

Figure 10: Printing non-uniformity measurements, evaluated by image analysis by means of the »Proton Surface« software (ICP internal standard) show better results of printing uniformity on the non-calendered base paper surfaces

Printing non-uniformity or mottling was determined by measuring the full reproduction field (100 % covered surface). The influence of roughness is well visible with all samples; however, it is more accented with paper samples, made of mechanical fibres than with paper samples made of chemical pulp (Figure 10).

Wicking was determined by means of the NIH image software (Scion Image) on the smallest letter E as the compute area percentage.

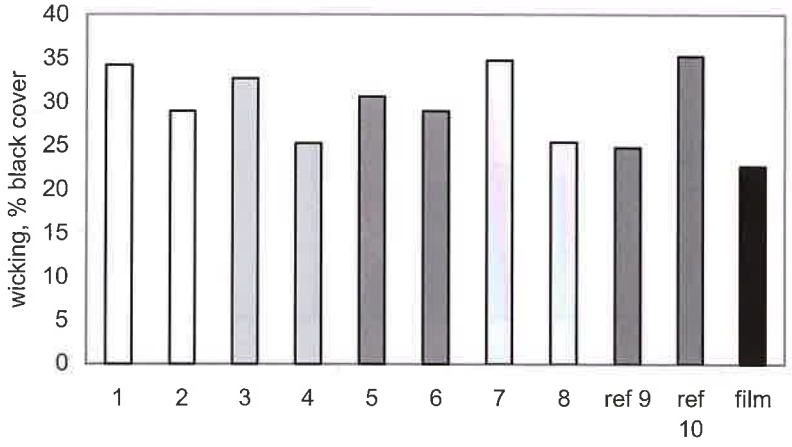

Figure 11: Wicking is expressed as the percentage of the black cover

Visual evaluation of the sharpness of the line reproduction with the smallest letter E, is rather good with calendered samples. However, toner particles are dispersed around the letter, which gives an appearance of blur and is showed in the percentage of black cover (Figure 11). With non-calendered samples, the letter E print is more unique - there are fewer irregularities on the trunk of the letter and without surrounding toner particles.

Print quality was determined by measuring the print characteristic curve (print gradation) that indicated the ability of paper to reproduce the grey scale. All samples typically attained a lower reproduction quality in lighter tones, well in middle tones and a very poor reproduction quality with darker tones.

4. Conclusion

A research was conducted into the influence of fibre and filler quality on the properties of paper for electrophotographic printing. The results indicate that paper made of mechanical pulp is less appropriate for electrophotographic printing due to mechanical pulp properties such as stiffness, fibre flexibility, chemically lower activity that reflects in roughness properties, extremely high surface electric resistance, and surface energy. Printing on paper made of mechanical pulp results in lower toner adhesivity, print mottling and poor reproduction in print gradation and with lines and text. Better results were attained by using paper sheets made of chemical pulp. The influence of the filler, calcium carbonate with positively charged particles, was visible in the technological process and had a positive effect on total retention in the system, which was unfortunately reflected in a slight deterioration of paper properties.

The research results indicate both the importance of raw material choice in manufacture of paper printed by electrophotographic techniques, and the influence of surface properties on the quality of print.

Literature references

Terrance E. Conners, Sujit Banerjee, (1995): *Surface Analysis of Paper, 32, 90 - 108*

Levlin J-E., Söderhjelm, L., (1999): *Pulp and Paper Testing, Papermaking Science and Technology, Book 17, Tappi Press*

Mallourris M., Moore G., (1994) *Absorbency related phenomena and their importance to end use performance in paper products, Papernakers Conference, Pira Interantional TAPPI Proceedings, 291 - 296*

Etzler F.M., Conners J.J., (1995) *Surface Analysis of Paper*

Modified calcium carbonate coatings with rapid absorption and extensive liquid uptake capacity

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Abstract

Special rapidly absorbing coatings with high absorption capacity are demonstrated based on new modified calcium carbonates which have been designed based on the absorption behaviour predicted by previous modelling using discrete pore and throat size distributions (Ridgway and Gane, 2002a). The absorption driving force is determined by the proportion of fine pores present up to a size equal to a Bosanquet inertially-defined optimum within the timescale of absorption.

Three new pigment morphologies, based on natural ground calcium carbonate (gcc) with special surface structure modifications are contrasted with standard gcc by using consolidated tablet blocks made from a suspension of each pigment and chosen mixtures thereof. The blocks are characterised after drying by mercury porosimetry, and the absorption dynamic of a selected liquid is studied. It is clear that the new pigments develop a pore structure that absorbs at a much faster rate and have capacities for up to 10 times more fluid than conventional gcc pigment. These properties are advantageous for many types of digital printing including both oil-based and water-based inks. The combination of nano- surface features and pores (intraparticle voids) on an otherwise micro-particle provides a combination of two discrete pore networks which allow the driving force associated with the nano- features and the permeability of the bulk (interparticle voids) to be separated. In such unique discrete network systems, the mercury intrusion curve provides a separable analysis of permeability and capillarity in respect to the inflection point of the cumulative intrusion curve. These properties can then be studied in relation to the absorption capacity expressed in terms of porosity. This experimental work confirms the principles derived from modelling.

1. Introduction

The physical phenomena occurring during and after the application of printing ink in a print process are considered to be important factors in achieving the desired print properties. Ink vehicle, the continuous liquid phase, is removed either from a setting film (offset) or by selectively adsorbing dyestuffs (inkjet) or filtration of ink pigment (inkjet and flexography) by absorption into the porous network structure which forms, for example, a paper coating surface.

The mechanism of liquid absorption into coating pigment structures has been previously investigated (Gane *et al.*, 2000). Studies in the past have shown that despite the presence of big pores, associated with highly porous paper surfaces, liquid is absorbed observably slower than when fine pores are also present (Gane and Hooper, 1989), (Bown *et al.*, 1988), despite an often lower porosity and permeability. This cannot be explained using the Washburn equation (Washburn, 1921) alone but requires the inclusion of a pore differentiating mechanism. This can be achieved in different ways, one of which is by including inertial wetting terms, such as in the equation developed by Bosanquet (Bosanquet, 1923). An evaluation of this equation shows that there exists an optimum for flow in a single capillary as a function of time coupled with capillary radius (Schoelkopf *et al.*, 2000a). The

consequence is that pores up to a given diameter in a porous network, this diameter being in turn a function of time, fill very fast while bigger features remain by-passed and tend to remain unfilled, especially under conditions of limited supply volumes of fluid as might be found in the case of thin applied ink films. Inertial flow in a glass capillary was observed by Quéré using a high speed camera (Quere, 1997). This promotes what we call a preferential pathway flow, unique to network structures. The existence of unfilled or by-passed pores is also known from soil science and studies made with micro models (Bernadiner, 1998). This was demonstrated in respect to paper coating structures by modelling the pore structure in terms of discrete pore and throat size distributions (Schoelkopf *et al.*, 2000b). These models were then further applied in the same work by Ridgway and Gane (Ridgway and Gane, 2002a) to idealised network structures of different pore size distributions to illustrate the effect of combining different structural features. This was extended further to include pore aspect ratio in terms of connecting throat length and diameter (Ridgway *et al.*, 2002b).

In this paper we introduce specially produced pigments which satisfy the criteria for maximum absorption rate based on the models of the porous network structure used in the previous studies (Schoelkopf *et al.*, 2000a). We show that by combining the fine pore driving force in capillary elements of correct aspect ratio (Ridgway *et al.*, 2002b), held within the pigment elementary particles themselves, it is possible to promote rapid absorption within the limiting factor of permeability of the interparticle network structure within which they are packed. Permeability can therefore be used to control absorption rate independently in such discrete network systems. It is shown that mercury intrusion data can be used in the case of discrete networks to separate the effects of permeability from the fine pore driving force and the capacity for absorption volume defined by porosity.

2. Materials

Special rapid and volume absorbing coatings using new modified calcium carbonates have been designed based on the theoretical understanding of the absorption behaviour of discretely defined network structures. This has been possible by using the principle of including within the pore size distribution a proportion of fine pores of low aspect ratio which represent discrete regions acting up to the limit of the Bosanquet-defined optimum. Three new pigment morphologies based on natural ground calcium carbonate with special surface and internal structure modifications are used to make consolidated blocks using a technique of formation from the wet suspension as described below.

The following figures (Fig. 1-3) show the different discrete structures of the three pigments studied.

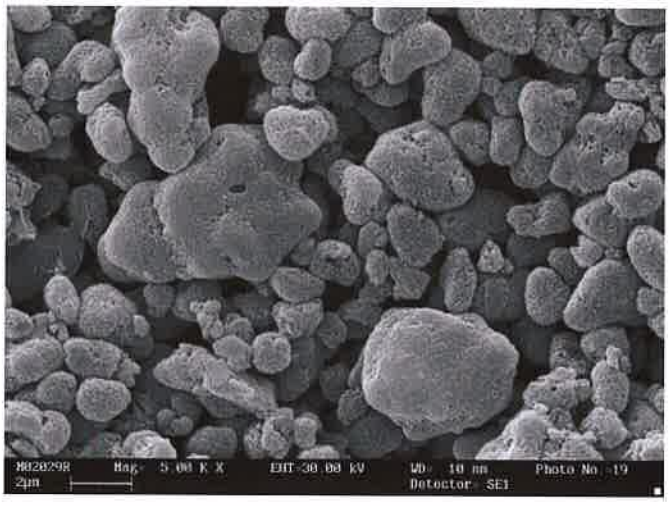


Figure 1: "Eggs" - a description of an internally nano-porous calcium carbonate

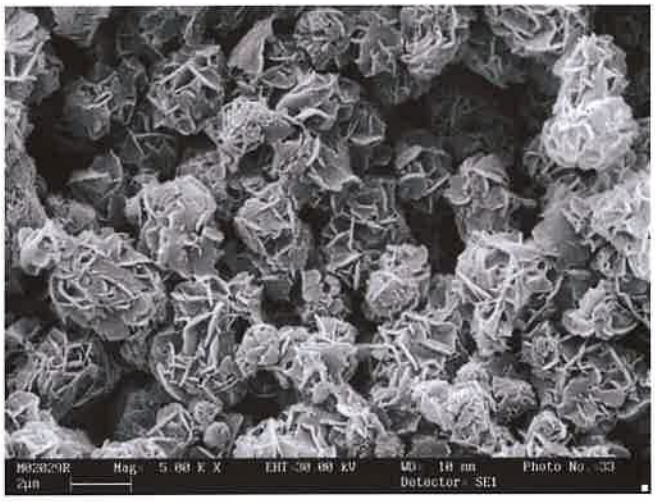


Figure 2: "Roses" - nano-dimensioned surface edge-like structures of high aspect ratio formed on micro-particles

Figure 3: "Golfballs" - a description of sub-micrometre pores contained within a micro-particle.

These pigments were contrasted against, and studied in mixes with, a spray dried predispersed natural ground calcium carbonate (gcc) derived from limestone with a particle size distribution of 91 wt% < 5 µm, 55 wt% < 2 µm and 30 wt% < 1 µm. The mixes are used to illustrate the impact of permeability on the absorption dynamic defined by the balance between viscous retardation in the interparticle structure compared with the absorption-driven forces of the nano- and micro- active intraparticle pores.

The impact of the addition of an oil non-interactive latex (styrene acrylate) on the speciality pigments was studied. This was used to illustrate the effect of adding a monosize particle additive on the capacity and absorption rate of the pigments. The particle size of the latex (~ 0.18 µm) is one that is commonly used in paper coatings.

As seen from the scanning electron microscope (SEM) pictures above (Fig. 1-3), the structures form discrete networks, one associated with internal (intraparticle) pores and another associated with external (interparticle) voids. This property of discreteness allows for the parameters of absorption driving force and permeability to be separated, and this is demonstrated in this paper. To destroy the

discrete nature of these structures, a simple gentle grinding was undertaken so as to partially homogenise between the two network structures. The behaviour of this partially homogenised network is used to describe the impact of departing from discrete structures and the loss of separability of the absorption controlling parameters, i.e. capillarity and permeability.

3. Experimental techniques

3.1 Wet tablet formation

Tablets were made from suspensions of the speciality pigments, "eggs", "roses" and "golfballs" and their mixes with standard gcc. The tablets are formed by applying a constant pressure to the suspension/slurry for several hours such that water is released by filtration through a fine 0.025 μm filter membrane resulting in a compacted tablet of the pigment. The apparatus used is shown schematically in Fig. 4.

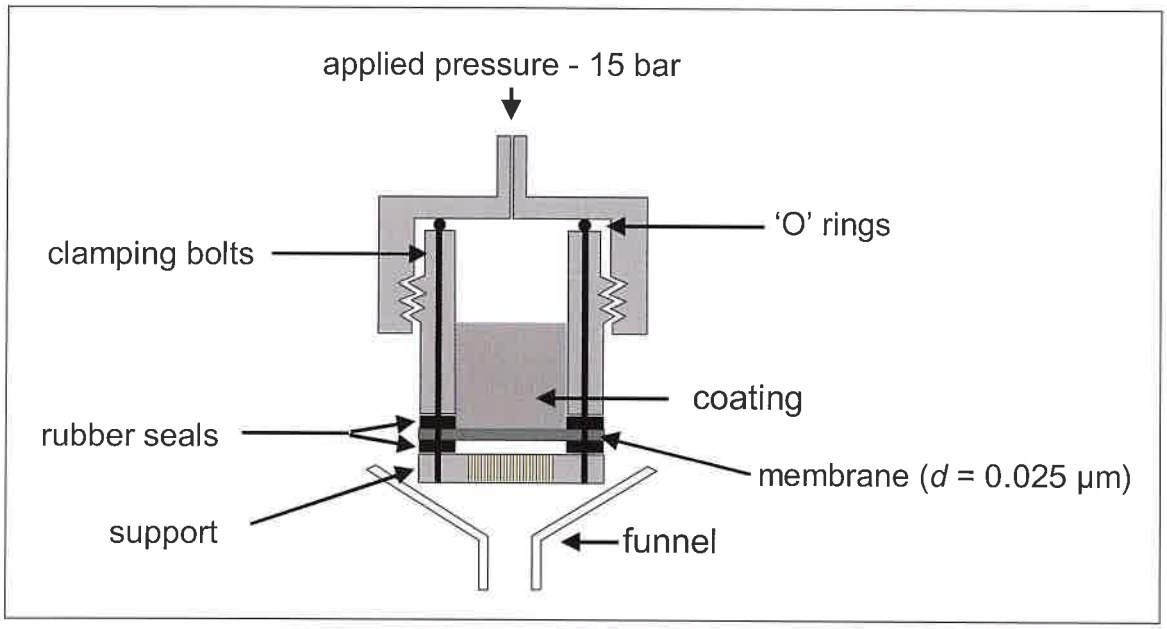


Figure 4: Apparatus designed for making tablets from wet suspensions

The tablets are removed from the apparatus and dried in an oven at 80 degrees for 24 hours. As described above, the pigments were formed either alone or in mixes with a standard gcc and with a latex, respectively.

3.2 Mercury porosimetry

Once dried, a portions of all the tablet blocks were characterised by mercury porosimetry for both porosity and pore size distribution using a Micromeritics Autopore III mercury porosimeter. The maximum applied pressure of mercury was 414 MPa, equivalent to a Laplace throat diameter of 0.004 μm (~ nm). The mercury intrusion measurements were corrected for the compression of mercury, expansion of the penetrometer and compressibility of the solid phase of the sample, using the equation of Gane *et al.* (Gane *et al.*, 1996), employed in the software Pore-Comp[1].

[1] Pore-Comp is a software name used by the Environmental and Fluid Modelling Group, University of Plymouth, PL4 8AA, U.K.

3.3 Absorption

The tablets were cut and ground to form regular 12x12x12 mm^3 blocks using a rotary disc grinder and a specially constructed, precisely adjustable jig.

To reduce artefacts caused by the wetting of their outer surfaces, samples were coated with a thin barrier line of silicone around the base of the vertical edges arising from the basal plane. The remainder of the outer planes were not coated, to allow for the free movement of displaced air during liquid absorption, and to minimise any interaction between the silicone and the absorbed liquid.

The dynamic absorption of a selected oil (PKWF af 6/9 neu) into these speciality pigment structures was measured in comparison to the standard calcium carbonate (gcc). The mineral oil was chosen as being typically used in offset ink formulations as the main solvent. It is a blend of aliphatic alkanes and shows a zero contact angle to a freshly ground (and dispersant-treated) calcium carbonate surface. Together with its low volatility, it is an ideal and practical model liquid which can be used for experimentation with many different pigment structures, having different porosities and mean pore sizes. The oil has the following properties, density 805 kgm^{-3}, surface tension 0.0274 kgs^{-2} and viscosity of 0.0043 $kgm^{-1}s^{-1}$. The rate of liquid uptake was recorded using an automated microbalance, namely a PC-linked Mettler Toledo AT460 balance with a precision of 0.1 mg, capable of 10 measurements per second. The apparatus was described previously in more detail in Gane *et al.* (Gane *et al.*, 2000)

4. Results

4.1 Speciality pigments and their mixtures with standard gcc

4.1.1 Porosimetry

The mercury intrusion curves of the samples consisting of the three speciality pigments (100 parts) and their mixtures with the standard gcc in three specific mix ratios 75:25, 50:50 and 25:75 are shown in Fig. 5 and Fig. 6. The control is a tablet made from just the standard gcc pigment (100 parts). Also investigated was the speciality pigment "roses" mixed with latex (12 parts) (Fig. 9) and finally the lightly ground/homogenised "roses" alone (Fig.12).

The porosities of the respective tablets are summarised in Table I. It is clear to see that the porosities fall into separate groups for all the mix ratios, with the 100 parts "roses" having the highest porosity of the speciality pigment tablets and the 100 parts "golfballs" having the lowest porosity of the specialities. The standard gcc tablet has a much lower porosity of 27 % - typical of a standard matt paper coating.

Table I: Summary of the porosity of the various structures

Parts of pigment constituting the sample in mixes with standard gcc	100	75	50	25
standard gcc	27			
"roses"	82	80	74	61
"eggs"	75	69	65	55
"golfballs"	70	67	60	51
"roses" plus added latex	75	72	61	47
ground/homogenised "roses"	68	62	59	54

These porosity values were also confirmed independently after absorption by knowing the dry weight of the sample and its weight after total saturation with the oil. Knowing the density of the oil (neu 6/9) the weight difference can be converted into a volume which is then expressed as a percentage of the total volume of the sample.

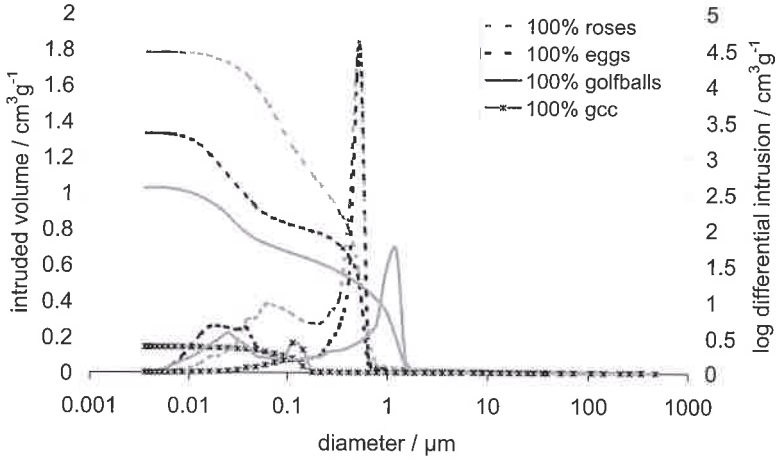
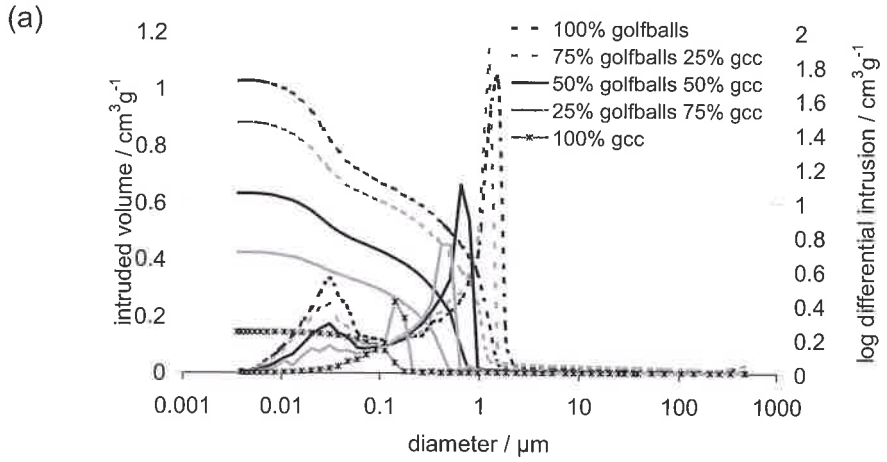
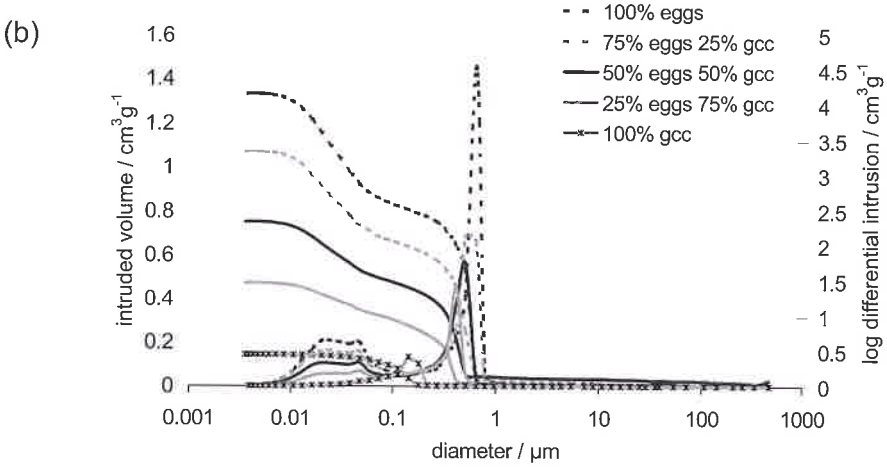


Figure 5: Mercury intrusion curves and pore size distributions for the speciality pigments and standard gcc





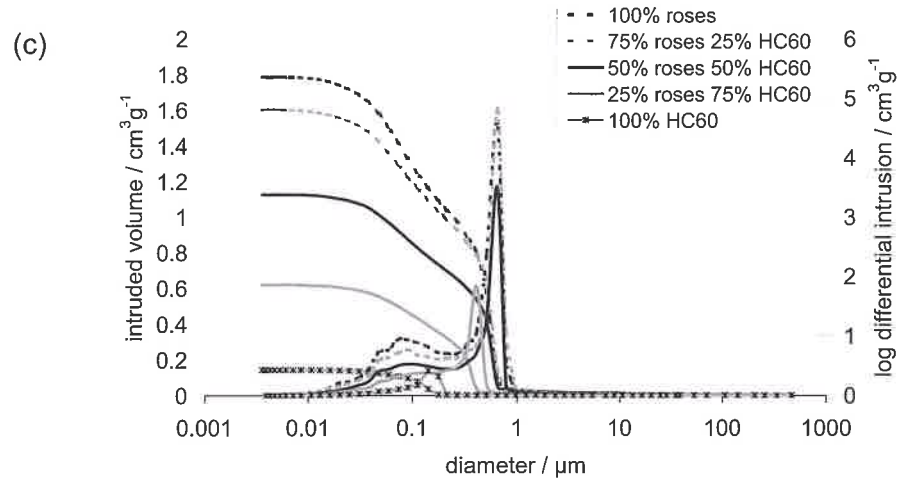


Figure 6: Mercury intrusion curves and pore size distributions for the speciality pigments and their combinations with standard gcc: (a) "golfballs", (b) "eggs" and (c) "roses"

4.1.2 Oil absorption

The actual fluid uptake capacities of the cubic pigment blocks are shown in Fig. 7 and illustrate some interesting trends. The saturation capacities follow the porosity as expected, with "roses" having the highest capacity, followed by the "eggs" and then the "golfballs". The blocks hold up to 10 times more fluid volume per gram of sample than a block of standard gcc alone. The volume capacity of the modified pigments are reduced respectively with the addition of the standard gcc.

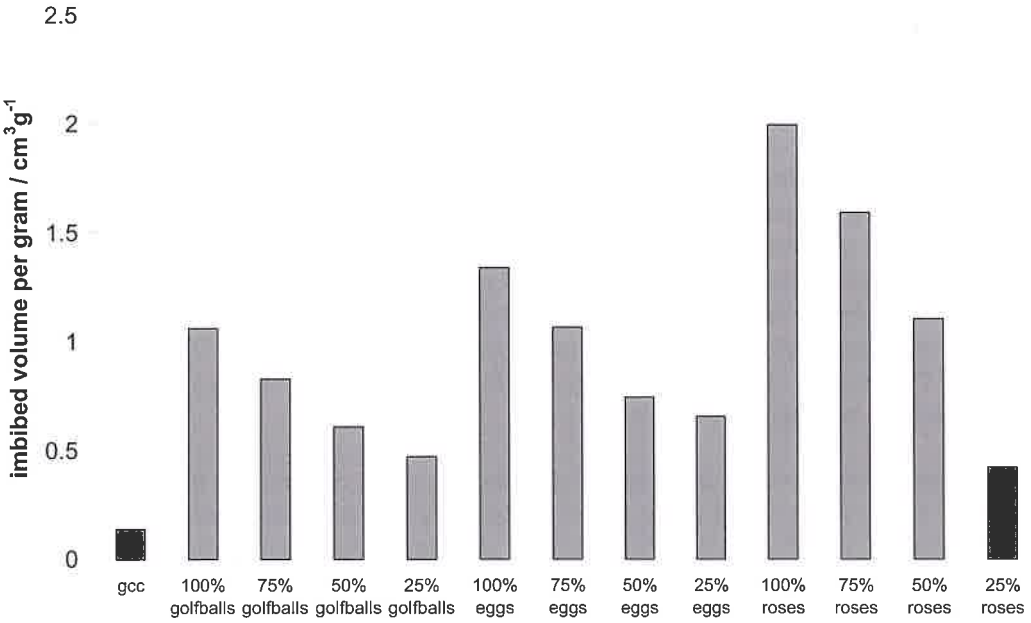


Figure 7: Saturation capacity of the speciality pigments alone and also blended with standard gcc

The respective absorption dynamics are represented in Fig. 8 by the amount absorbed per unit cross-sectional area of the sample differentiated with respect to the square root of time after the initial uptake has equilibrated. This gradient forms a useful universal parameter for such experiments. It is clear that the rates are much faster for the tablets with the novel calcium carbonate pigments.

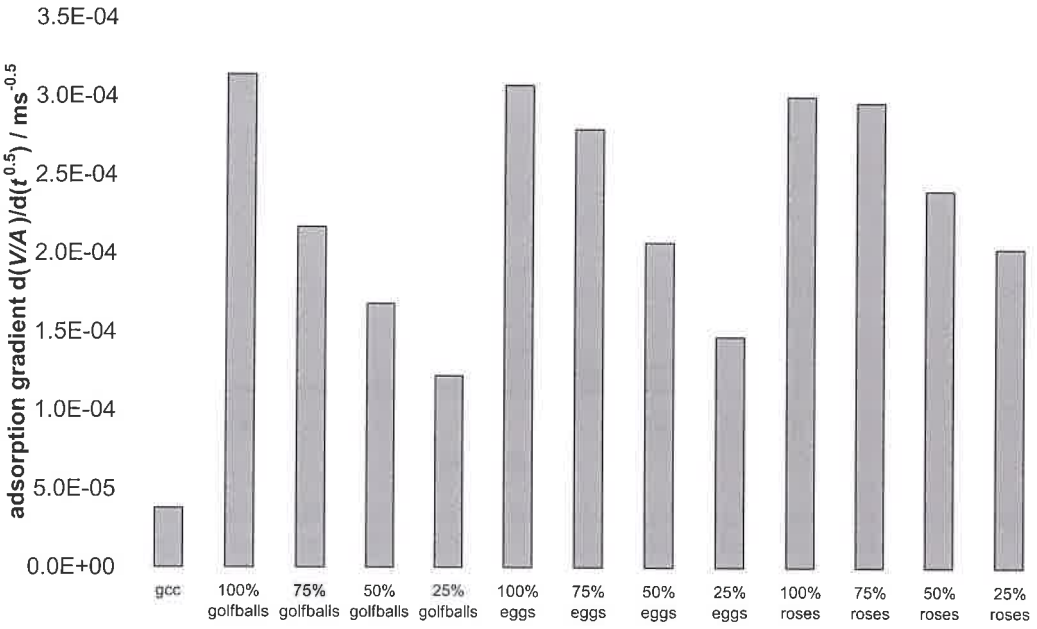


Figure 8: Absorption gradients of the speciality pigments alone and also blended with gcc

It can be seen that blending 25 % standard gcc with the "roses" did not change the absorption rate significantly even though the saturation capacity was reduced (Fig. 7). This is in contrast to the case where mixes are made with the other two specialities. The change of absorption rate for each of the speciality pigments in combination with increasing amounts of standard gcc is related to the original absorption capacity. This is an important phenomenon in these clearly discrete network systems.

It was shown from modelling (Ridgway and Gane, 2002a) that within a porous structure it is the smaller voids that supply the necessary driving force for absorption to take place. From the same models it was shown that a structure also needs larger voids to act as local supply reservoirs of fluid if this driving force is to continue unhindered by lack of liquid volume. Furthermore, the interconnectivity of the larger voids define the permeability of the network, i.e. the structure also needs to be con-nected with a high permeability so that the fluid can flow through to the reservoirs and hence to the smaller pores to promote the faster absorption rate defined by the high capillarity of the discrete finer pores. The interpretation of the separability of the intrusion curves to classify these two parameters, of absorption driving force and liquid delivery limitation, is only possible if the driving force exists in a network structure discrete from that of the bulk structure determining the permeability. This we go on to show is very much the case for the mixes of these specialities with standard blocky non-porous gcc particles.

The mercury intrusion curve for the standard gcc shows that in comparison to the speciality pigments there are very much fewer small pores and therefore this structure has a relatively low driving force to cause absorption, Fig. 5. The 100 % "golfball" sample, in comparison, has a significantly greater number of fine pores together with a high permeability (larger pore diameter at the point of inflection of the intrusion curve) and therefore a high liquid delivery rate with the higher number of fine pores providing the driving force. The 100 % "eggs" sample has an even higher driving force (nano-pores) than the "golfballs". The 100 % "roses" also has a high driving force (many small pores) but the lower network permeability compared with the other specialities (lower pore size at the inflection point) limits the liquid availability such that it cannot reach these pores fast enough to satisfy the driving force, i.e. the structure is absorption rate self-limited in respect to permeability. Therefore, once again, the absorption rate is similar to that of the 100 % "golfball" and 100 % "eggs". These data show that the combination of fine pore size regions and the permeability of the whole are acting

as separable parameters in discrete network structures. This separability is now further confirmed when we study the data from the mixtures.

With the addition of 25 % gcc, Fig. 6(a), the permeability of the "golfball" sample is starting to reduce (lower pore size at the inflection point) which in turn reduces the rate of absorption, i.e. the permeability is the controlling factor now for absorption rate in the mix. In the case of the "roses" sample, Fig. 6(b) there is no change in the diameter at the point of inflection as standard gcc is added and this is reflected in the constant absorption rate. This confirms that the absorption rate of the 100 % "roses" was indeed self-limiting, the limitation being the permeability. Only when the permeability is further reduced by the greater addition of gcc does the absorption rate start to decrease. The "eggs" have a slightly reduced permeation, Fig. 6(c), compared with the other two specialities, and the mixes begin directly to influence this permeability. In the case of mixes containing up to a level of 25 % standard gcc, the absorption rate maximum of each speciality is only reduced if the addition of gcc reduces the permeability, i.e. the driving force remains effectively constant.

At 50 % introduction of gcc, the picture begins to change. The additive pigment has different effects depending on whether it is increasing or decreasing permeability in combination with the impact on the reduced number of fine pores by dilution. The "golfball" absorption rate is further reduced as the resistance is higher again due to a further reduced permeability. The mix with "roses" has much the same resistance but the driving force is now greatly reduced by the reduced number of the smaller pores. The higher amount of gcc in the mix with the "eggs" has now in fact caused a reduced resistance - greater permeability but the driving force is reduced in parallel due to the dilution of the fine pores, so the overall absorption rate is the same as that for the "golfballs" with the 50 % addition of calcium carbonate (gcc).

4.2 Addition of Latex

The addition of latex (12 parts by weight of Acronal S360D[2] based on 100 parts of pigment) was investigated in the case of the "roses" and its mixes with gcc. Some additional dispersant was added to the system to aid stabilisation (sodium polyacrylate: 0.5 parts added to the 100 % "roses", 0.07 parts to the 75 % and 50 % "roses", respectively, and 0.05 parts to the 25 % "roses").

4.2.1 Porosimetry

The effect on the structure is seen below in the mercury porosimetry curves, Fig. 9. The total intruded pore volume is reduced with the latex addition. The point of inflection is, however, unaffected in the cases of 100 % "roses" and 75 % "roses", but the point of inflection is decreased in pore size for the other samples. This means that the addition of monosize particles tends to maintain the permeability of the speciality pigment but once in combination with a broad size distribution material, such as gcc, the particles interpack to reduce permeability.

It can be seen that the permeability (absorption-rate controlling) and porosity (absorption capacity) increase monotonically as the "roses" are added. The clearly defined bimodal distribution is maintained with the addition of the latex with a more pronounced separation between the two pore size distributions when the latex is present in the structures. The large pore sizes in the distribution are due to the interparticle voidage and the smaller pore size distribution is representative of the intraparticle pores. The dip in the pore size distribution at 0.1-0.2 μm corresponds with the void filling action of the monosize latex[3].

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[2] Acronal is a product name of BASF, Ludwigshafen, Germany

[3] A similar analysis can be made for idealised light scattering, where, in such systems, the differentiation between the two size distributions would be even more pronounced with the separation occurring at 0.2 μm.

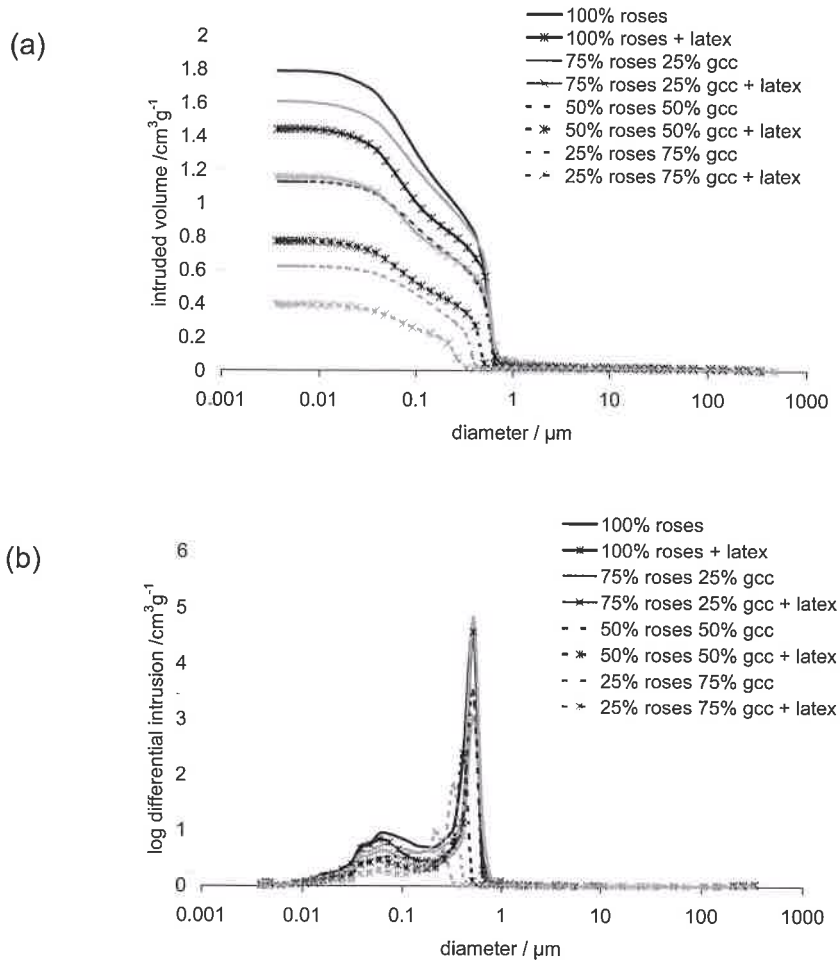


Figure 9: Mercury intrusion curves (a) and pore size distribution (b) of tablets made from "roses with different amounts of gcc with and without the addition of latex (12 parts)

4.2.2 Oil absorption

The absorption gradients on the addition of latex are reduced, Fig 10. They show a plateau being maintained at a maximum value between 100 % "roses" and 75 % "roses", but then decrease more rapidly as the gcc is added than when there is no latex present.

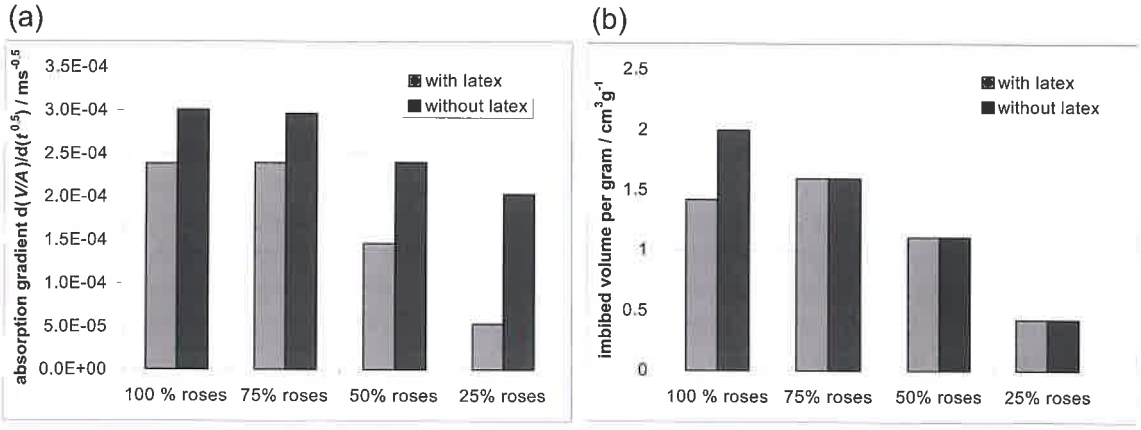


Figure 10: Absorption gradients (a) and total imbibed volume per gram (b) for "roses" with different amounts of added gcc with and without the further addition of latex

The imbibed volume per gram of sample is apparently maintained completely for all samples on the addition of latex except for the single case with 100 % of the speciality "rose" pigment. The mercury intrusion showed a decrease in total intruded volume with the addition of latex so there is a clear difference in the sampled volume depending on whether non wetting mercury or wetting oil is used. This suggests that the compressible latex under external mercury pressure can distort to fill pores which the mercury is then excluded from. These pores apparently remain open for the wetting liquid to access but the overall structure shows reduced permeability.

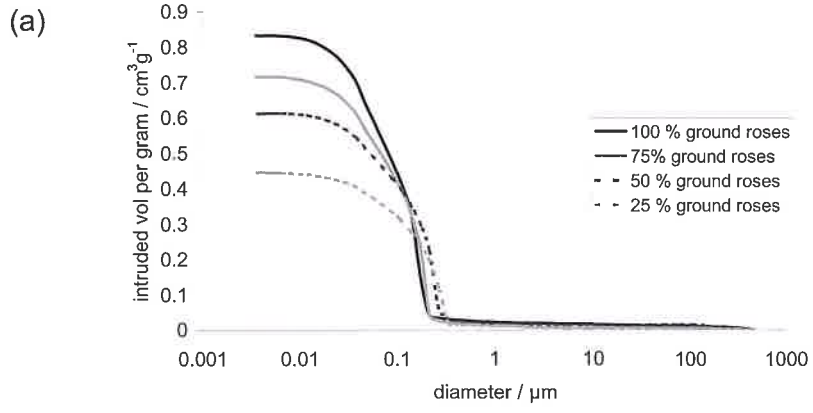
4.3 Homogenising the "roses"

The "rose" pigment was ground slightly in a wet mill and then investigated using the same methods described previously to observe the effects of this procedure on the behaviour of the tablet-packed structures. An SEM of the pigment is shown in Fig. 11. This was studied both as 100 % pigment and once again in mixes with the standard gcc.

Figure 11: Ground "roses" showing the tendency to homogenise the structure

4.3.1 Porosimetry

The porosimetry curves are shown below in Fig. 12, and it is clear here that the permeability (inflection point) of the structure is increased with the increasing addition of the gcc. An inverse relation between permeability and porosity is seen over the range of gcc additions, i.e. the higher gcc amount, the lower the porosity but the higher the permeability. This is in distinct contrast to the case when the "roses" were in their original unground form.



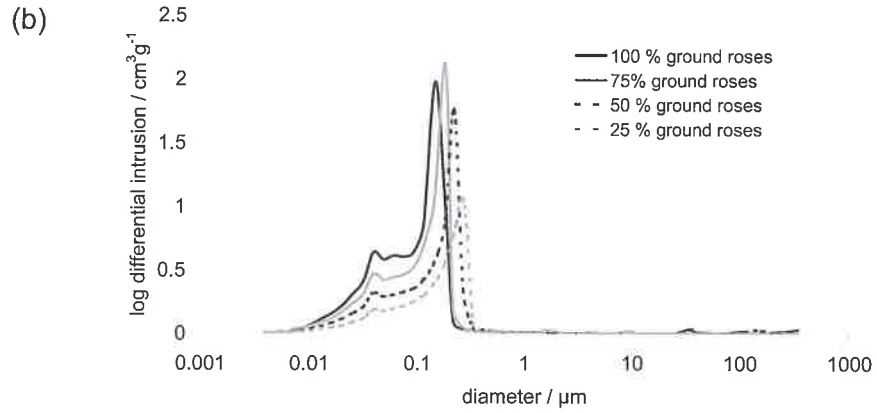


Figure 12: Mercury intrusion (a) and pore size distribution (b) of tablets made from the ground "roses" with the addition of gcc

4.3.2 Oil absorption

The results from the oil absorption saturation are shown in Fig. 13. It can be seen that the trend between the total absorbed volume per gram (absorption capacity) coincides with the porosities of the tablets and reduces with the addition of gcc as expected.

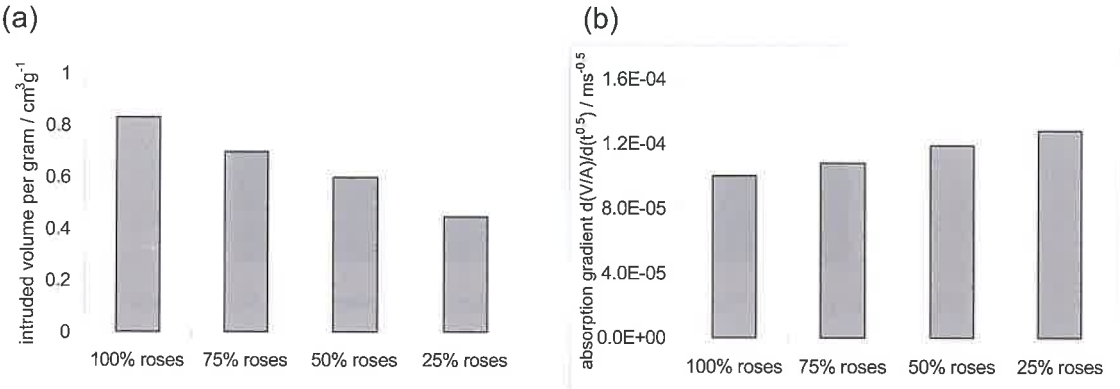


Figure 13: Total imbibed volume per gram and absorption gradients of tablets made from ground roses with different amounts of calcium carbonate

The absorption rate, however, increases with the addition of gcc despite the reduced capacity and this reflects the impact of the point of inflection of the intrusion curves, i.e. the increased permeability. The sample with 25 % roses has the largest diameter at this point and therefore has the highest permeability of these structures. This is in contrast with the previous cases where the gcc reduced the permeability. The homogenising effect on the speciality pigment therefore reduced the permeability which the gcc is partly reinstating - the overall values are lower for absorption with the homogenised material indicating that it would take a greater increase in the permeability than can be provided by gcc to reach the previous absorption rates. A monosize system would tend to improve the permeability in such an homogenised system.

5. Discussion and conclusions

It has been demonstrated how a new group of novel surface modified calcium carbonate-based pigments can be used to enhance absorption rate and absorption capacity of network structures. These pigments can be generally described as having nano- surface features and pores on an

otherwise micro-particle. They act to provide a high driving force for fast absorption rate by their intraparticle structure and form networks when packed together that have a discrete permeability related to the interparticle voids and connectivity. The balance of driving force and permeability leads to the control of absorption rate. Porosity controls the saturated absorption capacity independently. In discrete network systems, such as these pigments provide, one can therefore combine monosized additives and broad size distribution additives to control absorption rate through permeability provided sufficient fine pores are present to generate the driving force for inertially-related imbibition. Once the discreteness of the system is lost by, for example, forming an homogenised fine pore structure, the absorption rate can only be increased by introducing an additive that creates a higher permeability within this homogenised structure, i.e. re-introduce to some extent the discrete nature of two or more distinct combined network structures.

The principles of combined discrete networks have been illustrated by the combination of the example speciality pigments with broad size distribution ground calcium carbonate which acts to modify permeability and to dilute the fine pore concentration. When permeability decreases, the absorption rate decreases. When the fine pore driving force is diluted sufficiently then so also is the absorption rate decreased. Addition of monosize latex is shown to modify permeability in that it maintains the high permeability of the speciality pigment until the level of added gcc becomes high enough to create a tighter packing.

The principle of increasing permeability in an otherwise homogeneous fine pore structure to increase absorption rate was demonstrated by gently grinding the speciality pigment so that it partially lost its discrete network structures and showing that the reduced permeability reduced the absorption rate and that addition of gcc then acted to increase the absorption rate.

This work with practical experimental pigments confirms the predictions made by modelling pore networks using discrete pore throat size distributions and connectivity (Ridgway and Gane, 2002a).

Literature

Bernadiner, M.G., (1998), A capillary microstructure of the wetting front, *Transport in Porous Media* **30,** 251-265.

Bosanquet, C.H., (1923), On the flow of liquids into capillary tubes, *Philosophical Magazine, Series 6* **45,** 525-531.

Bown, R., Gane, P.A.C. and Hooper, J.J., (1988), Coating thickness analysis: an evaluation of interactions between coating colour and basepaper, *Wochenblatt für Papierfabrikation.*

Gane, P.A.C. and Hooper, J.J., (1989), Coating profilometry: an analysis of coating colour-basepaper interactions, *Fundamentals of Papermaking, Transactions of the Ninth Fundamental Research Symposium* Vol II, Mech. Eng. Publ. Ltd. London, 871.

Gane, P.A.C., Kettle, J.P., Matthews, G.P., and Ridgway, C.J., (1996), Void Space Structure of Compressible Polymer Spheres and Consolidated Calcium Carbonate Paper-Coating Formulations, *Industrial and Engineering Chemistry Research* **35,** 1753-1764.

Gane, P.A.C., Schoelkopf, J., Spielmann, D.C., Matthews, G.P., and Ridgway, C.J., (2000), Fluid transport into porous coating structures: some novel findings, *Tappi Journal* **83,** 77-78.

Quere, D., (1997), Inertial capillarity, *Europhysics Letters* **39,** 533-538.

Ridgway, C.J. and Gane, P.A.C., (2002a), Dynamic absorption into simulated porous structures, *Colloids and Surfaces A: Physicochemical and Engineering Aspects* **206,** 217-239.

Ridgway, C.J., Gane, P.A.C., and Schoelkopf, J., (2002b), Effect of capillary element aspect ratio on the dynamic imbibition with porous networks, *Journal of Colloid and Interface Science* **252,** 373-382.

Schoelkopf, J., Gane, .A.C., Ridgway, C.J., and Matthews, G.P.: (2000a), Influence of Inertia on Liquid Absorption into Paper Coating Structures, *Nordic Pulp and Paper Research Journal* **15,** 422-430.

Schoelkopf, J., Ridgway, C.J., Gane, P.A.C., Matthews, G.P., and Spielmann, D.C., (2000b), Measurement and Network Modeling of Liquid Permeation into Compacted Mineral Blocks, *Journal of Colloid and Interface Science* **227,** 119-131.

Washburn, E.W., (1921), The dynamics of fluid flow, *Physical Review* **17,** 273-283.

Influence of coating colour ingredients on paper and printing properties of ink-jet paper

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Abstract

Ink-jet (IJ) printing technique can be seen as a big challenge to the papermaking industry. In particular, paper surface has to be appropriately treated in order to meet numerous, often contradictory requirements dictated by this printing technique. This is usually accomplished by pigment coating containing high surface area pigments such as precipitated calcium carbonate (PCC) or silicon dioxide (silica) as the major component. The remaining coating ingredients - binder, cobinder, dye fixative, etc. - also play important roles in providing optimum paper surface.

In our study, a series of designed experiments was performed in order to systematically study effects of various coating colour components - three pigments, a binder and a dye fixative - on the quality of both nonprinted and printed paper. Results of experimental work, which consisted of lab coating, printing with a Canon IJ printer and measuring paper properties of interest, were statistically evaluated by means of multifactorial ANOVA (analysis of variance). We determined relative importance of individual coating ingredients for nonprinted paper properties, such as dry pick resistance or contact angle as well as for printed paper characteristics, i.e. optical density and waterfastness - separately for cyan, magenta, yellow and karbon IJ ink.

As could be expected, dry pick resistance depends almost exclusively on the amount of binder - polyvinyl alcohol - in coating colour. On the other hand, when observing optical density of cyan, magenta and yellow colour, it turned out that the type and the combination of tested pigments were the most important parameters. Coating colours with 20 parts of binder exhibited the best results when containing the following pigments or their combinations: precipitated silica, colloidal silica, combination PCC-colloidal silica and combination precipitated silica-colloidal silica. In case of coating colours with higher amount of binder (40 parts) best pigments/combinations proved to be PCC, combinations PCC-colloidal silica and precipitated silica-colloidal silica and mixture of all three pigments: PCC-precipitated silica-colloidal silica.

1. Introduction

Papers for ink-jet (in the following text: IJ) printing can be divided into two major groups (1): multipurpose office papers treated with surface sizing agents and starch belong to low- and middle-end segment while IJ papers with high quality demands in terms of colour brilliancy, dot shape and regularity, water absorption rate, waterfastness and other properties (2) must be coated using specialty pigments and additives. In our study effects of three synthetic pigments - precipitated and colloidal silica and precipitated calcium carbonate (PCC) -, a binder (polyvinyl alcohol, PVOH) and a dye fixative (polyDADMAC) on some quality parameters of non-printed as well as those of IJ printed paper were examined. Statistical evaluation and visualization of results was made by means of multifactorial analysis of variance (ANOVA).

2. Experimental

Three coating colour components were tested using a 3-factorial experimental design (Table I): first factor (pigments, PIGM) was tested at 7 levels, i.e. combinations of a single (mono, M), two (pair, P) or all three (triple, T) specialty pigments. Both second (PVOH, BIND) and third (polyDADMAC, FIX) factor were evaluated at two levels. With each of the 28 different coating colours three paper sheets were coated using a lab bench-top draw-down coater. After dry pick resistance (DRYPICK; instrument IGT) and contact angle after 1 s (DAT_01; FIBRO DAT) had been measured on these samples, papers were printed using HP DeskJet 690C and our IJ test chart. Optical densities (OD_X) for each of the four ink-jet colours (C, M, Y and K) were determined by means of a densitometer. In addition, from differences of optical density values before and after immersion of printed samples in a water bath (BASF method) waterfastness of samples was calculated: lower values are an indication of better waterfastness and vice versa. Particular regions of printed samples were also tested on degree of bleeding and wicking by means of image analysis.

Table I: Coating components and characteristics of non-printed and printed papers

		Label	Levels or range of values
Factors: coating colour ingredients	Pigments – PCC (1), precipitated silica (2), colloidal silica (3)	PIGM	M1 / M2 / M3 / P12 / P13 / P23 / T123
	Binder – PVOH; parts	BIND	20 / 40
	Dye fixative – polyDADMAC; parts	FIX	0 / 3
Responses: Paper and print characteristics	Dry pick resistance; m/min	DRYPICK	0 – 2,5
	Contact angle after 1s; deg.	DAT_01	0 – 113,2
	Optical density of cyan colour; -	OD_C	0,6 – 1,4
	Optical density of magenta colour; -	OD_M	1,2 – 1,6
	Optical density of yellow colour; -	OD_Y	0,8 – 1,5
	Optical density of black colour; -	OD_K	1,4 – 1,6
	Waterfastness of cyan colour; -	WF_C	-0,7 – 0,7
	Waterfastness of magenta colour; -	WF_M	0,3 – 0,9
	Waterfastness of yellow colour; -	WF_Y	0,5 – 1,3
	Waterfastness of black colour; -	WF_K	-0,1 – 0,0

3. Results

Results of multifactorial ANOVA for each of the four tested paper and print characteristics - dry pick resistance, contact angle, optical density and waterfastness - are summarized in Tables II to VII. Due to the fact that cyan, magenta and yellow IJ colour behave very similarly in terms of their optical density as well as waterfastness, only OD_M and WF_M results are shown. To see effects of various pigments or their combinations in coating colour on the responses, samples/results with 20 parts of PVOH (BIND = 20) in coating colours were treated separately from those containing 40 parts (BIND = 40). Results are presented in diagrams showing also PIGM-FIX interactions (Figures 1 - 5). Influence of individual pigments, binder- and fixative level on degree of bleeding and wicking on printed samples is shown in Figure 6.

Table II: ANOVA table for dry pick resistance

Analysis of Variance for DRYPICK - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:PIGM	6,02619	6	1,00437	80,35	0,0000
B:BIND	21,6043	1	21,6043	1728,34	0,0000
C:FIX	0,107143	1	0,107143	8,57	0,0049
INTERACTIONS					
AB	4,53905	6	0,756508	60,52	0,0000
AC	0,462857	6	0,0771429	6,17	0,0001
BC	0,0	1	0,0	0,00	1,0000
ABC	0,303333	6	0,0505556	4,04	0,0020
RESIDUAL	0,7	56	0,0125		
TOTAL (CORRECTED)	33,7429	83			

Table III: ANOVA table for contact angle after 1 s

Analysis of Variance for DAT_01 - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Valu
MAIN EFFECTS					
A:PIGM	64609,0	6	10768,2	231,18	0,000
B:BIND	20479,7	1	20479,7	439,68	0,000
C:FIX	47,8519	1	47,8519	1,03	0,315
INTERACTIONS					
AB	12105,5	6	2017,58	43,32	0,000
AC	150,958	6	25,1597	0,54	0,775
BC	0,373333	1	0,373333	0,01	0,929
ABC	207,95	6	34,6583	0,74	0,616
RESIDUAL	2608,39	56	46,5783		
TOTAL (CORRECTED)	100210,0	83			

Table IV: ANOVA Table for optical density of magenta colour

Analysis of Variance for OD_M - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Valu
MAIN EFFECTS					
A:PIGM	0,0955476	6	0,0159246	28,52	0,000
B:BIND	0,00634405	1	0,00634405	11,36	0,001
C:FIX	0,0186012	1	0,0186012	33,32	0,000
INTERACTIONS					
AB	0,088681	6	0,0147802	26,47	0,000
AC	0,0436571	6	0,00727619	13,03	0,000
BC	0,00241071	1	0,00241071	4,32	0,042
ABC	0,022181	6	0,00369683	6,62	0,000
RESIDUAL	0,0312667	56	0,000558333		
TOTAL (CORRECTED)	0,308689	83			

Table V: ANOVA table for optical density of black colour

Analysis of Variance for OD_K - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:PIGM	0.0650952	6	0.0108492	29.30	0.0000
B:BIND	0.00171905	1	0.00171905	4.64	0.0355
C:FIX	0.0000190476	1	0.0000190476	0.05	0.8214
INTERACTIONS					
AB	0.0370476	6	0.0061746	16.68	0.0000
AC	0.00361429	6	0.000602381	1.63	0.1568
BC	0.00137619	1	0.00137619	3.72	0.0589
ABC	0.00082381	6	0.000137302	0.37	0.8944
RESIDUAL	0.0207333	56	0.000370238		
TOTAL (CORRECTED)	0.130429	83			

All F-ratios are based on the residual mean square error.

Table VI: ANOVA table for waterfastness of magenta colour

Analysis of Variance for WF_M - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:PIGM	0,429957	6	0,0716595	70,57	0,0000
B:BIND	0,0842333	1	0,0842333	82,95	0,0000
C:FIX	0,7581	1	0,7581	746,55	0,0000
INTERACTIONS					
AB	0,274167	6	0,0456944	45,00	0,0000
AC	0,0799667	6	0,0133278	13,12	0,0000
BC	0,00583333	1	0,00583333	5,74	0,0199
ABC	0,0525	6	0,00875	8,62	0,0000
RESIDUAL	0,0568667	56	0,00101548		
TOTAL (CORRECTED)	1,74162	83			

Table VII: ANOVA table for waterfastness of black colour

Analysis of Variance for WF_K - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:PIGM	0.00375714	6	0.00062619	1.07	0.3907
B:BIND	0.000685714	1	0.000685714	1.17	0.2834
C:FIX	0.00107143	1	0.00107143	1.83	0.1812
INTERACTIONS					
AB	0.00198095	6	0.000330159	0.56	0.7564
AC	0.00529524	6	0.00088254	1.51	0.1918
BC	0.000119048	1	0.000119048	0.20	0.6535
ABC	0.00108095	6	0.000180159	0.31	0.9301
RESIDUAL	0.0327333	56	0.000584524		
TOTAL (CORRECTED)	0.0467238	83			

All F-ratios are based on the residual mean square error.

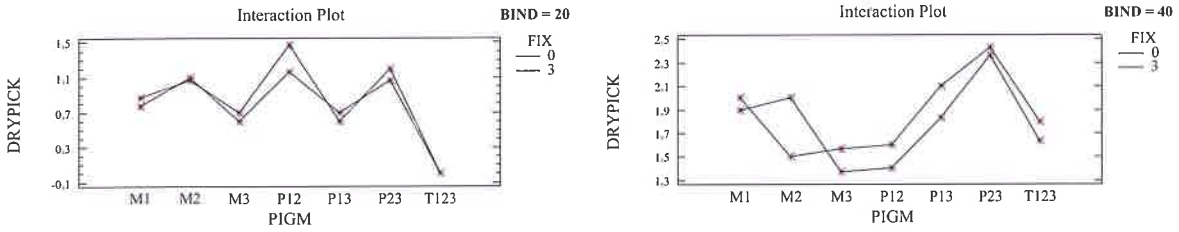

Figure 1a) and b): Influence of pigment type (PIGM) and dye fixative (FIX) amount on dry pick resistance for BIND = 20 (a) and BIND = 40 (b)

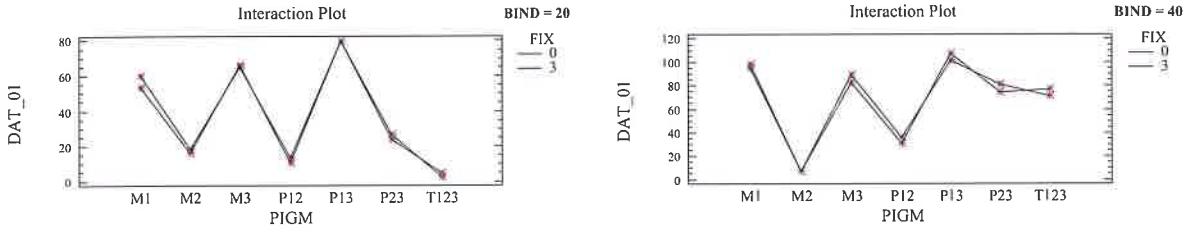

Figure 2a) and b): Influence of pigment type (PIGM) and dye fixative (FIX) amount on contact angle for BIND = 20 (a) and BIND = 40 (b)

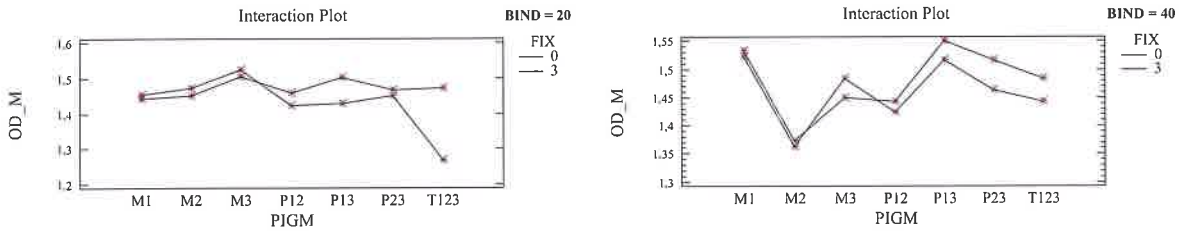

Figure 3a) and b): Influence of pigment type (PIGM) and dye fixative (FIX) amount on magenta optical density for BIND = 20 (a) and BIND = 40 (b)

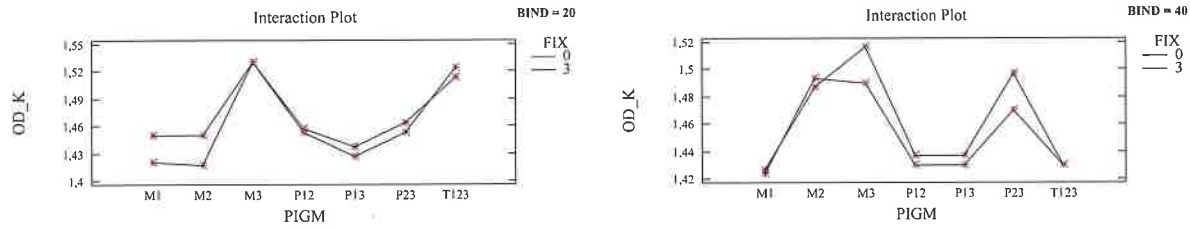

Figure 4a) and b): Influence of pigment type (PIGM) and dye fixative (FIX) amount on black optical density for BIND = 20 (a) and BIND = 40 (b)

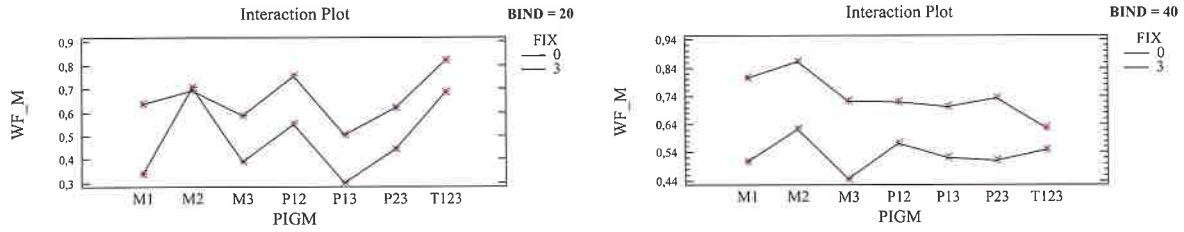

Figure 5a) and b): Influence of pigment type (PIGM) and dye fixative (FIX) amount on magenta waterfastness for BIND = 20 (a) and BIND = 40 (b)

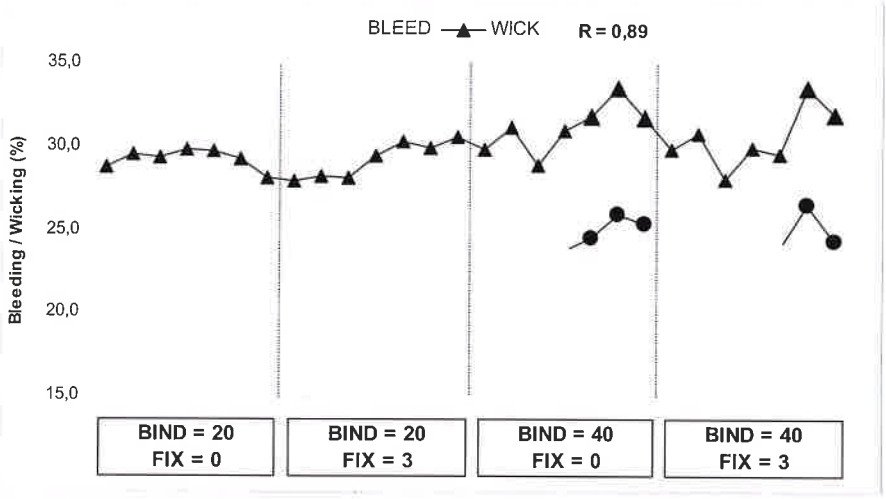

Figure 6: Bleeding and wicking on printed paper samples

4. Discussion

ANOVA results show which of the three factors (main effects) and/or their combinations (interactions) have important and statistically significant ($p<0,05$) influence on the particular response. Due to an extremely high F ratio (1728; Table II), **dry pick resistance** (DRYPICK) is, according to expectations, dependent almost solely on BIND level: the higher the binder amount, the stronger the dry pick resistance, i.e. surface strength. Although other main effects and interactions are also statistically significant at 95% confidence level, their contribution to dry pick is, comparing to that of binder, negligible. As Figure 1a) and b) show, pigment combinations PCC-precipitated silica (P12) and precipitated silica-colloidal silica (P23) give highest surface strength for samples with 20 and 40 parts of PVOH, respectively.

Contact angle 1 s after paper surface-drop contact (DAT_01), i.e. paper surface hydrophilicity/hydrophobicity, is determined mainly by PIGM, BIND and their interaction (Table III). It can be seen that, in case of BIND = 20 (Figure 2a), all the papers coated with precipitated silica (M2, P12, P23, T123) have very low contact angle values after 1 second. This is due to extremely porous, hydrophilic structure of the pigment causing almost instantaneous penetration of water drop and reduction in contact angle below 20 degrees. With BIND = 40 (Figure 2b) situation is similar, although here contact angles with samples coated with precipitated silica-colloidal silica combination (P23, T123) are considerably higher than with BIND = 20.

While cyan, magenta and yellow IJ inks are aqueous based dye solutions, black ink is a water based pigment dispersion. This fact explains similar **optical density** behaviour for the former three colours. Here all factors and their interactions show statistical importance (Table IV; only OD_M is displayed). Also, the same pigment combinations provide highest OD values for C, M and Y alike: M2, M3, P12 and P23 for BIND = 20 (Figure 3a) and M1, P12, P23 and T123 for BIND = 40 (Figure 3b). Optical density of black ink (OD_K; Table V) is dependent both on pigments and binder amount as well as on their mutual interaction. Colloidal silica (M3) seems to be the most appropriate pigment when one wants to achieve high black optical density of IJ print (Figure 4a) and 4b).

In case of **waterfastness** of cyan, magenta and yellow prints all factors and their interactions are influential (Table VI; only WF_M is shown), but the biggest impact has presence of dye fixative in coating colour. This is in agreement with known beneficial effect of polyDADMAC on waterfastness,

since this agent fixes ink at the coated paper surface. Figure 5a) and b) show this effect clearly (lower WF values indicate better waterfastness, as explained in the Introduction). On the other hand, for WF_K none of the factors and/or their interactions proved to be statistically significant (Table VII).

Two phenomena typical for IJ ink - black-to-yellow ink bleeding and black ink wicking - were evaluated using an image analysis software. There is a strong linear relationship between both phenomena ($r = 0.89$). It seems that, in general, high binder amount (BIND = 40) has adverse effect on print quality (Figure 6). Both bleeding and wicking are also considerably dependent on the type and amount of coating pigment.

5. Conclusions

Statistical analysis of measured paper and print properties showed that individual coating components influence these characteristics in various ways and intensity. Dry pick resistance depends almost entirely on binder present in the coating colour, while for contact angle, on the other hand, decisive factors are pigment type and binder amount and their interaction. Optical densities and waterfastness values for cyan, magenta and yellow IJ ink show similar patterns in terms of their dependence on pigment type and combination, binder and dye fixative amount, while black ink due to different chemical nature behaves completely different. Dye fixative has strong influence on cyan, magenta and yellow print waterfastness.

Acknowledgements

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Literature

Sangl R., Weigl J.: *On the interaction between substrate and printing ink for ink-jet printing;* TAPPI *Printing and Graphic Arts Conference, Savannah USA (2000)*

Hladnik A., Muck T.: *Characterization of pigments in coating formulations for high-end ink-jet papers; Dyes and Pigments,* ***54****, 253.-254., (2002)*

Print quality and market potential for ink-jet technology

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Abstract

The quality of two ink-jet applications, large format ink-jet on different substrates and high quality photo print ink-jet, is discussed in terms of print quality, essentially colour and detail rendering. The study was performed in order to investigate the quality demands of different segments where ink-jet technology is increasing in use and to analyse how well the quality responds to the demands. Two different segments were chosen to represent the growing field of ink-jet applications. The quality results are linked to the possibilities they give for the market in these segments.

The study shows, however, that there are deficiencies in the quality expected with regard to the various quality parameters and how well they are adapted to certain products.

The quality of ink-jet has increased very rapidly during recent years and it is in many ways well adapted to meet the demands in different product segments. The results within the large format study show the high potential to colour match a wide variety of printers and printing substrates. At the same time the results indicate that improvements are needed, mainly in the software field, to increase the quality even more. With further research on the influence of different substrates and the mechanisms involved in colour rendering the potential to be able to colour match prints on very different substrates seems good.

The photo prints produced by inkjet printers seem to achieve at least the quality obtained by professionally produced photocopies. With even more sophisticated colour control the potential for this field of application seems very promising.

1. Introduction

The field of application of inkjet technology is growing fast, especially in certain segments. Inkjet traditionally has its roots in the Small Office/Home Office market. This market is considered to be mature, or at least nearly mature, at the present time and is expected to decrease in growth. The greatest growth is in the large-format inkjet and also in special industrial applications. Although the costs for inkjet ink and coated paper are relatively high (IT Strategies, July 2002) the low printer costs together with an increasing familiarity with the technology encourage an increasing growth for inkjet. Since it is a non-impact method, a large variety of substrates as well as surfaces with varying contours can be used. Not only paper but all kinds of plastics, cloth, metal and many other materials can be used. One spectacular substrate is food, with a lot of applications from the decorating of cakes to advertising on sausages, bread and so on.

The technology is also relatively simple since print heads can be integrated in an existing printing line to give interesting combinations. Large volumes of packages can for example be printed with flexography,

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while the customised/variable data can be printed with inkjet. Dramatic changes are predicted in the period up to 2007 mainly because of the recently achieved progress within inkjet technology in on-demand printing on packages (Temple, 2002). On the whole, the production of highly qualified variable data products, customised in an exceedingly high degree, which (Bondy, 2003) claims is not the fact today, must be considered easier to implement with the possibilities that the development within inkjet technology provides.

The option of being able to use a large variety of substrates makes inkjet viable for a large range of applications. The development of inks has resulted in both a variety of different types (pigmented, dye based) and, for each type, water-, oil- or solvent-based grades. By combining dye-based and pigmented inks it is possible to develop the properties desired in certain specific applications. Inks based on UV-curing are growing. A new and interesting development is in invisible inks that are useful for instance for bar codes which can be invisible to the customer.

There is a clear trend towards the use of more than four colours. The addition of orange and green is a way to expand the colour gamut and the addition of light cyan and magenta gives a better tone gradation.

There is a development towards decreasing droplet size. Ultra microdots are droplets as small as two picolitres. Printers are also available with variable droplet sizes. The ability to print with variable droplet sizes using variable dot technology (Epson website) opens new opportunities. By combining the ultra microdots with this technology, a dot-on-demand procedure with appropriate droplet sizes being produced for a certain area, print speeds can be maintained. At the same time, it is claimed that enhanced print quality with no or at least negligible graininess and more fine detail rendering can be achieved.

Combining 8 colours with variable droplet technology will improve output capabilities. It is also possible to increase speed by adding a second print head.

It is claimed that the new generation of inkjet-based photo printers has a quality much superior to conventional methods. However, it is also claimed that non-professionals will not yet be able to take full advantage of the high quality, due to the difficulty of controlling the transfer of colour, brightness and contrast conditions between camera and printer. Epson has developed a special photo print technology, Print Image Matching (PIM), which transfers information between camera and printer regarding the conditions in which each photograph was taken (Bogo, 2002). Inkjet technology can according to Savastano (2002) be the dominating imaging technology by the year 2010. For industrial and commercial applications, the development of wide print heads with high durability is considered to be essential, together with a stable ink release technology (Ohta, 2002).

The objectives of the study presented in this paper were:

- to analyse the quality of two ink-jet applications, segments in which there is a growth; large format ink-jet on a variety of substrates and high quality photo print ink-jet;
- to study for the combination of large format inkjet with pigmented inks and a variety of substrates how well colours could;
- to each other simply by using standard colour management routines, taking into consideration quality aspects such as colour and detail rendering on these different substrates;
- to analyse the quality of photo printers, essentially focusing on the colour gamut, colour rendering and detail rendering, where the reference was a professionally produced photograph;
- to compare prints produced with pigmented ink and dye-based ink.

2. Background and market for inkjet technology

Technology

The two main types of inkjet technology are the continuous tone and drop-on-demand technologies. In the 1970s, among other continuous tone techniques, the Hertz technology was developed and later licensed to different companies to produce commercial high-quality colour images for proofing applications (Hue, 1998). The development of the drop-on-demand technique, which is much more simple than the continuous tone technique, led to the development of different types of DOD-techniques as can be seen in Figure 1, where some of the most common techniques are presented.

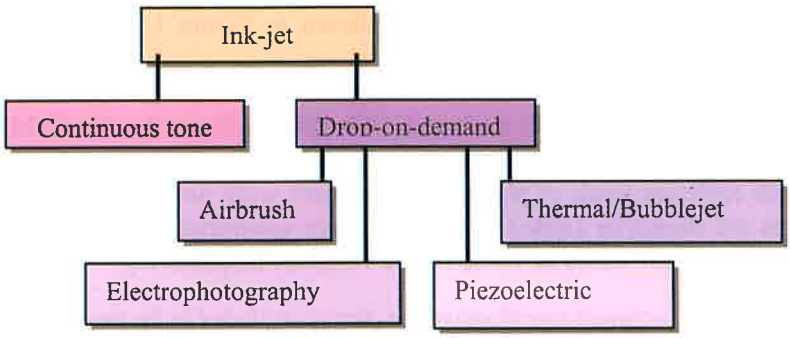

Figure 1: Some of the most common inkjet techniques

The print heads using piezoelectric technology are today based on a multiple layer ceramic construction including thin layers of piezo elements. The technique makes it possible to a high degree to control reproducibly not only the droplet size but also the positioning of the droplet on the substrate. The shape of the droplet is said to be even and round. Thus the piezo technology gives high precision in the generation of the droplets with subsequent high print quality.

The development of the technique using multiple droplet sizes to give a grey-scale with an apparently higher resolution than it is possible to achieve with a binary technique is one of the finely tuned developments of existing technology which improves quality.

Market

The growth on the home and office market is decreasing but it is steadily growing in the wide format as well as in industrial applications. One example is the rapidly growing photo-printing market. In the packaging field, drop-on-demand ink jet is poised to compete with traditional printing technologies such as flexography and screen printing. With the ability to reproduce variable information and the capability of print nozzles to be integrated into production lines (Temple, 2001) applications in the field of packaging are obvious. By combining volume printing with conventional technology and variable data printing with digital printing, so called hybrid printing, even more applications can be envisaged.

In the Digital Printing Report (IMI, 2002), the digital print market concerning ink jet in USA is divided into the following segments:

- *Wide-format digital colour graphics market*
  - Printers for graphic arts print, photo, posters, banners > 24''.
- *The colour business market*
  - A4 and A3 thermal and piezo liquid and solid inkjet printers, A4 and A3 colour laser printers, dye sublimation and colour thermal transfer printers.

- *The narrow home/small office ink jet market*
  - A4 and A3 size thermal and piezo liquid ink jet printers. These products typically have a lower print volume and are found outside the general business environment.
- *The digitally printed textile market*
  - Dedicated inkjet and electrostatic printers generally used for proofing and strike-off applications

3. Methods

Tests were performed with standard colour charts and with images chosen representing skin tone and details. The chart used for the CMYK printers is shown in Figure 1 together with the images used mainly for the perception evaluation.

The test charts used were CMYK TC 6.02 and TC9.18RGB from the ProfileMaker 6.02 software. Four different large format printers, each with one or several kinds of substrate as well as three small format printers with different kinds of photographic papers were used for the tests. The characteristics of the print devices are shown in Table I and the different substrates used for the large format test and the photographic print test are listed in Table II and Table III respectively.

Table I: Technical specifications for devices included in the investigation

	Technology	**Format (max)**	**Inks**	**Resolution (max)**
LARGE FORMAT				
Printer X	Piezo, variable dot	Web 210 - 1615 mm	8 colour, CMYK light C, light M, Orange, Green	1440 x 1440 dpi
Printer Y	Piezo	Web 420-1372 mm	6 colour CMYK lC lM	
Printer Z	Piezo			
Printer V	Micro piezo			
SMALL FORMAT				
Printer A	Micro piezo, variable dot	A4	6 colour	2880 x 1440 dpi
Printer B	Bubble jet, 2 pl droplets	A4	6 colour	4800 x 1200 dpi
Printer C	Thermal inkjet	A4	6 colour	4800 x 1200 dpi

Table II: Printer and substrate combinations used for the large format test

Substrates/Printers	**X**	**Y**	**Z**	**V**
PMhc (paper, matte, high coated)	XPMhc			
PMlc (paper, matte, light coated)		YPMlc		
Roll (Rollup, woven)		YRoll		
PVC (Banner pvc)			Zpvc	
Decal (adhesive)			Zdecal	
Cloth (woven)			Zcloth	
Ph (Photo paper semi gloss)				VPh

Table III: Printer and substrate combinations used in the photo print test

Substrates/Printers	A	B	C
5 (High gloss paper for imaging)	A5	B5	C5
6 (Medium gloss, satin, paper for imaging)	A6	B6	C6
8 (Gloss paper for photo)	A8	B8	C8
9 (Gloss paper for photo)	A9	B9	C9

Test prints and test photographs were produced:

- For the large format: with Onyx Postershop 5.6 for printers X, Y and Z and Best Screenproof 4.6.3 for printer V.
- For the photographic prints (small format): with for each particular device, the internal software for best quality of the output print. The papers were chosen to be appropriate for the device in which they were to be printed.
- The professional photograph was produced with Fuji's digital photo lab, Frontier 350, which is an integrated system combining silver halide and digital laser exposing techniques.

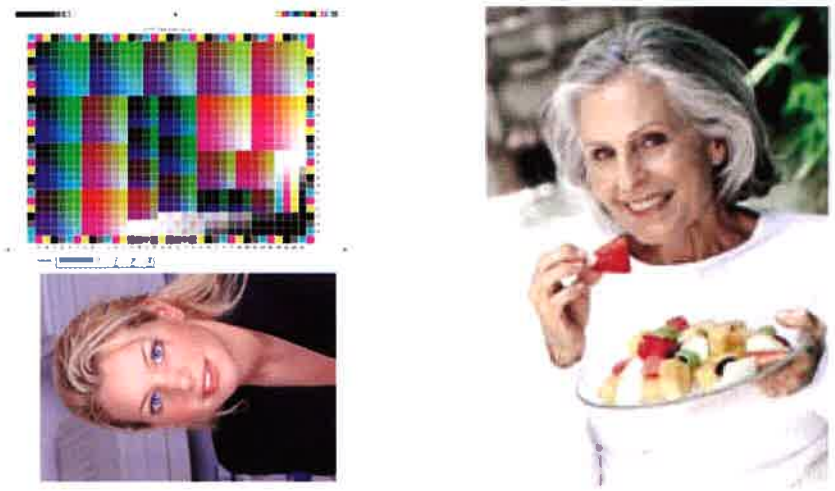

Figure 1: Images used for the measurements and the perception examination

Colours were measured with a Gretag Spectroscan. From the colorimetric values, colour difference, ΔE -values, were calculated according to:

$$\Delta E^*_{ab} = \sqrt{(\Delta a*)^2 + (\Delta b*)^2 + (\Delta L*)^2} \qquad \text{[Eq. 1]}$$

For the large format test prints, the reference was the printer with the largest gamut in the a*-, b*-plane and, for the photographic prints the professional photograph. Although other, perhaps more adequate colour difference formulae are available (Klaman p. 42, 2002) the ΔE^*_{ab} -value was chosen considered in this case to give the required information. The new colour difference formula CIEDE2000 (CIE, 2001) (Lou et al., 2001) will however be of interest to evaluate and compare in the next step of this application.

The ΔE^*_{ab} -values were measured for six colours chosen to represent representative colours in the gamut. They are characterized as cyan, magenta, blue, skin tone, orange and lime. The images were perceptually examined:

- *For the large format* according to the colour rendering and detail in the test images from the different printers in relation to each other.
- *For the photo prints* according to the colour gamut, colour rendering and detail rendering compared with the reference, which was the professional photograph.

The visual examination was done by the authors.

4. Results

Technical measurements, large format

Figure 2 shows for the six chosen colours in the gamut the colours displayed in a CIELAB a*-, b* diagram, and Figure 3 shows the related ΔE^*_{ab}-values. The differences are greatest for the magenta tone and in the lime and orange tones. For the skin tone, the differences are small.

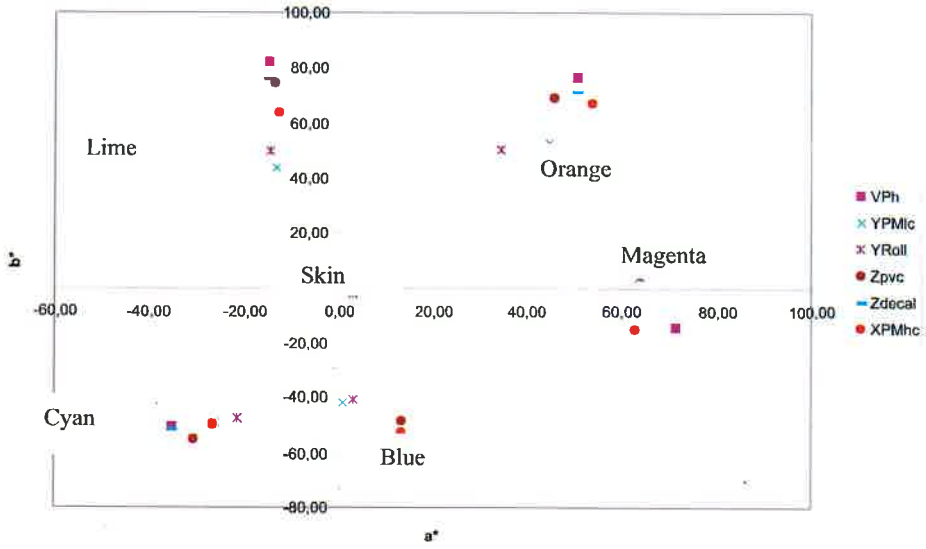

Figure 2: The six colours , blue, skin tone, orange, cyan, magenta and lime are displayed in CIELAB a-, b*-diagram for the printer/substrate combinations given*

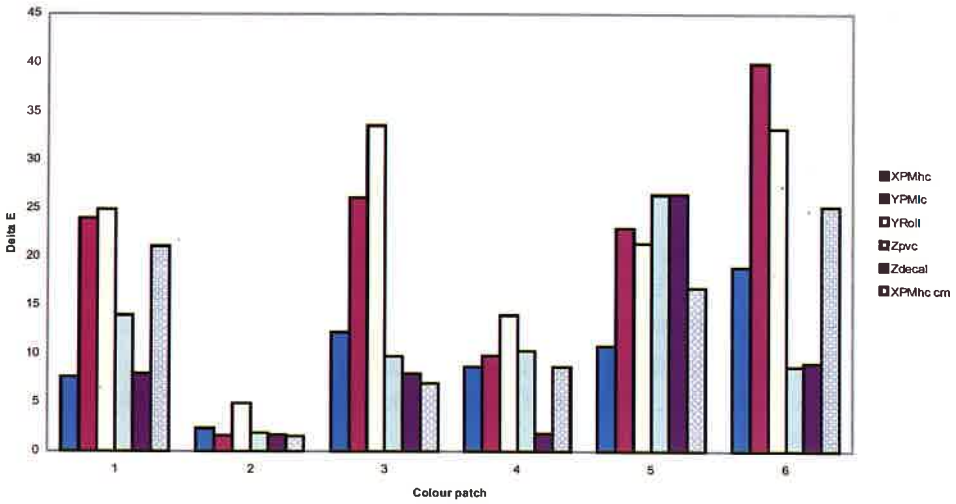

Figure 3: ΔE-values for the six colours , where 1=blue, 2 = skin tone, 3 = orange, 4 = cyan, 5 = magenta and 6 = lime. XPMhc cm stands for the colour managed print from printer X

Figure 4 shows all the measured spots for each combination of printer and substrate. The combination of printer V and photo paper has a large gamut, but it can also be seen here that the printer with Hifi colours covers the gamut in the green and orange range although it performs poor in other parts of the gamut. The print on the woven material (cloth) has a much smaller gamut.

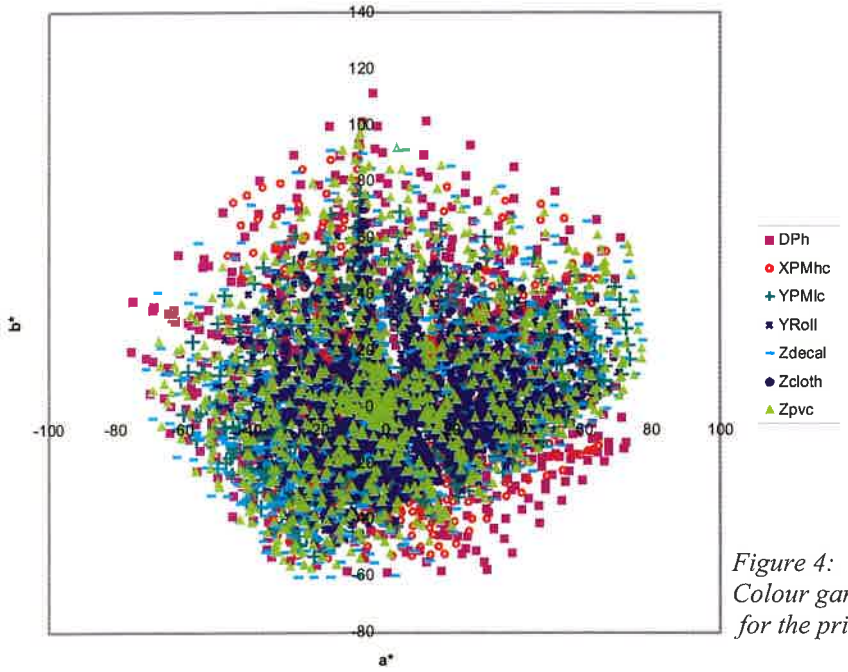

Figure 4:
Colour gamut in the a-, b* plane, CIELAB, for the prints from the large format devices*

Table IV lists the mean ΔE^*_{ab}-values in relation to the reference printer V with photographic paper calculated for all the colour patches measured (875) for some of the combinations of printer/ /substrate. This is done for the prints both with and without profiles for colour control. For the Hifi colour printer, X, the ΔE^*_{ab}-value increased after profiling, probably because the colour management software used did not take into consideration the Hifi colours, which are of importance if the expected enhancement of print quality is to be fulfilled.

Table IV: Colour patches with and without profiles, mean value for ΔE of the 875 patches. Reference is printer V

Printer/Substrate	With profile	Without profile
YRoll	0,92	0,92
YPMlc	0,45	1,2
Zpvc	1,05	-
XPMhc	0,58	0,16
VPh	0,88	1,14

Perceptual examination large format

After profiling, the images are more similar than they were from the beginning without profiles. The ΔE^*_{ab}-values in Table IV show the degree of improvement. The exception is the case with the hifi colours, which clearly indicates the need for an ICC profile based on other criteria with consideration taken to Hifi colours.

The detail rendering was good for all the prints but in rollup and woven cloth, the structure of the substrate tended to be more visible than the detail of the image.

Technical measurements, photographic prints

It is only in the region of the red-violet and related colours that the professionally produced photograph reaches beyond the gamut of what it is possible to achieve with the inkjet photo printers. They cover different regions:

- B more in the green region.
- C throughout the gamut, except for the red-violet part where the professional photograph exceeds the gamut, see Figure 5.
- A in the orange-magenta region.

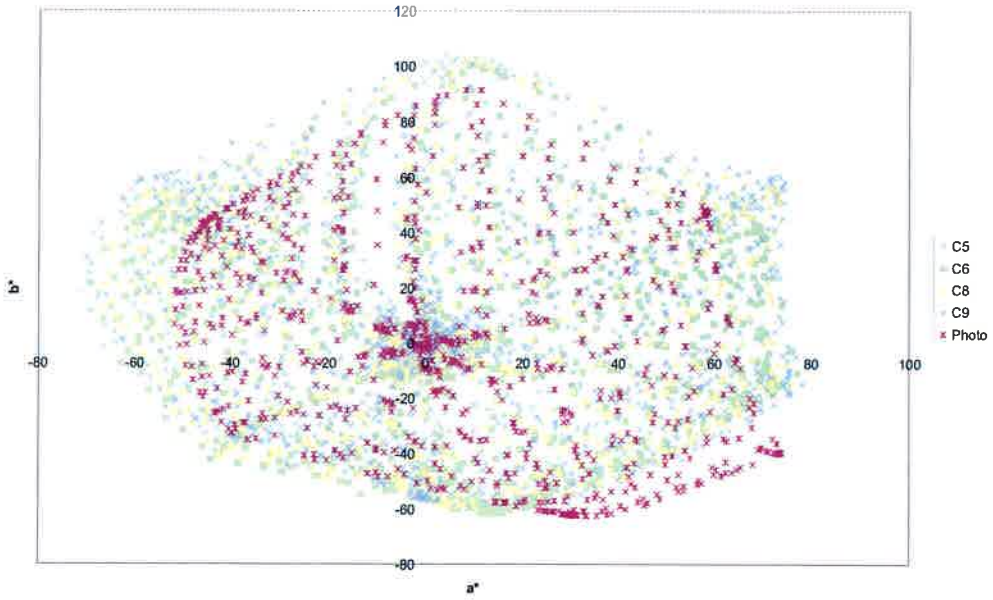

Figure 5: Gamut in the a-, b*-plane for printer C and the different substrates compared with the professional photo (the dark points)*

The six colours chosen in the gamut are represented in Figure 6 and the related ΔE^*_{ab}-values are seen in Figure 7. Part of the reason why the ΔE-values are generally high lies in the fact that the reference photograph was generally darker which means, that besides the a*-, b*-values, the L* value makes a

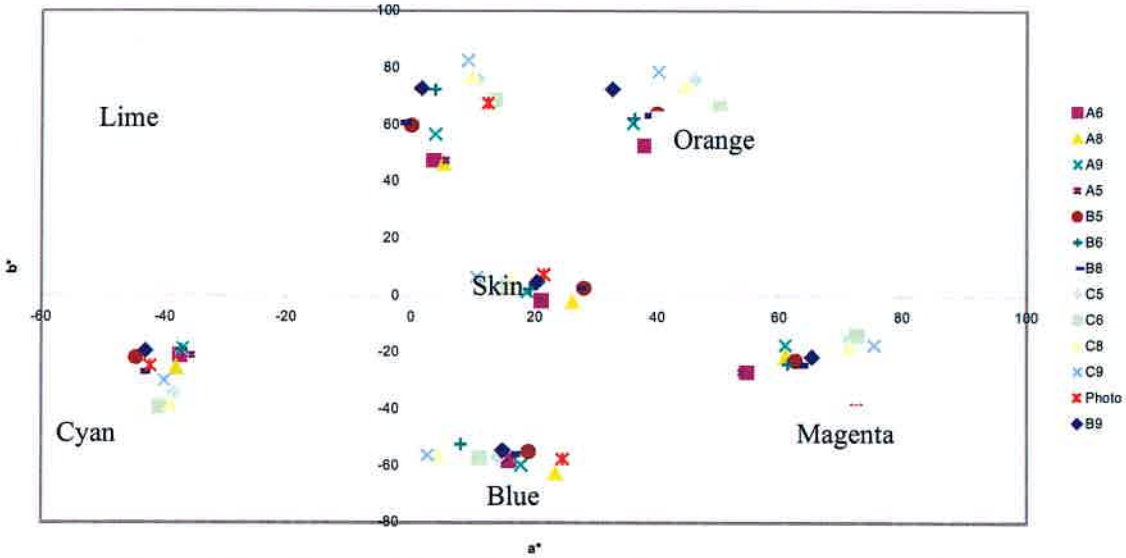

Figure 6: Six colours and their relationship for the different printers and substrates

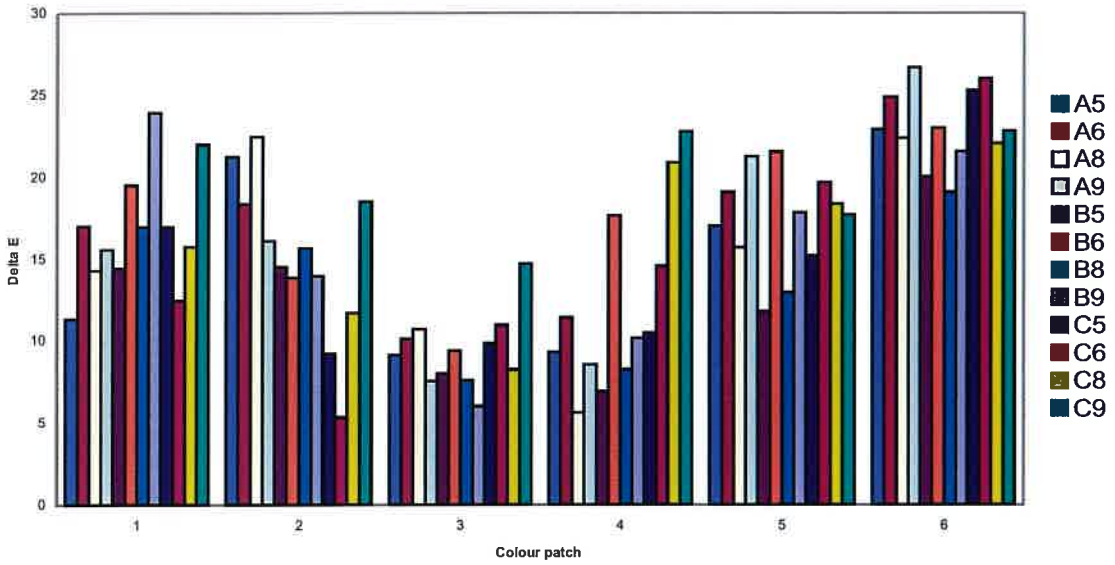

Figure 7: The ΔE-values for the six colours where 1=orange, 2=lime, 3=skin, 4=blue, 5=cyan and 6=magenta. The reference is the professional photograph

considerable contribution to the colour difference value. As for the large format study, the magenta colour differences are high, here indeed the highest, but the cyan differences are also large here. The differences for orange and lime (green) are at the same level. The differences are smallest for the skin tone and thereafter for the blue.

Perceptual examination photo prints

The perceptual examination of the inkjet photographs and the professional photograph shows that the inkjet photographs are of at least the same quality as the professional photograph. For C8 and C9 it is obvious that the larger gamut, as can be seen in Figure 5, is also clearly seen in some of the images.

Comparing the photographic prints on the four different substrates for each one of the printers the following could be concluded:

- The prints from printer A was in many ways most alike the professional photograph and they were also similar to each other and neutral on all paper grades.
- The prints from printer B had a change from being neutral on paper 5 to have a slight green colour cast strongest on paper 9.
- Besides having a large colour gamut the prints from printer C showed the same pattern as B with neutral appearance on paper 5 and then a slightly growing green colour cast to paper 9.

The detail rendering was overall good.

5. Comparison between pigmented ink and dye-based ink for photographs

Since the reference print in the large format study was produced on photograde paper, it was possible to compare photo printing with pigmented and dye-based inks. Figure 8 shows that the print with the pigmented ink yields an even larger gamut than the largest of the dye-based ones, with the same exception in the red-violet and blue region where the border of the gamut is inside that of the professional photograph, and also slightly inside that of some of the dye-based inks. Since the tests are made with different colour charts, due the difference of the printers, and with different settings it maybe not adequate to draw too strong conclusions from the differences of gamut size but it opens a need to continue comparisons in this aspect.

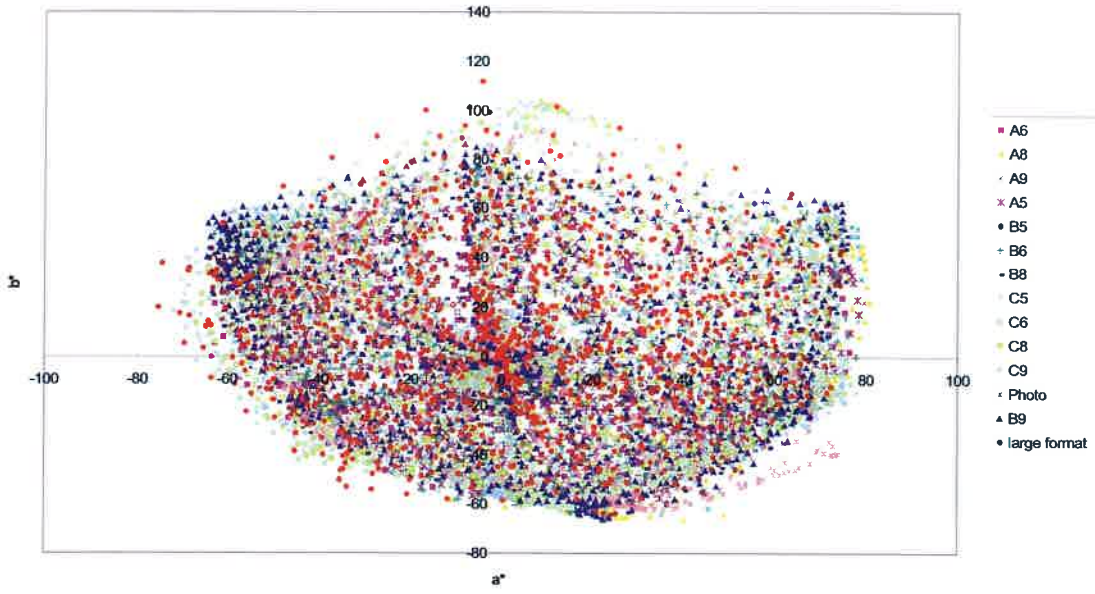

Figure 8: The a-, b*.values for the large format printer V on photo paper is plotted in the same diagram as the values for all the dye based prints*

6. Discussion

The results from the large format study must be considered from the perspective that they give a preliminary picture of the possibility to match different printers and different substrates so that they look alike. This scenario is of interest for instance for a marketing campaign where the message is displayed on several kinds of substrates, banderols, decals and large woven cloth.

To understand the mechanisms behind the colour differences, deeper studies must be performed. The fairly good result obtained by applying standard colour management routines is nevertheless obvious. The development of dedicated colour management software for inkjet would without doubt enhance the quality of colour matched outputs considerably.

Although the primary ink, magenta, differed in each of these tests, it was still possible to achieve a rather good colour matching in skin tones and also in some of the other colours. For orange and lime which are considered to be difficult colours, there is an advantage in having these colours as a complement in the ink set up (hifi colours).

Though the print on cloth has a much smaller gamut, the visual impression still gives an acceptable colour match. The effect of the transparency with light passing through the cloth must be considered in this case, as it possibly enhances the impression of the colours.

Since the dye-based photographic prints are not controlled to be similar to each other but are printed with the best possible output for each device they differ from each other and from the reference and this give differences between the printers at different levels in different parts of the gamut. The colour cast that prints on certain papers from two of the three printers shows, clearly demonstrates the need for continued research on the influence on colour rendering of different paper parameters. The results indicate that, with a proper combination of device and substrate, and also a relevant colour control, it would be possible to improve the quality considerably more.

As is claimed in the literature, it seems that the quality exceeds what it is possible to achieve by conventional photographic output. It must also be kept in mind that the technical charts and images

have been printed with standard software and standard settings for each of the output devices, and yet the quality obtained is good. If the kind of professional software mentioned in the introduction was applied the potential to increase the quality seems promising.

Concerning the gamut sizes provided by dye-based inks contra pigmented inks further studies are necessary.

7. Conclusions

The conclusion is that it is possible to colour match a wide variety of printers and printing substrates to give a similar appearance, although these preliminary data can only give an indication of what is possible. With further research on the influence of different substrates and the mechanisms involved in colour rendering, the potential to be able to colour match prints on very different substrates seems good. Although some of the large format printers have a low resolution since the output is meant for large outdoor applications, the perceptual impression is also acceptable concerning detail rendering.

The photographic prints produced by inkjet printers seem to give at least the quality obtained by professional photocopiers. With even more sophisticated colour control, and a better knowledge of the mechanisms involved in the interaction ink-substrate, the potential for this field of application seems very promising.

Photographic prints with pigmented inks maybe have an even larger potential for increasing the colour gamut.

Acknowledgement

The graphic arts research group within M-Real, is thanked for cooperation and for producing some of the prints on which the measurements and results presented here are based.

Literature

IT Strategies, (2002) *I.T. strategies reports minimal impact of ink jet expected for next five years, Ink World vol. 8, no. 7, Part 1 of 2, July 2002, p. 18.*

Anon., 2002), *World ink jet revenues to total USD41 bn in 2006, IT Strategies press release, 23 Aug. 2002, 1p.*

Bogo, K., 2002, *High quality photo printing from Epson, Aktuel Gr. Inf. no. 382, June 2002, pp 30-31.*

CIE Publication 142-2001.

Epson website, www.epson.com

IMI (Information Mangement Institute/I.T. Strategies), 2002, *The numbers...Worldwide Digital Printing Market Report, Commissioned by IMI from I.T. Strategies*

Klaman, M., 2002, *Aspects on Colour Rendering, Colour Prediction and Colour Control in Printed Media, Doctoral dissertation, Royal Institute of Technology, 2002*

Le, Hue P., 1998, *Progress and Trends in Ink-jet Printing Technology, Journal of Imaging Science and Technology, vol. 42, Number 1, January/February 1998, p. 49-61*

Lou, M. R., Cui, G., 2001, *The Development of the CIE 2000 Colour-Difference Formula: CIEDE2000, Color Research and Application, Volume 26, Number 5, October 2001.*

Ohta, T.,2002, *High-speed ink-jet printing, J. Print. Sci. Technol., vol. 39, no. 2., 2002, pp 97-102 Abstract eng., article Japanese)*

Savastano, D., 2002, *Ink jet report, Ink World vol. 8, no. 7, Part 1 of 2, July 2002, pp 26, 28 30-35.*

Temple, S., 2001, *Jet propelled disciplines, Packaging Today, vol. 23, no. 12, Dec 2001, pp 35, 37-38.*

Bondy, C., Digital Production Printing, DPP2003: IS&Ts International Conference on Digital Production Printing and Industrial Applications, May 2003.

Temple, S., 2002, *New opportunities in demand printing with ink jet: package printing, Envaspres no. 214, May 2002, pp 38, 40-42 (abstract English, article Spanish)*

Surface analysis of printed matter by using an atomic force microscope

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Abstract

Atomic force microscope (AFM) is very useful for measuring surfaces in three dimensions. We studied the surfaces of black print using AFM and scanning electron microscope (SEM) to obtain high quality printed matters. Samples were obtained using a printability tester with black ink for sheet feed off-set printing and a cast-coated paper (the smoothest paper available in Japan). When the amount of transferred ink (y) was sufficiently small (ca. 0.05 g m^{-2}), small ink particles adhered to the paper surface [average particles size = ca. 8 (length = L), ca. 5 (width = W), and ca. 0.5 mm (height = H)] with smaller particles [ca. 1.5 (L), ca. 0.7 (W), and ca. 0.3 mm (H)]. The former particles were transferred ink and the latter were from ink mists. The particles became larger with increasing y. At y = ca. 0.8 g m^{-2}, the ink particles adhered in a net-structure. For $y > 1$ g m^{-2}, the paper surface was completely covered with ink, although there were very unevenly. The averaged highth became small and these numbers decreased with increasing the y value. Next, we measured the surfaces of half-tone printed matter [screen ruling, 200 LPI; dot area (a), 2,5 - 95 %]. There are many pinholes (∅ = ca. 2-3 mm, depth: ca. 1 mm) that seemed to be caused by emulsified water in ink. Even for a = 10 %, there were hollows around the dots. The average angles at the dot edge of ink and paper surfaces from horizontal level were (86 ± 2) and (20 ± 6), respectively. The heights of a dot above the horizon of the paper was about 0.7 mm. Consequently, there were hollows about 0.3 mm deep in the paper.

1. Introduction

The formation of a flat printed surface is very important in obtaining high-quality printed matter. We have studied the printed surface of solid patches by using a gloss meter [1], a non-contact type surface roughness meter [2], and a scanning electron microscope (SEM) [3]. The glossiness of a surface is a macroscopic parameter of the surface. Although a non-contact type roughness meter is an useful equipment for uniaxial measurements on a scale of several tens of microns, the size of ink particles is below this resolution. SEM is very useful for measuring small particles. Unfortunately, the surface layers appear as shadows on the paper surface in electron micrographs when viewed from above. We obtained clear, accurate electron micrographs by taking SEM images at an oblique angle (70°) with a low acceleration valtage [3]. When the amount of ink transferred is very small ($y <$ ca. 0.1 g m^{-2}), ink particles attach to high points on an uneven surface. As the amount of ink transferred increases ($y < 0.8$ g m^{-2}), the particles become larger and joint to be as like a net-like structure [3]. Although the paper surface is covered completely with the ink particles when $y > 1$ g m^{-2}, there were many ink peakss on the printed surface after drying. Recently, we detected many ink peaks on the surface immediately after printing [4]. These peaks affect the glossiness of the printed matter after drying. With oblique SEM, it is impossible to measure depth and height. Atomic force microscope (AMF) is a good way to measure small partcels in three dimensions, although the areas measured is very small [50 mm (length, L) x 50 mm (width, W) x 1 mm (height, H)]. We studied printed surface using an AFM and digital microscope.

2. Experimental

2.1 Sample

Solid printing matters was obtained using an Akira Seisakusyo RI-tester type RI-4 printability tester [5], using offset proofing ink (non-solvent type ink, Tack = 14.2 at 293 K) and cast-coated paper (ca. 110 g m^{-2}, the smoothest paper available in Japan). The nip width between the ink and paper rolls were regulated to be 3 mm. After allowing 10 minutes to distribute the ink on the tester, we transferred the ink. The amounts of ink transferred was determined gravimetrically. Printing companies donated half-tone printed matters, with half-tone printed pattern obtained using offset printing with 50 - 200 LFP square dot patterns on the cast coated paper using black ink. The amount of ink transferred was controlled using the reflection density of the solid patch ($d = 1.85 \pm 0.04$).

2.2 Measurements

Immediately after the printing, the wet surface was observed directly with a type VP-6300 digital microscope (Cheyenne Co. Ltd., Osaka, Japan) at a magnification of 450 - 3000. The Glossiness was also measured [6]. After drying, the surfaces were observed using AFM and SEM. A type SPM-9500 atomic force microscope (Shimazu Co. Ltd., Kyoto, Japan) with Si_3N_4 micro cantilever was used to measure the surface of the printed matter. Before making the measurements, we confirmed that the samples were free of pinholes and scars using a 200 magnification loupe. Samples (10 mm x 10 mm) were adhered to the sample stage using double-sided tape. In each sample, at least five areas were measured. The surfaces were also observed using a Hitachi S-510 scanning electron microscope (SEM, Hitachi Co. Ltd., Tokyo Japan). Each sample was coated with gold four times for 30 seconds each time to avoid heating the sample at ca. 1 x 10^2 Pas using an ion coater (IB-2, Eiko-Engineering Co. Ltd., Ibaragi, Japan). Observations were made from directly above (0°) and at an angle of 70° to the surface (acceleration voltage: 15 - 30 kV; vacuum, ca. 1.3 x 10^{-3} Pas).

3. Results and Discussion

3.1 Effect of amount of ink on the surface

The printed surfaces were observed by using AFM and SEM. Figure 1 shows those images of printed surfaces [amount of ink transferred (y) = 0.00 (1), 0.05 (2), 0.22 (2), 0.40 (3), 1.38 (4), and 2.20 g m^{-2} (5)]. The SEM image of paper (picture 1b of Fig. 1) shows many pinholes (f = ca. 0.5 mm), which were probably due to the evaporation of steam when the paper was made. Following addition of a small amount of ink (y = 0.05 g m^{-2}, pictures 2a and 2b of Fig. 1), many ink particles attached to the surface. The particles were classified into two groups: small particles [average particles size = ca. 8 (length = L), ca. 5 (width = W), and ca. 0.5 mm (height = H)] and very small particles [ca. 1.5 (L), ca. 0.7 (W), and ca. 0.3 mm (H)]. The former appeared to be transferred ink, while the latter were depoited from ink mist. The particles became larger with increasing y. At y = ca. 0.8 g m^{-2}, the ink particles adhered to the paper in a net-like structure.

For $y > 1$ g m^{-2}, the paper surface was covered completely with ink,through unevenly. The average height decreased with increasing the y value (H = 0.1 to 0.2 mm). Immediately after the printing, many ink peaks were observed on the wet surface, as shown in Figure 2. As shown in Figure 3, the number of peaks decreased with increasing the y value. Conversely, the average height of the ink peaks increased.

The peaks observed on the dry surface must have occurred during ink transfer.

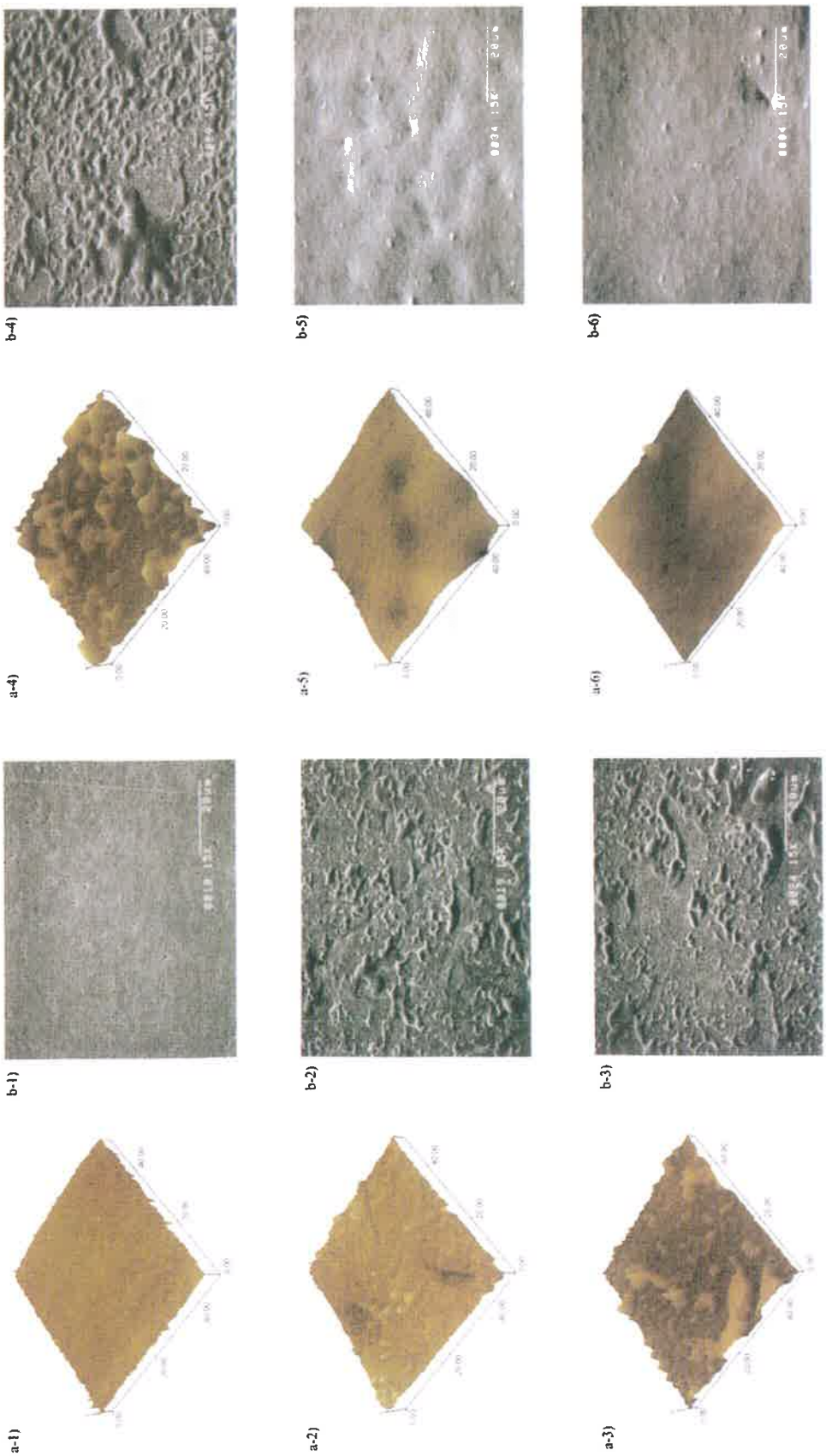

Figure 1: AFM (a) and SEM images (b) of printed matters. y = 0.00 (1), 0.05 (2), 0.22 (3), 0.40 (4), 1.38 (5), nd 2.20 g m^{-2} (6)

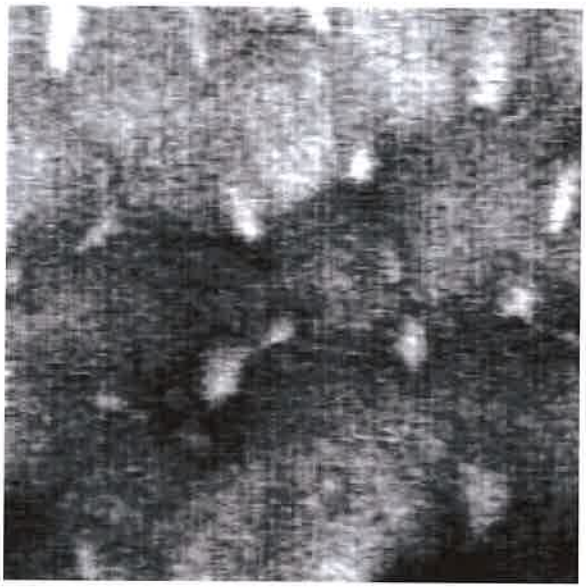

Figure 2: A digital microscope image of the wet surface immediately after the printing (450 magnifications). The black peaks of the ink were observed

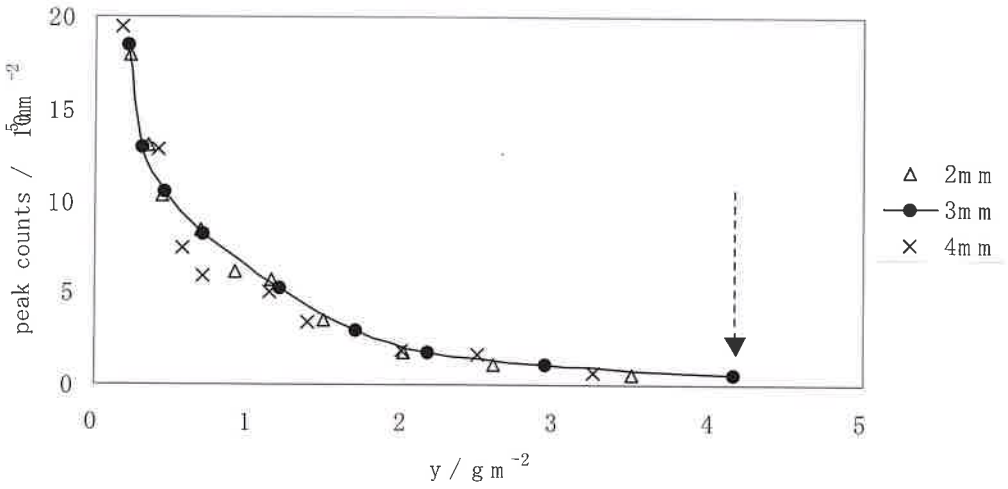

*Figure 3: Relation between peak counts and the **y** value.*
(y = ca. 4.2 g m^{-2}; Nip widths, 2, 3 and 4 mm).
*An arrow in this figure indicates the **y** value of the picture in Figure 2*

3.2 Dot Pattern

Next, we measured the surfaces of half-tone printed matter [screen ruling, 200 LPI; dot area (a), 2.5 - 95 %]. Figure 4 shows AMF images of the samples (a = ca. 2.5 %). Although sides of the square dot were small as ca. 20 mm, the dots composed of 5 to 9 grain particles. There were various grain shapes, i.e., larger, smaller, notches, etc. Some large grains were joined, while smaller grains remained separate. There are no rules for the dispositions of the grains in the dot independent of gripper direction. Therefore, we postulated that the large grains formed at convexities of the dot area on the paper. Many pinholes were observed on the surface of the paper (∅ = ca. 2 - 4 mm). Most were shallow, round-bottomed, black cavities, as observed using the digital microscope with a head drop type illuminator, as shown in Figure 5. The remaining pinholes reached the paper surface and were of variable shape. The paper surface had many pinholes [3]. Most were formed during the process of paper making (f = ca. 0.5 mm) and a few were formed by drops on the coated surface layer (f > 5 mm). The pinholes in the ink surface were not the result of pinholes on the paper surface: the former were caused by water during printing, and the latter were gaps between the grains. As AFM can used to obtain measurements in three dimensions, the edges of the dot were observed, as shown in Figure 6. Around dot edge, the paper surfaces was concave, while the ink surface was convex. The shapes of the dot were very variable, we measured the many dot edges (> 30 tmes). The average angles of the ink and paper surfaces from horizontal level at the dot edge were (86 ± 2) and (20 ± 6), respectively. The dots were raised by about 0.7 mm above the horizon of the paper. Consequently, the hollows were about 0.3 mm depth.

4. Conclusion

We studied the wet and dry printed surface by using SEM, AFM, and digital microscope to obtain high quality printed matter. There are many interesting phenomena, i.e., ink peaks on the wet surface, hollows on the surface, emulsified water in ink, etc. We clarified small results. When the y value was very small, the ink particle attached on the convexus of the paper. The particles became large according to the increase of y. Over y > ca. 1 g m^{-2}, ink transferred completely on the paper surface. The surfaces of the half-tone printed matters were also studied. There were many hollows that seemed to cause by emulsified water in ink. More detail measurements and discussion will make clear the ink transfer and producing high quality printed matters.

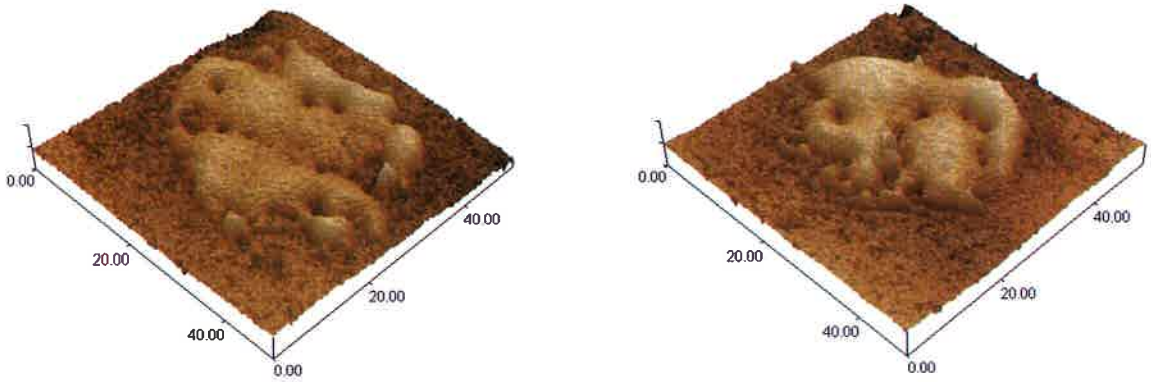

Figure 4: AFM images of dot (a = ca. 2.5 %)

Figure 5: A digital microscope image of a half-tone pattern (a = ca. 50 %; 3000 magnifications)

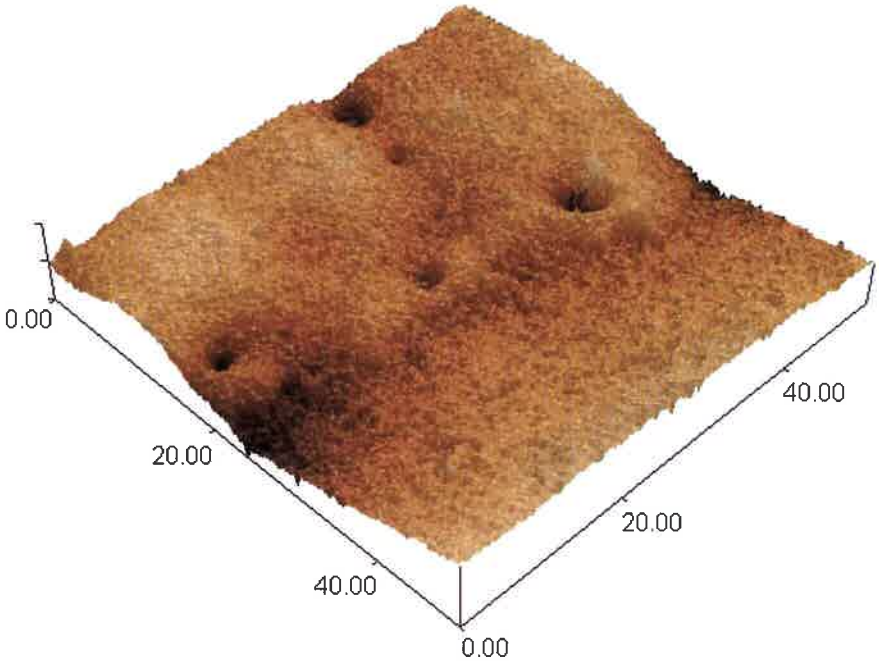

Figure 6: A AMF image around the boundary of the dot (a = ca. 50 %). A back side of this picture is printed area

Acknowledgment

We are grateful to to Mr A. Nomura of Dainippon Screen Mfg. Co., Ltd. and Mr Y. Matsumoto of Nozaki Insatsu Sigyo Co. Ltd. for donating the half tone printed matters. I.N. also thanks Mr Y. Nitta of our university for the opperations of the SEM and the digital microscope.

References

[1] Naito I., Ezaki Y., Tsuzumi S. and Kinoshita A., (1991), *"Studies of Gloss of Off-Set Printed Matter", Preprint of the meeting of the Japanese Society of Printing Sci. Technol., No. 87, pp. 37-40;* Naito I., Kinoshita A. and Yonekawa Y., (1992), *"Studies of Gloss Appearence of Printed Marrer", Kyushu Sangyo Univ. Res. Rep. Fac. Art, 23, 1 ,97-102.*

[2] Naito I., Suzuki T. and Kinoshita A., (1994), *"Studies of Roughness of Printed Surface", J. Printing Sci. Technol., 31, 3, 147-153.*

[3] Naito I., Hayano T., Maki K. and Kinoshita A., (1998), *"Studies of Roughness of Printed Surface (II) - Direct Monitoring by Scanning-type Electron Microscope -", J. Printing Sci. Technol., 35, 3, 139-144*

[4] Naito Ikuo, Shibata K. and Nitta Y., *preparation of manuscript*

[5] JIS K5701

[6] JIS Z8741

A bridge between colour and process related magnitudes in autotypic printing

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Abstract

Autotypic printing processes as offset printing is used to create colours on substrates; these colours may be measured with colorimeters based on various systems. On the side these colours are adjusted through the process magnitudes ink film thickness and dot gain, to which we have rather access by use of densitometry measurements. The dominant magnitude is the dot area, where actually the dot gain is regulated by modulating the ink film thicknesses.

A bridge between both, colour and process related magnitudes are needed. Colour and density measurements may be carried out with the same universal instrument, the spectrophotometer.

The way chosen was to measure the dot areas of the inks on the fields with halftone printing of C, M and Y by using a modified version of the Murray Davies equation, applied over suitable wavelength bands. The modification consists to consider the optical effect of the light absorption, but also of the light scattering by the pigments of another inks.

The results obtained in this way are different, sometimes quite different from those by using the "usual" Murray-Davies equation. Important is that the Neugebauer equations, where the dot areas from the modified Murray-Davies give results quite consistent with the direct colour measurement: the results are only some few ΔE-units away from those of a direct colour measurement, also applicable for problematic halftones, as those near to the "chromatic-grey-halftones" (grey reached by halftone printing of C, M and Y). We call these dot areas, obtained with the modified Murray Davies equation "Chromatic Effective Dot Areas". By using dot areas from the "classical" Murray-Davies-equation the differences to the direct colour measurement may be much larger.

Either more important is that by using this "Chromatic Effective Dot Areas", the dot area drift between a OK- sheet and a sheet with colour drift corresponds over the Neugebauer equations is almost exactly to the colour drift between them.

This means, that we have here a good diagnosis instrument for colour drifts and an important component in a tool for the compensation of them. The measurement in "chromatic grey" fields make sure that any effects as gradual fading, trapping etc. are present in the measurement.

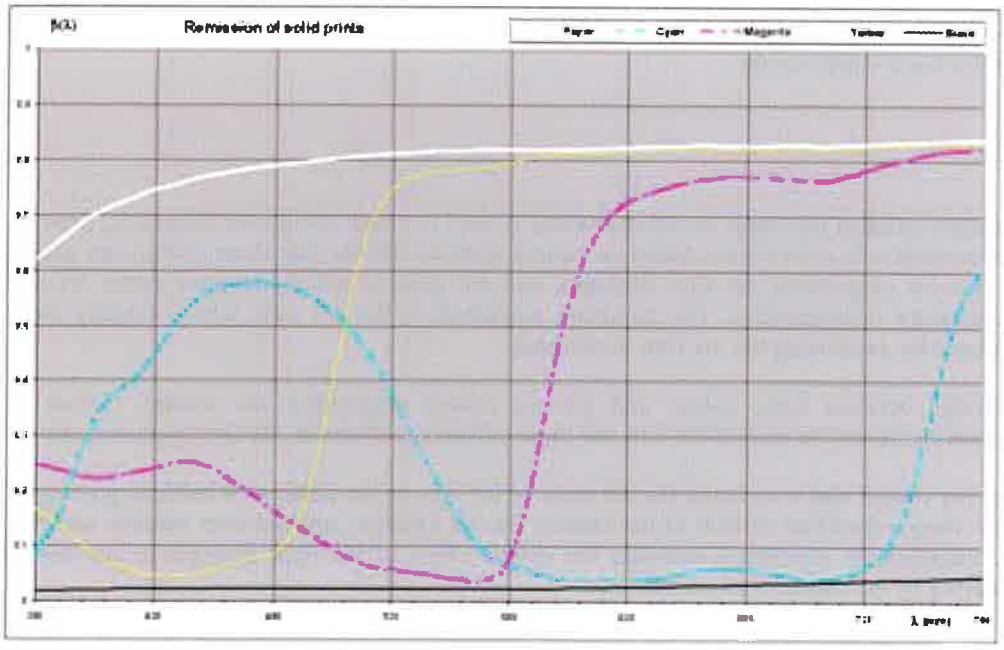
1. Measurement of the dot areas with a modified Murray Davies equation

The way chosen was to measure the dot areas of the inks on the fields with halftone printing of C, M, and Y by using a modified version of the Murray Davies equation, applied over suitable wavelength bands. The modifications consist to consider the optical effect of the light absorption, but also of the light scattering by the pigments of another inks.

Now follows the core of the used method, a detailed description of the applied software may be confusing. In three steps, with measurements at three wavelengths we find out the dot areas of Cyan, Magenta and Yellow.

First step: the Cyan dot area

If we look at the remission of the process inks C, M and Y, as shown in Picture 1 we can see (for our set of inks) that at a wavelength "λ_C" of 710 nm is possible to measure the dot area of Cyan on the halftone field without problems because at λ_C:



Picture 1

- the both another inks do not absorb radiation and
- the abnormal dispersion on their pigments (ref. 1 and 2) does not lead to light scattering as the absorption Band is far enough from them.

In a first step the dot area F_C of Cyan can be find out from:

$$\beta(\lambda_C) = (1 - F_C)\, \beta o(\lambda_C) + F_C\, \beta_C\, (\lambda_C) \qquad [1]$$

where:

- $\beta(\lambda_C)$ is the remission of the CMY- halftone print at λ_C
- $\beta o(\lambda_C)$ is the remission of the unprinted paper at λ_C
- $\beta_C\, (\lambda_C)$ is the remission of Cyan at λ_C

All these values may be measured with the Spectrophotometer. Actually, equation [1] is the well-known Murray Davies equation (ref. 3).

Second step: the Magenta dot area

If we look again the remission of the process inks C, M and Y, as shown in Picture 1, we see that for the dot area measurement of Magenta, the choice is to measure at a wavelength "λ_M" of 550 nm. As

this wavelength yellow do not absorb or scatter light, but the effect of Cyan at λ_M must be considered by calculating F_M from the relation:

$$\beta(\lambda_M) = (1 - F_C)\,(1 - F_M)\,\beta o(\lambda_M) + F_C\,\beta_C(\lambda_M) + F_M\,\beta_M(\lambda_M) - F_C\,F_M\,\beta_{MC}(\lambda_M) \qquad [2]$$

where:

- $\beta(\lambda_M)$ is the remission of the CMY- halftone print at λ_M
- $\beta_O(\lambda_M)$ is the remission of the unprinted paper at λ_M
- $\beta_C(\lambda_M)$ is the remission of Cyan at λ_M
- $\beta_M(\lambda_M)$ is the remission of Magenta at λ_M
- $\beta_{MC}(\lambda_M)$ is the remission of Magenta over Cyan at λ_M

The value of F_C used for the Cyan dot area is the value obtained from the first step.

[2] may be seen as a modified Murray Davies equation or as the Neugebauer equation for the wavelengths λ_M in the special case in which only two inks must be considered (ref. 4, 5 and 6).

Third Step: the Yellow dot area

The Yellow dot area F_Y is measured at a wavelength "λ_Y" of 450 nm from a modified Murray Davies equation, actually the Neugebauer equation for λ_Y and three inks (ref. 4, 5 and 6):

$$\beta(\lambda_Y) = (1 - F_C)\,(1 - F_M)\,(1 - F_Y)\,\beta o(\lambda_Y) + F_C\,\beta_C(\lambda_Y) + F_M\,\beta_M(\lambda_Y) + F_Y\,\beta_Y(\lambda_Y) - \\ - F_C\,F_M\,\beta_{MC}(\lambda_Y) - F_C\,F_Y\,\beta_{YC}(\lambda_Y) - F_M\,F_Y\,\beta_{YM}(\lambda_Y) + F_C\,F_M\,F_Y\,\beta_{YMC}(\lambda_Y) \qquad [3]$$

where:

- $\beta(\lambda_Y)$ is the remission of the CMY - halftone print at λ_Y
- $\beta_O(\lambda_Y)$ is the remission of the unprinted paper at λ_Y
- $\beta_C(\lambda_Y)$ is the remission of Cyan at λ_Y
- $\beta_M(\lambda_Y)$ is the remission of Magenta at λ_Y
- $\beta_Y(\lambda_Y)$ is the remission of Yellow at λ_Y
- $\beta_{MC}(\lambda_Y)$ is the remission of Magenta over Cyan at λ_Y
- $\beta_{YC}(\lambda_Y)$ is the remission of Yellow over Cyan at λ_Y
- $\beta_{YM}(\lambda_Y)$ is the remission of Yellow over Magenta at λ_Y
- $\beta_{YMC}(\lambda_Y)$ is the remission of Yellow over Magenta over Cyan at λ_Y

And:

- The value of F_C used for the Cyan dot area is the value obtained from the first step.
- The value of F_M used for the Magenta dot area value obtained from the second step.

To find out F_C F_M and F_Y of the CMY halftone printed patch with an algorithm based on equations as [1], [2] and [3] we need the measurement of:

- the remission of this CMY halftone printed patch at λ_C, λ_M and λ_Y

and:

- the remission of the unprinted paper or substrate at λ_C, λ_M and λ_Y — o
- the remission of Cyan at λ_C, λ_M and λ_Y — C
- the remission of Magenta at λ_M and λ_Y — M
- the remission of Yellow at λ_Y — Y
- the remission of Magenta over Cyan at λ_M and λ_Y — MC
- the remission of Yellow over Cyan at λ_Y — YC
- the remission of Yellow over Magenta at λ_Y — YM
- the remission of Yellow over Magenta over Cyan at λ_Y — YMC

This means that for the measurement of F_C F_M and F_Y on a CMY halftone printed patch we need also to measure on following solid tone patches:

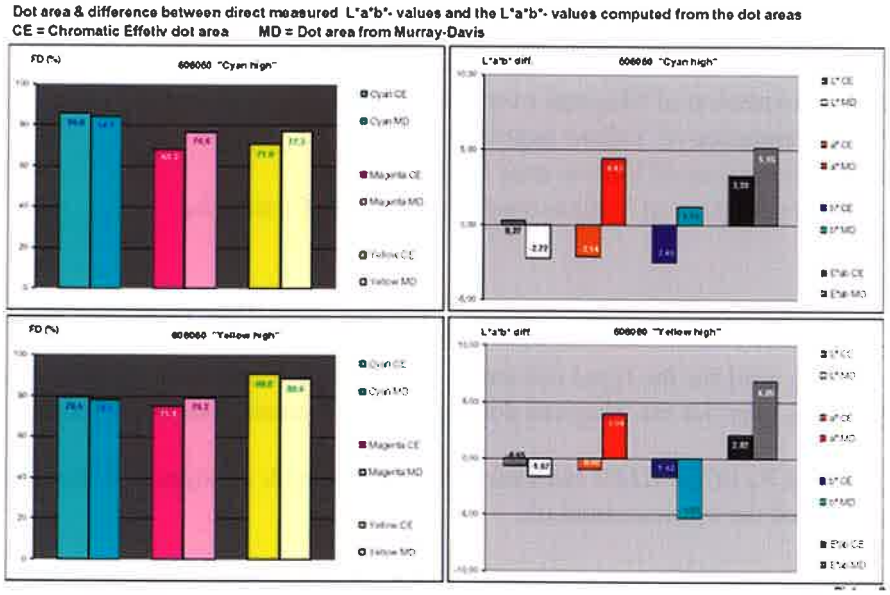
o C M Y MC YC YM YMC

The instrument to perform these measurements is the spectrophotometer. We used a Gretag "SPM100 II" spectrophotometer with a wavelength resolution of 10 nm. The measured values were imported and evaluated using the table's calculation software on a windows based PC.

2. Chromatic effective dot areas

The results obtained in this way are different, sometimes quite different from those by using the "usual" Murray-Davies equation. To compare the results we have also printed patches for each inks separately and over solid prints of another inks.

Important is that the Neugebauer equations, with the dot areas from the modified Murray-Davies give results quite consistent with the direct colour measurement: the results are only some few ΔE-units away from those of a direct colour measurement and even for problematic halftones, as those near to the "chromatic-grey-halftones" (grey reached by halftone printing of C, M and Y). Therefore we call these dot areas, obtained with the modified Murray Davies equation "Chromatic Effective Dot Areas"; by using dot areas from the "classical" Murray-Davies-equation the differences to the direct colour measurement may be much larger. One example is shown in picture 2.



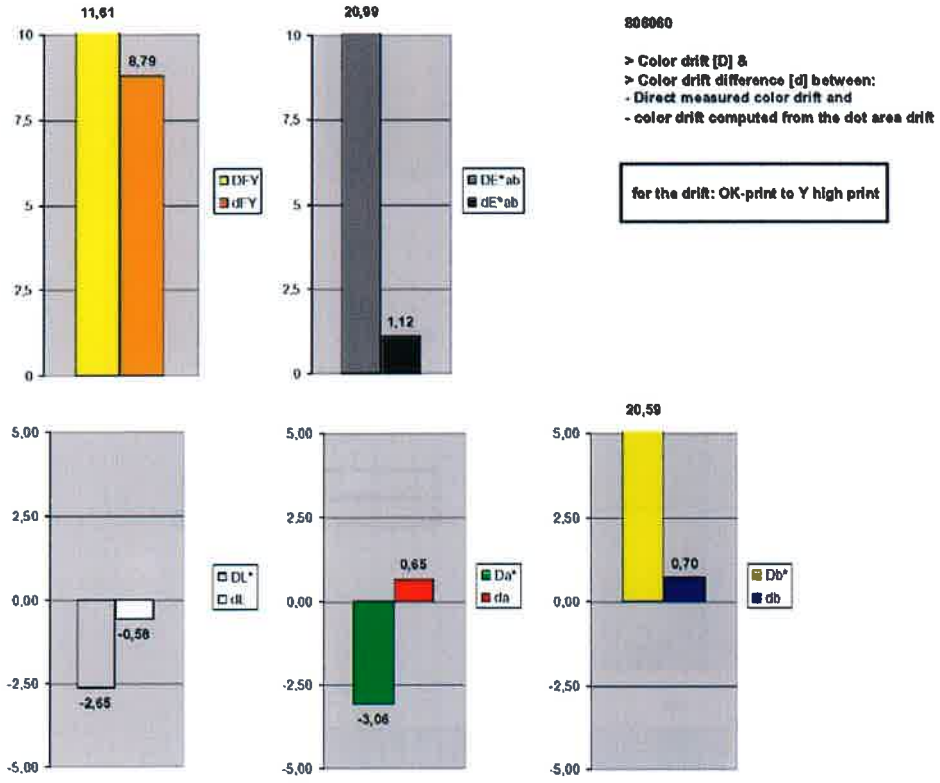
Picture 2

3. Correlation between colour drift and the drift of the chromatic effective dot areas

It is more important to note that by using this "Chromatic Effective Dot Areas" the dot area drift between a OK- sheet and a sheet with colour drift correspond over the Neugebauer equations nearly exactly to the colour drift between them.

We have tested this on production presses and we have seen that in both, in "natural" drifts along larger runs as also by in "larger intentional" drifts the colour drift and the drift of the Chromatic Effective Dot Areas correlates as mentioned about the Neugebauer equations. In the following pictures 3, 4 and 5 show the results of larger drifts.

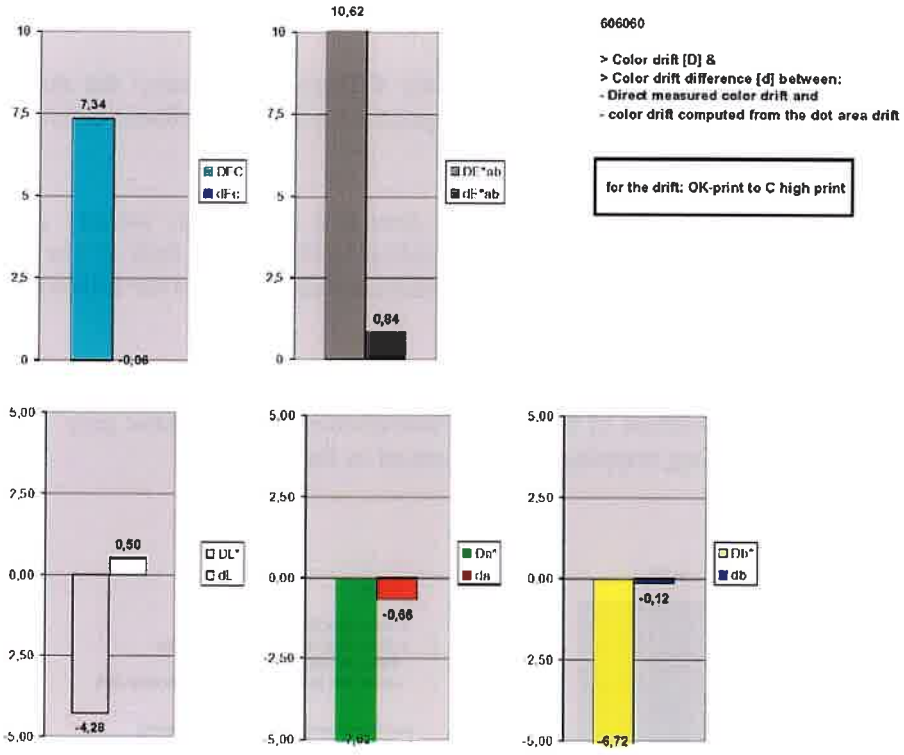
This means, that we have here a good diagnosis instrument for colour drifts and a important component in a tool for the compensation of them. The measurement in "chromatic grey" fields make sure that any effects as gradual fading, trapping etc. are present in these values.



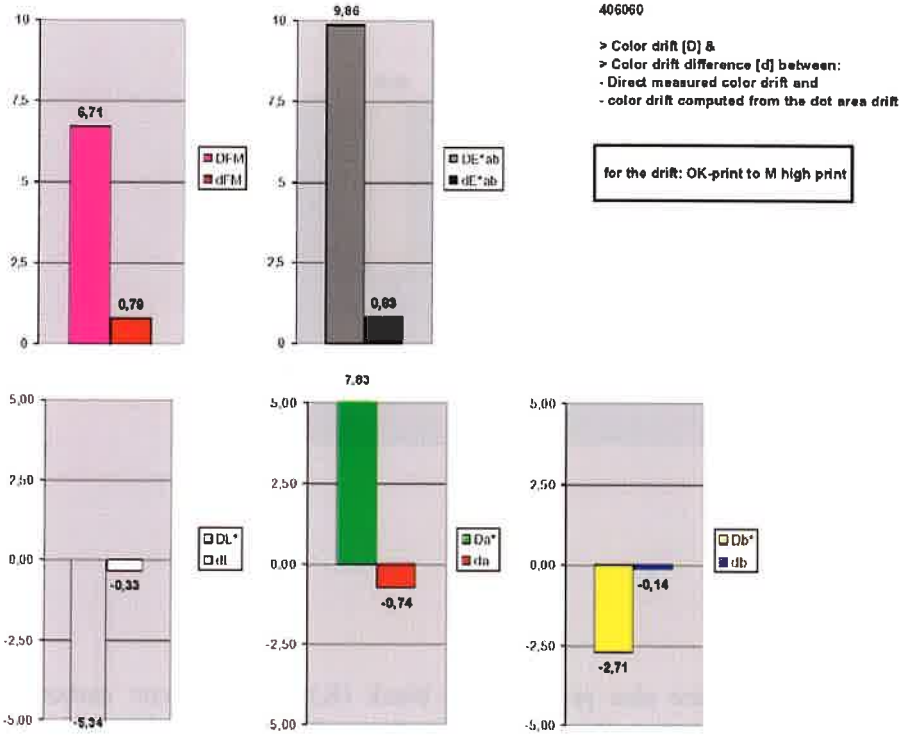
Picture 3

4. Further developments

Measurements in patches which are also printed with black (K) ink (pigment: carbon black), is important for measurement on the picture. It is well known, that only the Carbon black pigmented inks absorb near infrared radiation with a wavelengh λ_K of about $\lambda_K = 900$ nm. As in near infrared the pigments of the another process inks do not absorb radiation, the following equation is valid:



Picture 4



Picture 5

$$\beta(\lambda_K) = (1 - F_K)\,\beta_O(\lambda_K) + F_K\,\beta_K(\lambda_K) \qquad [4]$$

where:

- $\beta(\lambda_K)$ is the remission of the CMYK- halftone print at λ_K
- $\beta_O(\lambda_K)$ is the remission of the unprinted paper at λ_K
- $\beta_K(\lambda_K)$ is the remission of Black at λ_K

And the equations [1], [2] and [3] should be modified by replacing:

$\beta_O(\lambda_C)$ with $(1 - F_K)\,\beta_O(\lambda_C) + F_K\,\beta_K(\lambda_C)$,

$\beta_O(\lambda_M)$ with $(1 - F_K)\,\beta_O(\lambda_M) + F_K\,\beta_K(\lambda_M)$ and

$\beta_O(\lambda_Y)$ with $(1 - F_K)\,\beta_O(\lambda_Y) + F_K\,\beta_K(\lambda_Y)$.

where:

- $\beta_K(\lambda_C)$, $\beta_K(\lambda_M)$ and $\beta_K(\lambda_Y)$ are the remissions of Black at λ_C, λ_M and λ_Y.

Evaluation of the change in the ink feed for the compensation of a colour drift:

For this evaluation is needed to know how changes the dot area Fi on the i-th ink if the ink film thickness si is modified, this means the value of dFi/dsi or the value of dFi/dDi if the solid tone density is approximately proportional to the ink film thickness.

It is possible to get dFi/dsi or dFi/dDi from the relation between densitometry measurements on a solid tone and a half tone field of the ink.

References

Pahlke, H. *"Kritische Betrachtungen zu den Begriffen Deckvermögen und Transparenz", Farbe und Lack, Nr. 5, 1967*

Vogel, H. *"Gerhsen Physik", Springer-Verlag Berlin Heidelberg, 1997*

Riedl, R., Neumann, D. *"Technologie des Offsetdrucks", VEB Fachbuchverlag, 1989*

Schläpfer, K. *"Farbmetrik in der Reproduktionstechnik und im Mehrfarbendruck", UGRA St. Gallen 1993*

Neugebauer, H. E. J. *"Zur Theorie des Mehrfarbendrucks", Zentralantiquariat der DDR Leipzig 1989*

Heidelberger Druckmaschinen AG/ Gretag AG, *European Patent 0 324 718, 1987*

3

Protection through printing

Some properties of thermochromic inks

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Abstract

In the area of security for paper applications or of a use as visual information agents, thermochromic inks were developed since the seventies. These inks are also utilized for more special purposes in the packaging industry.

Thermochromic inks are characterized by their specific ability to undergo either reversible or irreversible color changes with temperature. This effect is due to an interaction between encapsulated liquid crystals and other organic or inorganic components. The capsules are utilized either in water based or solvent based inks according to various printing processes (screen printing, gravure, flexography, lithographic offset, ...).

The color change occurs at a given temperature (called "activation temperature") which may vary with the nature and quantity of the interacting materials. This temperature depends on the energy which has to be supplied to the molecules to promote their internal structure reorga-nization. A reversible color change corresponds to molecules which are able to come back to their original configuration.

Our paper presents some results about the reversibility and the precision of the color changes of several inks. The beginning of the color change does not occur at the same temperature depending on whether it is lowered or increased. Thus, we highlighted a hysteretic phenomenon. The kinetic of this behavior was studied by both densitometric and spectro-photometric measurements. The results were expressed by either trichromatic values or hue angles variations.

1. Introduction: the market of thermochromic inks

The colour-change technologies exist in a great variety of forms. They were at first introduced by the Japanese who used them by encapsulated dyes in the seventies for "mood rings"; then, stress testers were produced during the eighties. At the beginning of the nineties, a series of flexographic inks were developed to give access to higher production speeds. Nowadays, offset inks are also available and widen the opportunities for new market applications such as business security. The two major groups of colour-changing inks are thermochromic, which change their colour in response to temperature fluctuations, and photochromic, which respond to variations in exposure to UV light.

Both materials are often reversible and will change colours over and over again with the appropriate exposure. Other emerging colour-changing technologies include hydrochromics, which change in response to water, and piezochromics, which change colour in response to pressure. Depending on the application, colour-changing inks can be applied with a number of printing processes, including offset lithography, flexography, gravure, and screen printing. These are highly specialised inks that combine standard ink components with one of several colour-changing agents. Since these inks are used on a wide variety of screen-printing substrates, it follows that they are offered in the typical solvent-based, water-based, plastisol and UV formulations.

According to industrial suppliers, annual sales of thermochromic and photochromic inks reach a level around 10 million US dollars. Considering the overall size of the printing ink industry itself, this represents a very small portion of sales. These inks are truly a "niche market". Thermochromic inks have increasing new end uses such as packaging graphics and security measures; their average annual growth rate during the period 1998-2003 is 15%.

This study is the result of an agreement between an industrial partner and our Institute. Due to the requirement of our partner, Oxadis S.A. (a company of the agricultural packaging sector), we limited ourselves to thermochromic inks, as they are easily applied in technologies available today.

2. Classification of thermochromic inks

There are two kinds of thermochromic inks: liquid crystal and leucodye (or chemical) inks. A liquid crystal based thermochromic ink is sensitive to small changes in temperature, but is fairly difficult to manufacture. This makes it suitable for use in items like thermometers where you need the sensitivity, but troublesome in an item that needs to be inexpensive and in which a large, abrupt change in temperature will occur. One another hand, leucodyes are specially formulated substances that change from a specific colour, like blue or red, to a clear state when subjected to a temperature change of about 3°C or more.

Thermochromic inks can be formulated to change colour at specific temperatures. Such inks typically comprise an electron-donating chromogenic substance, an electron-accepting substance, and a solvent which undergo a reversible colour change in response to a change in the ambient temperature, for example, from ambient to freezing or from ambient to elevated temperatures. The colour change which takes place may be a change from one colour to another, from coloured to colourless, or from colourless to coloured.

The most famous thermochromic application, i.e. the "mood-ring", was based on a liquid crystal ink. Today, liquid crystals are used in many products, including aquarium thermometers, stress testers, and forehead thermometers. Unfortunately, liquid crystal thermochromic materials are very difficult to work with and require highly specialised printing and handling techniques.

Because of these processing difficulties, we have mainly oriented our investigations to the other kind of thermochromic inks, the leucodye (chemical) class. Leucodye thermochromic inks are used in a wide range of applications because they add value in unique ways. Some of the applications include security printing, novelty stickers, product labels, advertising specialities, and textiles.

In its cool state, a leucodye exhibits colour, and when warmed, it turns clear or even translucent. According to the suppliers, it takes a 3 to 6°C shift to bring about a change in colour, making leucodyes suitable for novelty items and general-purpose products not requiring distinct temperature determinations. This is the reason why liquid crystal thermochromic substances, rather than leucodyes, are used in the production of thermometers.

Some products printed with chemical thermochromic inks change from one colour to another, rather than transitioning from coloured to clear. This is achieved with an ink that combines a leucodye with a permanent-coloured ink formulation. For example, the ink manufacturer may formulate a green ink by adding a blue leucodye to a yellow ink. In its cool state, the printed ink layer is green, and once warmed, reverts to yellow as the leucodye becomes clear or translucent. Leucodyes can be designed to change colour at various temperature ranges, from as low as -25°C up to 65°C. A wide range of colours are also available.

3. Further considerations

Accordingly, there is still a need in the art for a thermochromic ink which may be printed on a document as well as a need for providing good toner adhesion to products subsequently printed by non-impact printers onto areas previously printed with the thermochromic ink.

The ink composition includes a thermochromic aqueous slurry and an ink vehicle comprising either a phenolic modified and a compatible oil, a styrene maleic anhydride resin and a glycol, or an acrylic resin varnish. The ink composition is printed on at least a portion of a substrate using letterpress printing methods and provides enhanced adhesion to toner when applied to areas of a substrate which are subsequently printed with a non-impact printing device such as a laser printer.

Some solvents destroy the leucodyes; therefore, any aldehydes, ketones, and diols, and most aromatic compounds should be removed from the formulation and if needed they should be replaced with solvents preferably having a large molecular weight (i.e. greater than 100) and a low reactivity. Secondly, the formulation should be adjusted to be neutral (i.e. 6.5-7.5 pH) or to have a low acid value. These two adjustments will allow the thermochromic dye to be added to the formulation without a loss of its colour change properties.

4. Experiments

Six chemical thermochromic inks (from three French suppliers) and one liquid crystal ink (from a British supplier named Thermographic Measurements Company Ltd, i.e. T.M.C.) were used in our experiments; they are listed in Table I.

Table I: Suppliers and colours of the tested inks

Ink	Supplier	Colour	
		Low temperature	High temperature
a	SCIPA	Red	White
b	SCIPA	Turquise	White
c	PETREL	Blue	White
d	PETREL	Green	White
e	DUBUIT	Turquise	White
f	DUBUIT	Red	White
g	TMC	Greenish black	Bluish black

It is worth to add that the TMC ink needed a black background to be used in normal conditions: this explains the reported colours of Table I. All these inks were put onto four kinds of substrates:

- Polyvinyl chloride (PVC)
- Polypropylene (PP)
- Polystyrene (PS)
- Polyethylene (PE)

As all these inks were adapted for screen printing, it was almost impossible to use the IGT F1 or C5 test devices to control the quantity of printed liquid. Thus, we were led to make all the deposits by means of a Meyer bar. In order to fulfil the supplier's requirements, we used a 24 micrometers bar for the chemical inks and a 32 micrometers bar for the liquid crystal ink. Such figures correspond to a relatively high value of the ink thickness and it was rapidly found that the colour of the non-printed substrate had almost no influence on the data collected from the ink layers.

We were asked by our industrial partner to investigate the behaviour of our inks under temperature increase or decrease by both densitometric and colorimetric measurements. The samples were either removed from a refrigerator or put into it; the inside temperature was controlled within a precision of ±1°Celsius. The kinetics of the colour variations were followed as precisely as possible. It was also necessary to determine the colour of the samples for a series of given (and stable) temperatures. The measuring devices were:

- a Techkon densitometer and
- a X-Rite spectrocolorimeter

which were installed in situ in the refrigerator. The densitometric results were expressed after the device was set to zero on the unprinted substrate. It was recognised that the four substrate under consideration had not the same colours, but the differences were low enough (less than 0.02 density units) to be neglected when densitometric data were handled. On the contrary, colorimetric results were expressed by L*a*b* coordinates under a D65 illuminant.

Temperatures were measured by two methods:

- a thermoelectric sensor which was positioned in the vicinity of the tested samples; this method was reliable when the refrigerator temperature was stabilised,
- an infra-red device which provided a direct non-contact measurement of the temperature of the samples (in the non printed areas); this method was more useful in the case of kinetic measurements (response of the tested sample to a temperature step).

In a preliminary series of tests, it was verified that the two methods gave quite similar results in almost all the cases (for non printed surfaces).

Apart from these basic measurements, it was also interesting to test the adhesion of the ink coatings to the various substrates by abrasion tests which were made as a preliminary to all the experiments.

5. Results

5.1 Considerations about the printed substrates

As already explained, the chemical nature of the substrates had a negligible influence on the densitometric data, due to the thickness of the ink layer. On another hand, it was important to test the lifetime of the prints. The results were in accordance with the specifications of the suppliers: the colour stability of our ink layers did not exceed six to ten months, a period after which a fading tendency (i.e. a decrease of the colour saturation) is observed.

It was also shown that almost all the tested inks were characterised by a rather low adhesion on the series of polymeric substrates listed in paragraph 4. This tendency was more obvious in the case of PE: it was possible to remove the ink layer even by a nail. Consequently, this last polymer was eliminated from long term applications. A solution to this adhesion problem consists in using a primer coating between the substrate and the printed ink. On the practical point of view, we mainly used PVC during our colour evolution tests.

5.2 Effect of the temperature on the colour of chemical inks

The most important part of the experiments consisted in the determination of the colour variations of our inks under the effect of temperature. In a first series of tests, the temperature of the refrigerator

was set to a given value. After the stabilisation was obtained, the optical densities of our prints were directly measured for each chemical ink in the case of PVC samples. The most interesting (and rather surprising) phenomenon was the hysteretic behaviour of the inks: the colour was not the same whether the successive values of the temperature were set by increasing or decreasing order. Such a behaviour was systematically observed for all the tested inks. As shown in Figure 1, which presents the typical case of the ink f (see Table I), the hysteresis may be very important. Another observation is to be reported about the shape of the hysteretic cycle: it may be almost symmetric like in Figure 1. This property was shown by inks b, f and d (to a minor amount in the last case).

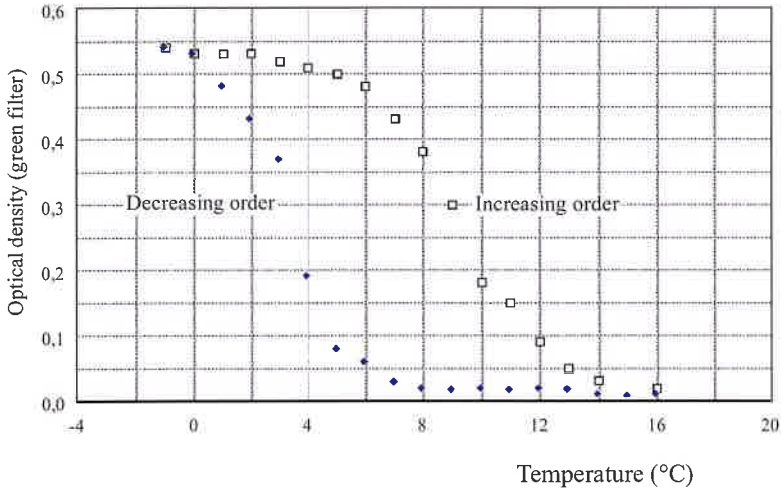

Figure 1: Hysteresic behaviour of the ink F on PVC

To be able to describe the shape of the cycle, we suggest to rebuild it by the consideration of Figure 2, where the positions of some specific points A, B, C, D, E and F are shown. In Figure 2, the slopes of the tangent lines at points B and C were arbitrarily chosen as 10% the maximum slope of the tangent line at point F, and the same criterion was applied to find out the positions of points A and D relatively to point E. It is worth to notice that the maximum slopes at points E and F are unequal in most cases. Table II shows the subsequent results.

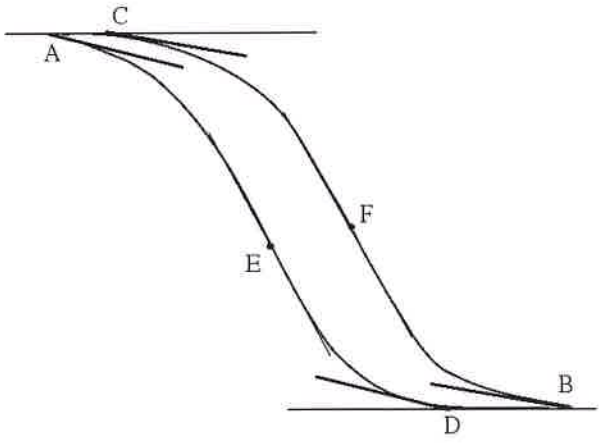

Figure 2: Schematic representation of a hysteresis cycle

We investigated the effect of the polymeric substrate on the densitometric behaviour of our six inks. A typical result of our measurements is shown in Figure 3, corresponding to the ink a submitted to a series of temperature in increasing order. It can be seen that the printed polymer has only a little influence on the colour change of the chemical ink.

Table II: Characterisation of the hysteresis cycles

Temp. (°C)	Ink :	a	b	c	d	e	f
Point	A	1	0	-1	-1	3	0
	B	17	13	13	8	16	15
	C	10	4	1	1	11	4
	D	14	8	12	5	13	8

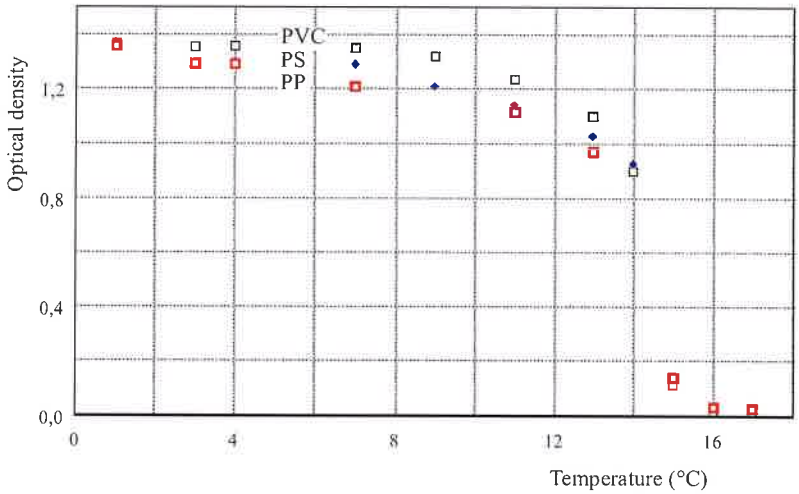

Figure 3: Influence of the substrate on the colour change of ink a

5.3 Effect of the temperature on the colour of liquid crystal inks

As previously said (paragraph 4), our liquid crystal thermochromic ink required the presence of a black background to be reliably used. A preliminary visual observation of printed patches involving ink g (Table I) allowed us to notice that this ink exhibits at least two hue changes as the temperature is varied. Due to the systematically high values of the optical densities, the corresponding data were difficult to handle; thus, we decided to consider the colorimetric values, which turned out to be more relevant by temperature variations. Table III gathers the collected data (h is the hue angle).

Table III: Colorimetric coordinates of ink g

Temperature (°C)	Increasing order				Decreasing order			
	L*	a*	b*	h(°)	L*	a*	b*	h(°)
2	17.2	-4.0	3.3	220		-		
5	18.5	-4.9	2.8	210		-		
7	20.2	-5.5	2.6	205	25.0	-8.2	2.7	198
9		-			30.5	-28.1	5.4	191
10	32.0	-20.2	7.0	199	27.0	-23.4	1.6	184
11	33.3	-27.2	5.2	191	28.8	-25.0	0.0	180
12	30.3	-23.1	1.9	185	26.7	-19.7	-2.2	186
13	26.0	-19.4	0.2	181	23.9	-14.9	-5.5	200
15	23.8	-8.8	-8.7	224		-		
16		-			24.0	-8.8	-14.1	238

Table III shows that the lightness L* goes to a maximum value which may be situated around 11°C; in turn this temperature corresponds to the minimum value of redness a*. In addition, Figure 4 shows that the hue angle h varies in an almost monotonous way. Let us also notice the offset of the data by

comparing the increase of temperature to its decrease; this phenomenon is to bring closer to the hysteresis which was highlighted for the chemical inks (paragraph 5.2.). Nevertheless, it may be concluded that the sensitivity of the ink g is found in the range [9°C, 13°C], which is in qualitative agreement with the data provided by the supplier.

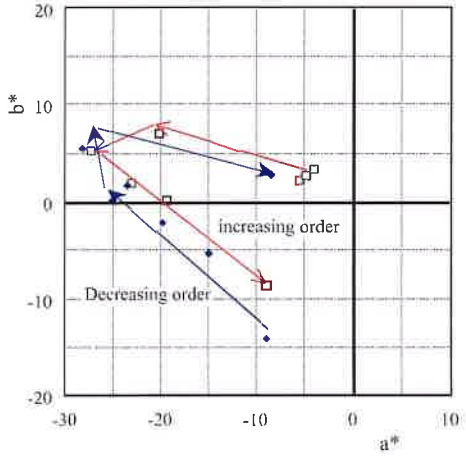

Figure 4: Hue variations of ink g

5.4 Some data about the colour variation kinetic of the printed samples

It was very easy to evaluate the variation speed of the colours of the chemical inks by visual observations. All the inks were submitted to a temperature step from a value less than the temperature at point A to a value higher than the temperature at point B (or the reverse order). We chose to start from -5°C and bring the samples to the room temperature (around 25°C). In every case, it was found that all the samples became colourless in less than 10 seconds.

In order the have a better idea of the phenomenon (i.e. to get quantitative data), we stored a series of similar samples (the same ink printed on the same substrate) in the refrigerator. They were separately brought out of it and optical density measurements were done at various moments ranging from 2 to 10 seconds (with an estimated precision around one second). In the cases were the number of reliable data was sufficient, they turned out to be compatible with an exponential behaviour (see Figure 5).

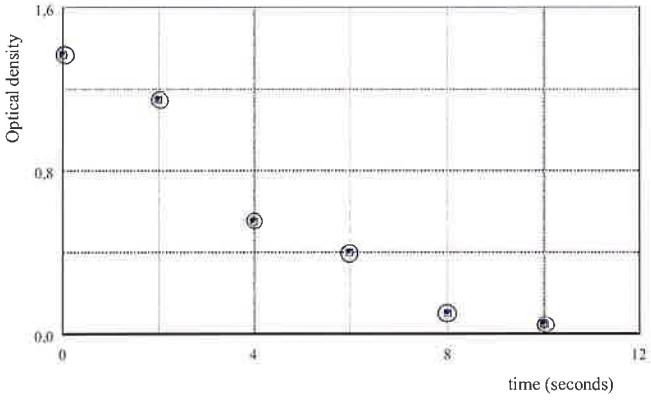

Figure 5: Density variations of ink a

The precision of the density data is around ±0.05 unit. On another hand, the same tests were almost impossible with the ink g (liquid crystal) due to the wide dispersion of the densitometric values.

6. Conclusion

The hysteresis highlighted in paragraph 5.2. shows that the behaviour of the molecules of the temperature sensitive material of the chemical inks is not so simple as expected: many suppliers maintain an "activation temperature" exist for any chemical ink. Our new results may be differently interpreted: to the state of our data, there is a temperature range within which the inks exhibit colour variations. These variations are different whether the temperature is increased or decreased. It would be interesting to verify if the temperature values corresponding to points C and D are as different as it seems from our data. The situation is more clear with the liquid crystal ink we studied. The existence of the black background makes its use as a temperature sensor uneasy, except if no precision is required. At first glance, it seems that the chemical inks reacts rather rapidly to temperature steps, but this feature has also to be clarified. The effect of the printed substrate (a polymeric material with low thermal characteristics) is surely not negligible. Thus, our coarse results are not sufficient to precise the kinetic of the chemical mechanism which promotes the colour change.

To summarise, our main result is the discovery of the hysteresis of chemical thermochromic inks; it is very likely that this phenomenon be the rule, even if its importance may widely vary according to the nature of the leucodye. On another hand, a lot of experiments remain to do in order to describe more precisely the behaviour of these inks, specially in the kinetic field. Such further investigations are necessary in the view of industrial applications of these materials.

Acknowledgements

The authors are pleased to thank Nadia Leghmizi for her valuable participation in the experiments. The financial support of our industrial partner (Oxadis S.A.) is also warmly acknowledged.

Metamery fading during three color reproduction

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Abstract

Four pairs of metamery colors were scanned and printed on two different ink jet printers. Considerable decrease or disappearance of metameric characteristics was found on the copies. It was pointed out the possibility of using the pairs of metameric colors in printing production of valuables because their forgeries do not show metamery effect.

1. Introduction

In 3-color reproduction spectral characteristics of colors are used in a very rough division in three ranges. Metamery is a very subtle relation between two colors, and it can be supposed that it will be disrupted, changed or it will completely disappear during the reproduction process. Metamery index which can be determined in various ways (Schläpfer K., 1993), (Wyszecki G., Stiles W.S., 1982), as well as according to the prescribed norms (DIN 6172, 1993) does not describe this phenomenon in details. Somewhat longer and more complicated process, which describes metamery in more details and more exactly, giving it three parameters, which will be here only shortly presented, is given in (D.Agic, D.Broz, 2000).

- Since the difference between two colors depend on the color temperature of the light source, it is most acceptable to use as the first parameter that color temperature for which the chromaticy difference in color is the smalest (the balancing color temperature T*m*) It is not necessary to know T*m* exactly, but to mark the interval of color temperature which contains it (interval of balancing temperature T*m*).

- The second parameter is the color difference for the balancing color temperature, calculated in the usual way (ΔE_m).

- The third parameter should describe the how "quickly" the cromaticity changes with color temperature in some chosen temperature interval which contains T*m,* and which can be indicated by $\Delta c/\Delta T_m$, with perhaps some more indices that describe it in more detail.

The coordinates u' and v' for temperatures of 2000 K to 10000 K for a pair of metametric colors are calculated after the measurement on spectral photometer. The coordinate difference $\Delta u'$ and $\Delta v'$ and belonging color temperatures are given in the diagram with $\Delta u'$ and $\Delta v'$ as the coordinate axes (Figure 1).

The obtained dependence, which can be conditionally called metamery function and marked by m(Tb), enables the determination of three parameters.

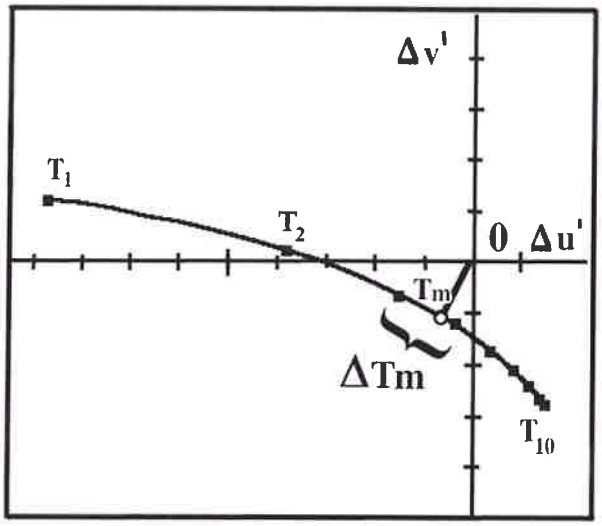


Figure 1: Metamery function

2. Experimental and results

Four pairs of metameric colors were tested and marked by R, G, B, N. Spectral reflectancy was determined with Datacolor spectrophotometer, and the results were given in figures 2, 3, 4, 5 in R, G, B and N diagrams. These samples were scanned on Hell 399er scanner under same conditions. The copies were made on two printers (Epson Stylus and Tectronic Phaser 140), which were measured again on spectral photometer.

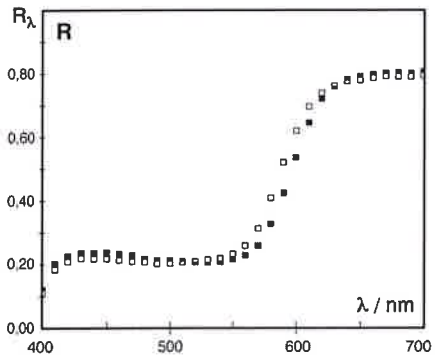
Their spectral reflectancies were given in figures 2, 3, 4, 5 in the diagrams RP, GP, BP and NP (copies on Phaser) and RE, GE, BE and NE (copies on Epson). For all these color pairs (original samples and their copies) according to the above mentioned process, the function m(Tb) for color temperature from 2 kK to 10 kK were determined and given in figures 2, 3, 4 and 5 in the diagrams RM, GM, BM and NM.

3. Conclusions

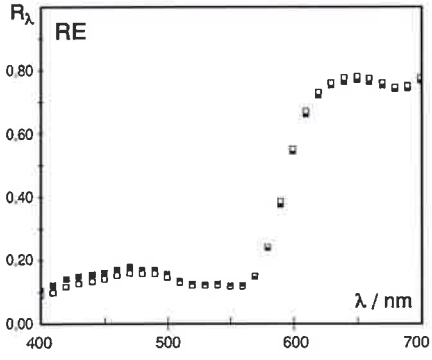
Metamery is an unpredictable phenomena, that could occur in various ways in reproduction. Metamery color characteristics are considerably disturbed during reproduction or they disappear completely. It can be supposed that among the commercial colours one could find such combinations whose metamery disappears during reproduction. This fact can be successfully used for printing valuables because from the original produced with such pairs of metamery colors one could not get "good" colors.

By visual observation of such copies illuminated with the incandescent lamp, and then with daylight (or the adequate fluorescent lamp), the color change characteristic for metamery colors clearly visible in originals, could not be seen.

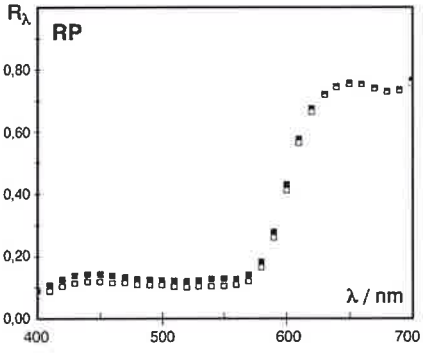
Metamery determinations as an alternative method could be included into already existing various series of processes for detecting forgeries, for which it would not be necessary to possess special sophisticated equipment.



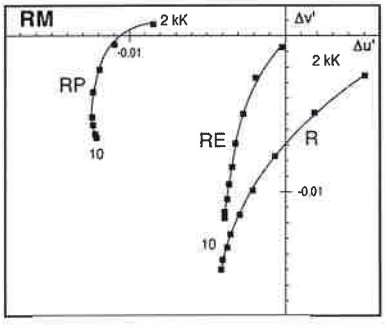
Spectral reflectancy of pair R



Spectral reflectancy of copies on Epson

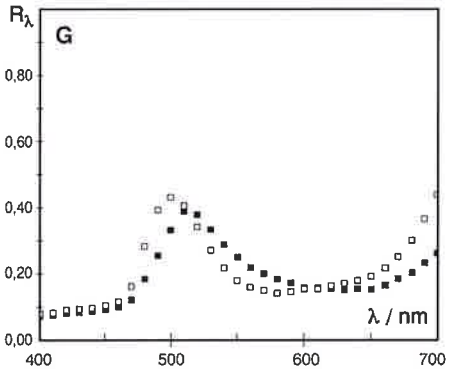


Spectral reflectancy of copies on Phaser

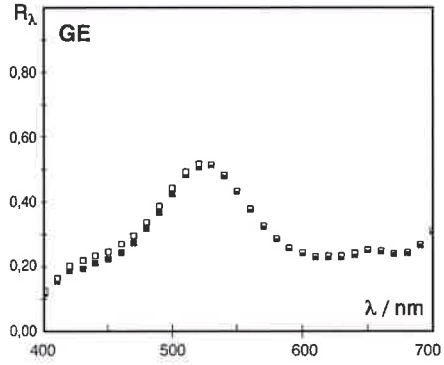


Metamery functions

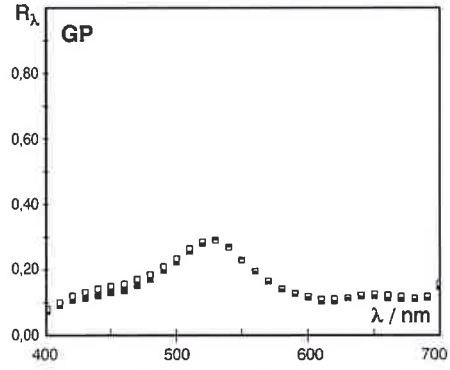
Fig. 2: Spectral reflectancies of pair R and copies



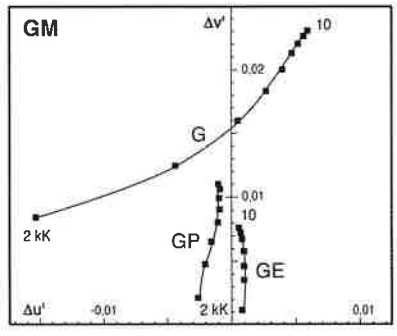
Spectral reflectancy of pair G



Spectral reflectancy of pair G

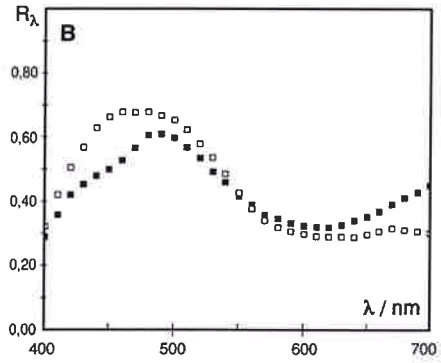


Spectral reflectancy of copies on Phaser

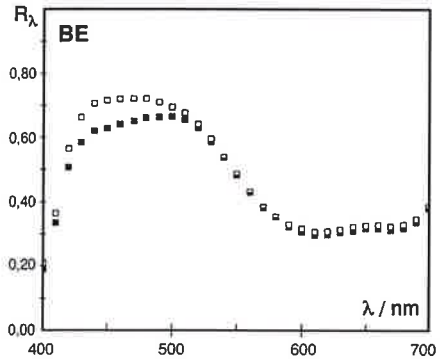


Metamery function

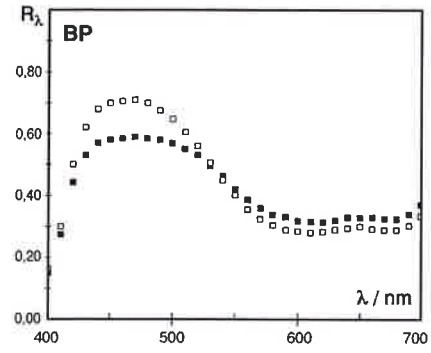
Fig. 3: Spectral reflectancies of pair G and copies



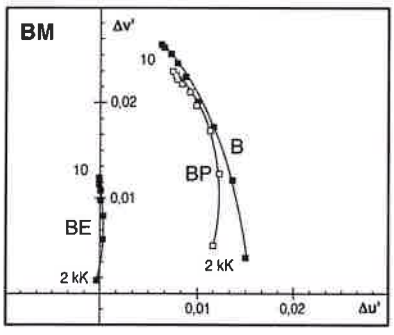
Spectral reflectancy of pair B



Spectral reflectancy of copies on Epson

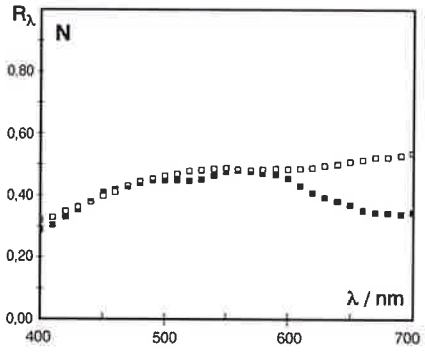


Spectral reflectancy of copies on Phaser

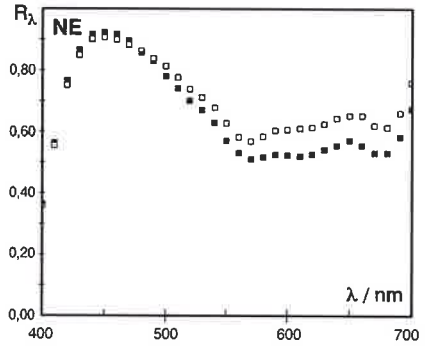


Metamery functions

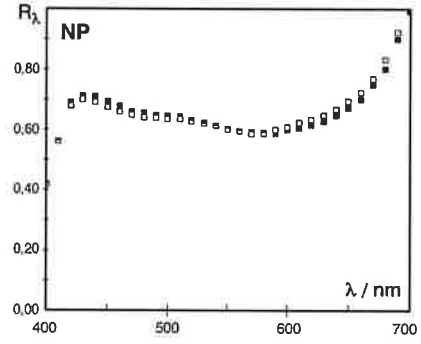
Fig 4: Spectral reflectancies of pair B and copies



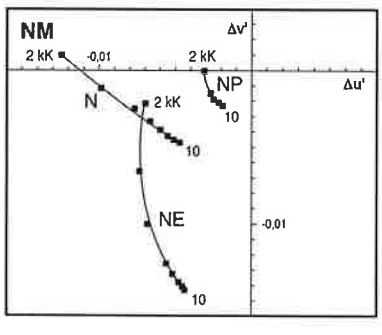
Spectral reflectancy of pair N



Spectral reflectancy of copies on Epson



Spectral reflectancy of copies on Phaser



Metamery functions

Fig. 5: Spectral reflectancies of pair N and copies

Table I: Result review according to diagrams RM, GM, BM and NM

RM	GM	BM	NM
R ΔTm = 2 kK - 3 kK ΔE = 0,034 Δc/1 kK = 0.0043	G ΔTm = 2 kK - 3 kK ΔE = 0,024 Δc/1 kK = 0.0117	B ΔTm = 2 kK - 3 kK ΔE = 0,020 Δc/1 kK = 0.0082	N ΔTm = 9 kK - 10 kK ΔE = 0,011 Δc/1 kK = 0.0002
RP Function m(Tb) has the form which is not characteristic for metamery colors. Metamery parameters cannot be determined.	GP For Tm = 2 kK is Δc/1 kK = 0.003. Chromaticity difference changes slowly with the Tb increase. For the change of 2-10 kK it is about 0.001 which is smaller than for the sample G for the change of 2-3 kK. Metamery parameters cannot be determined.	BP Metamery functions for BP follow the function for B well in one part, but not enough well to be able to determine metamery parameters.	NP The domain of metamery function is negligibly small. Metamery parameters cannot be determined.
RE Metamery function does not completely correspond to characteristics of the function for metamery colors, but the parameters still can be determined Tm = 2 kK ΔE = 0,004 Δc/1 kK = 0.0023 Metameric characteristics are weaker expressed than with the sample R but the color difference in 2 kK is much smaller.	GE Characteristics are worse than in GP	BE For Tb = 2 kK the chromaticity difference is insignificant (Δc< 0.002) but the metamery function inconsiderably changes with the increase of color temperature. For 2 - 10 kK about 0,01.	NE Metamery function has a form which is not characteristic for metamery colors, although the chromaticy changes at temperature of 2 - 10 kK are significant. Metamery parameters cannot be determined.

References

Agic D., Broz D., IARIGAI (2000), *Advances in Printing Science and Technology, Volume 26, 219-226*

Metameric Index von Probenpaaren bei Lichtartwechsel, DIN 6172, (1993), Beuth Verlag GmbH, 1000 Berlin 30

Schläpfer K., (1993), *Farbmetrik in der Reproduktionstechnik und in Mehrfarbendruck, Ugra-Empa CH 9001. St. Gallen*

Wyszecki G., Stiles W.S., (1982), *Color Science 2nd edition, John Wiley and Sons, New York*

New screening elements in multi-colour printing for special purposes

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Abstract

This investigation determines new procedures of screening applied to multi-colour reproduction. Total individualisation of the image is obtained by introducing the new different screening system for each separation. This process is extended to the microstructure of the individual screening shapes, which was not described until now. Understanding of such procedures is closely linked to security printing, and therefore details are poor and not accessible. Solving of such problems involves team-work in various fields of research: design, prepress, materials in graphic processes, mathematical definition of screen systems and shapes, as well as protection methods for valuables. Proposed methods are performed by PostScript programming of output devices, optical measurements and experimental digital printing, using special, as well as conventional inks.

1. Introduction

The first presentation on specially designed screen patterns [#1] (Iarigai 1999) with new applications of screen elements emphasized the topic of security printing and document application. Stohastic selection of screen patterns was suggested as well as stohastic attribution of lpi and angle for each pixel. The second article [(#2)] (Iarigai 2001) exposed four-colored application with individualized screening. It offered program-solutions as a combination of stohastic selection of screen parameters with a fixed screening element. While the first and the second report applied pixel graphic, and deconstructed image using a stohastic selection of lpi and a screen element type, this article discusses screening of vector graphics for printing with new screening patterns.

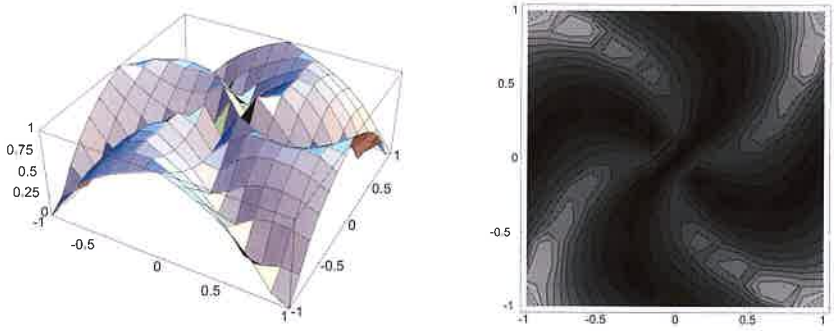
This article provides solutions for programming and application of new screening elements requested by digital printing techniques. It offers an original code for PostScript programming. Our applications fall under the area of complex integration of pixel and vector graphics: design for jumbo posters, documents and securities, as well as textile design. These applications do not involve only an image but also a structure of graphic interpretation creating the image. Portions of a graphic solution have been generated by PostScript algorithms.

2. Print

Surface objects of vector graphics are usually created as 100% spot colors. Designers emphasize use of spot colors hoping that each section of such a solution will result in print as a separate color. However, majority of their *spot ideas* result in four-colored CMYK screens.

Screening is necessary in case of designing of gradations and in majority of cases a standard AM or FM screening is applied. Since dotted image interpretation is considered as boring we have to minimize a screening element - "it is better when it is hidden". Tonal gradations in vector graphics should be screened and not printed with full tone. It would cause problems with color register and trapping. If a continued tone is dealt with a screen, a screening element should change its shape, whatever its size. It means that if a screen element is a crucifix it should be deformed in continuity

depending on planned bolding within a defined microstructure. An example is presented of a continued transformation of a screen element *propeller r14* as a print-out of liniature two screening elements per inch compared when the object is interpreted with continued changes (Figure 1), and when the object is bolded uniformly by 70% (Figure 2) and 15 % (Figure 3). Each example is associated with the original PostScript code (program 1, 2, and 3).




```
/r14 {dup 2 index 3 exp sub abs sqrt 3 1 roll 3 exp add abs sqrt exch sub abs 1 exch sub} bind
def
```

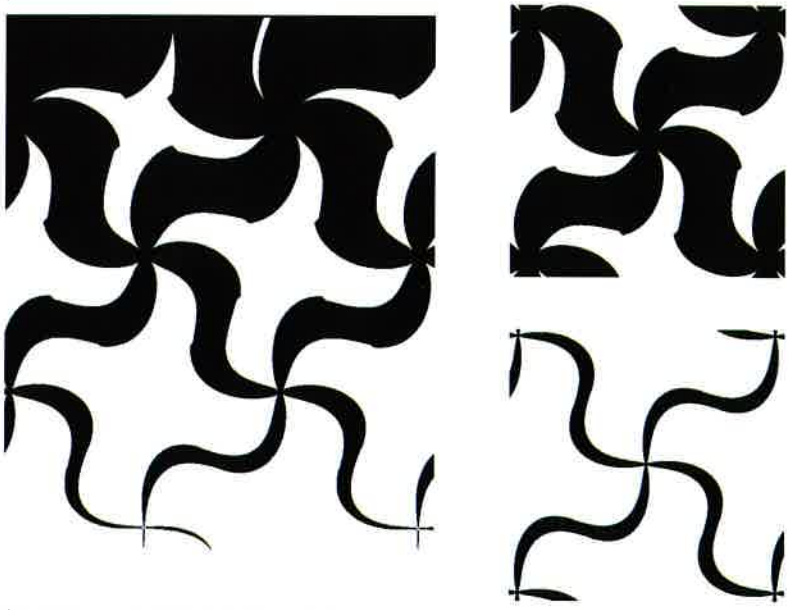


Figure 1 Propeller R14

```
L K {r14}bind setscreen 0 1 250 div 1
{/g exch def g setgray 0 0 moveto
160 0 rlineto stroke 0 -0.8 translate
}bind for
```

Figure 2

```
1 45 {r14} bind setscreen
0.3 setgray 0 0 moveto 150
0 rlineto 0 -150 rlineto -
150 0 rlineto closepath
fill
```

Figure 3

```
1 45 {r14} bind setscreen
0.85 setgray 0 0 moveto 150
0 rlineto 0 -150 rlineto -
150 0 rlineto closepath
fill
```

In cases where a solution calls for lines only (special interest lies with protective lines for documents), at present practice reaches for drawing and copying using vector graphics. Such a protection is not adequate since these programs are readily available. This article suggests a solution for line graphics by screening along an object placed under it. In case of selecting a screening element with a pattern of a twisting line, it is recommended to program a base as a continued full gradient shading. It is necessary to have an algorithm for designing that screening element. Screening the segment of an image with a low lpi will result in line base that cannot be interpreted with programs for vector graphics.

The next step in application is the use of two or more colors with various patterns of screening elements. Each color requests a separate procedure. Low lineatures will create a special impression. Such a three-colored solution has been applied to the Croatian currency *Kuna* and improved this year

with a new edition. One color reacts under ultraviolet light and another is visible in the infra-red range of the spectrum. At present we are planning solutions for each specialized application with a spot vector screening but the screening will be used only once.

This article presents seven unpublished images of screening elements and the reader may modify shapes of screening elements using the original code. These screening elements may be also used in vector and pixel graphic for printing. They can also be used for graphic solutions resulting from the PostScript program itself as presented on our Web pages [#3].

3. Programmable graphics

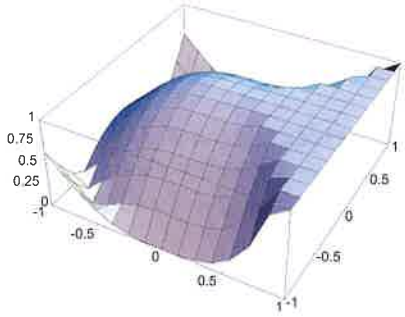
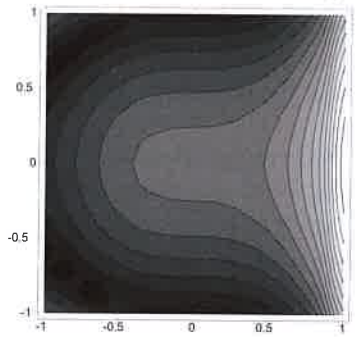
Microstructure of specialized graphic solution can be also created with copying tiny vector elements of an image. Such an file is huge so the question is whether we have a computer that can follow up within a reasonable timeframe how a designer develops an idea. On the other hand, programmed shape of a screening element does not burden computer's memory and speed. The screening is carried out through an act of display or a print-out. Shapes of these tiny elements are not stored in the memory. There are no Bezier points that overflow the vector graphics. There is only an algorithm on the manner of processing, showing how a drawing has been created for a display i.e. for printing. Preference is for programmable graphics that has not been recorded as vectors or pixels. In the same document a designer may use numerous screening elements, planned or visualized on the monitor or a printer. Programmable graphics may create both pixel and vector graphics. As noted earlier programmable graphics has been generated during display. This article contains PostScript algorithms with maximum reduction, simplified for screening vector graphics with new screening elements. Deliberately we have created a very clean algorithm without a PostScript indirect adressing in order to encourage further research by other graphic artists especially younger ones. More detailed contemplation of the algorithm structure should lead to the creation of a large library of screen patterns and enrich a tendency towards personalization in the printing industry.

Programmable graphics is generated graphics, generated design, created by algorithms, mathematical procedures and parameter tricks. Although this article does not cross into the area of fractals let us mention that programmable fractals present the most interesting area of developing personal approach to design and digital press. The application of fractal principles will enrich the microstructure of a screening cell. It will result in new proposals for development of FM screening especially in the application of printing with ten different colors.

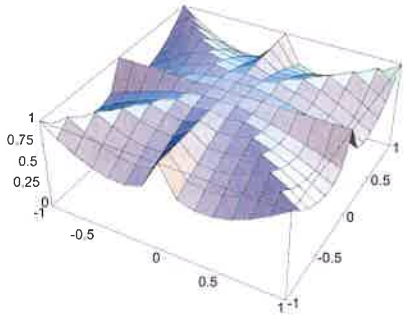
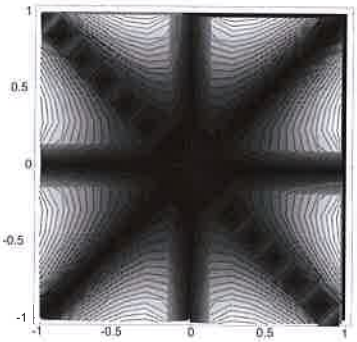
4. Experimental tests

A three-dimensional, two-dimensional pattern and an active screen may be depicted and named freely. All proposed screens have been shown as bolded continually (zero to 1, loop from 0 to 250, step 0.004). Example (b) shows an application with the same screen or in a combination with another one. Screen names are: /r2, /r3, /r4, /r5, /r12, /r14 and /r16.

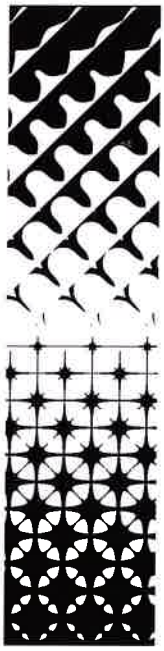
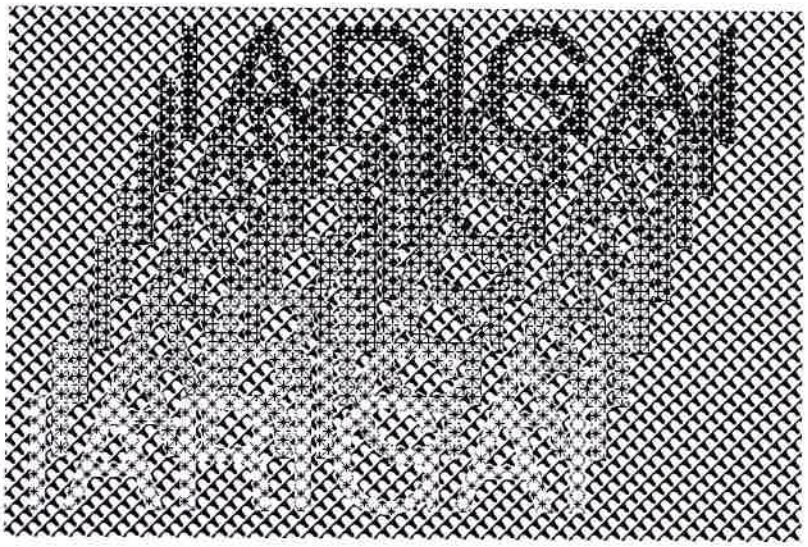
/r2 *Dropping Eiffel*: filling a screen up changes a shape from the imitation of a letter Y, a drop, houses and roofs.
/r3 *Cut Glass*: a crucifix linked to a dot shades into a closed window
/r4 *Wheat Ear* : a light linear structure is complemented by an ear, it shades into six horns
/r5 *Hanger*: columns with a triangle suspended to a horn-shaped column
/r12 *Coffee*: linked dots progress towards a coffee bean and a cat's eye
/r14 *Propeller*: propeller-shaped dots ranging from light to dark shade over from a white to a black propeller
/r16 *Bat:* a dotted ornament shades into a crown and a bat

```
/r2 {dup mul exch 3 exp 2.71828 exch exp exch sub 2 div abs 1 exch sub} bind def
```

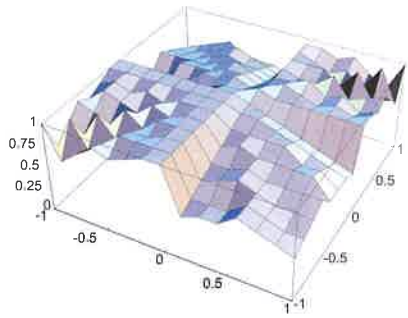



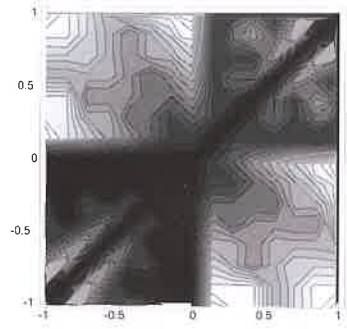
```
/r3 {dup 2 index dup dup mul mul mul abs sqrt 3 1 roll dup dup mul mul mul abs sqrt exch sub
    abs 1 exch sub} bind def
```

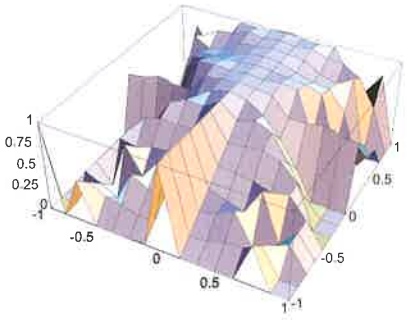
/r2 Dropping Eiffel
/r3 Cut Glass

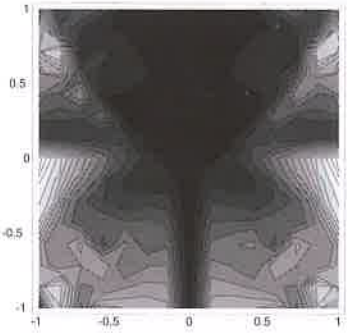
```
gsave
0.6 setgray 100 300 translate 0 0 moveto 300 0 rlineto
0 200 rlineto -300 0 rlineto closepath
15 45 {r2} bind setscreen fill
grestore
gsave 160 450  translate /FSHelvetica findfont 60 scalefont setfont
/g 0.2  def 8  {0 0 moveto (IARIGAI) false charpath g setgray
15 45  {r3} bind setscreen fill /g  g 0.09 add def -8 -20 translate} repeat
grestore showpage
```





```
/r4 {dup 2 index dup 2 index exch div floor mul sub 3 1 roll dup 2 index exch div floor mul
    sub sub 2 div abs 1 exch sub} bind def
```

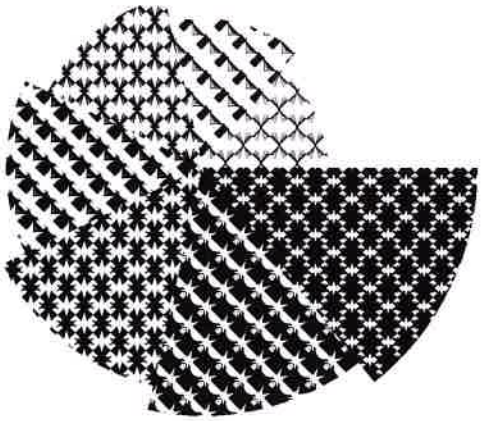


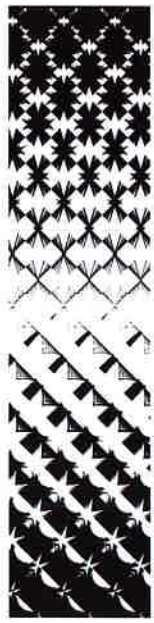


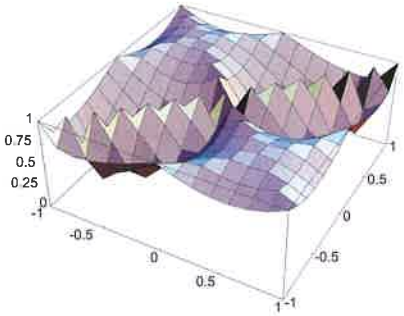
```
/r5 {exch dup mul dup 2 index dup 2 index exch div floor mul sub 2 mul 3 1 roll dup 2 index
    exch div floor mul sub exch sub 3 div abs 1 exch sub} bind def
```

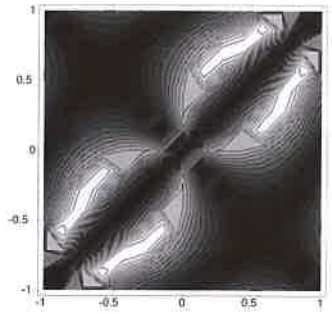
/r4 *Wheat Ear*
/r5 *Hanger*

```
/polje [{r4} {r5} ] def
/L 7 def        %linijatura
/K 45 def       %kut
/polumjer 50 def
/siva 0.9 def
gsave
250 300 translate
/j 0 def
7 {
siva 0.1 sub
/siva exch def
siva setgray
0 0 moveto
0 0 polumjer  0 360 7 div arc
0 0 lineto
50  10 add
/polumjer exch def
closepath  7 45 polje j get bind  setscreen fill
360 7 div rotate
/j j 1 add def
j 1 gt {/j 0 def} if
} repeat
grestore
showpage
```







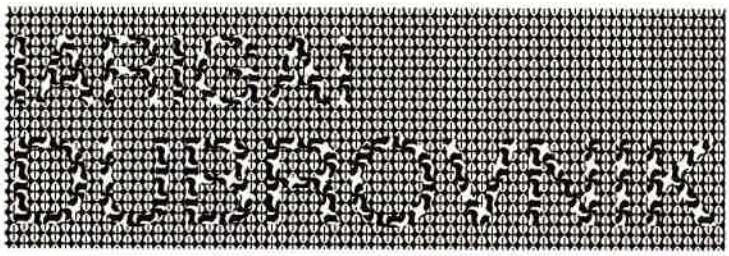


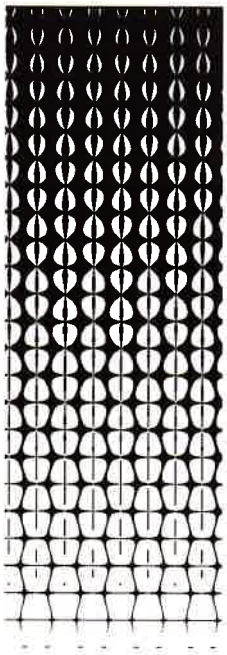

```
/r12 {dup 2 index 3 exp sub abs sqrt 3 1 roll 3 exp sub abs sqrt exch sub abs 1 exch sub} def
```

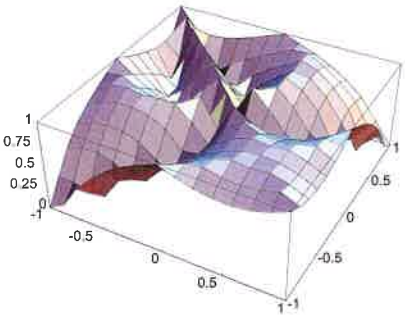
/r12 *Coffee*

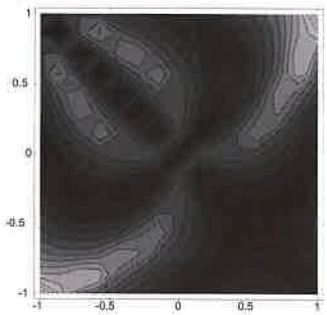
```
gsave
0.5 setgray
100 300 translate
0 0 moveto
300 0 rlineto
0 100 rlineto
-300 0 rlineto
closepath
L1 K1  {r12} bind setscreen
fill
grestore
```

```
gsave
100 310  translate
/FSHelvetica findfont 50 scalefont setfont
0 0 moveto
(DUBROVNIK) false charpath
0.4 setgray
L2 K2  {r14} bind setscreen
fill
/FSHelvetica findfont 40 scalefont setfont
0 50 moveto
(IARIGAI) false charpath
0.4 setgray
L2 K2  {r14} bind setscreen
fill
grestore
```

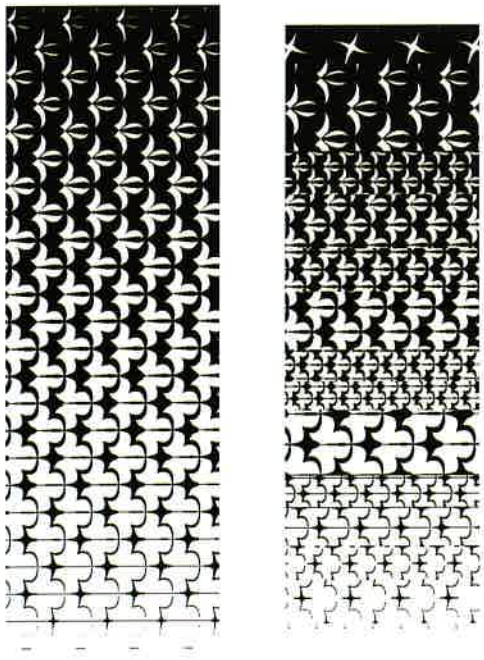









```
/r16 {dup 2 index 3 exp abs sub abs sqrt 3 1 roll 3 exp abs add abs sqrt exch sub abs 1 exch
sub} bind def
```



/r16 *Bat*

```
/L1 12 def
/K1 45 def

/L2 8 def
/K2 45 def

/sp 100 def
/vp 500 def
/brojsiveskale 250 def
/dlinije vp brojsiveskale div def
dlinije setlinewidth
/j 0 def



gsave
0.5 setgray
100 300 translate
0 0 moveto
300 0 rlineto
0 100 rlineto
-300 0 rlineto
closepath
L1 K1  {r12} bind setscreen
fill
grestore

gsave
100 310  translate
/FSHelvetica findfont 50 scalefont setfont
0 0 moveto
(DUBROVNIK) false charpath
0.4 setgray
L2 K2  {r14} bind setscreen
fill
/FSHelvetica findfont 40 scalefont setfont
0 50 moveto
(IARIGAI) false charpath
0.4 setgray
L2 K2  {r14} bind setscreen
fill
grestore
showpage
```

5. Design and personalization

Designers still do not realize that even internal screening structure calls for special even personalized solutions. The use of low liniatures of good visibility could bring sophistication into design. A question is how to create interesting screen structures that are not usually found around us. This article encourages designers to use new ideas in screening their graphic designs. Personalization has rocked the application of graphics, first in relation to security printing of documents and later through its application. Since personalization has proved its efficient application, it led to application at-large and abundant ideas. Personalization has been carried out everywhere, at all times and using all technologies. Our focus lies with the personalization in screening elements. The initial data or a seed for generating an incidental series of numbers that are selected for a screening element may be taken from a data with a personal value e.g. a date of birth or a car license plate. Such thinking will lead us to personalized printing at a level of a screening cell and a solution could be repeated only when possessing both pieces of data: the initial number and the algorithm used for screening.

6. Conclusion

At present a printing product results from a team effort, specialization and quick adaptation to advanced technologies. In the imminent future, designers' projects will become more complex, have more contents thus demanding original solutions that use new materials and colors and diverse

technological procedures. Optimal approach to productivity will be embraced by printing companies and designers prone to flexibility and adaptation to possibilities available to the printing industry at a certain environment. A graphic solution may be elaborated in various manners with minor differences. It is necessary to study all new proposals resulting from digitalization and Internet, to review them and build them into procedures for creating a graphic product. Screening an image, a graphic pattern and colored surface is a special trait of the printing industry. Methodology for display and visual presentation of a screening solution varies for each technology and it is completely different for Web, print, video and other aspects of multimedia. This article discusses new screening elements for print only that refer to personalization, digital printing, original visual solutions and their special application in designing documents. For these areas we have used printing with original screening elements thus opening up new opportunities with the creation of databases of new screenining elements and novel application in printing. This development is aimed towards a stohastic definition of screening types. The article offers original PostScript solutions with a sole purpose of creating interest with graphic artists and designers and providing incentives for their application in solutions for graphic products. We have tried to study the most detailed interpretation of screening printing and clarify all doubts so that the screening methodology could be used efficiently in a novel manner in the printing industry.

Bibliography

#1 Munchen Article + our web page = http://pubwww.srce.hr/%7Eviziljak/VZbiografija/INDEX.HTM

#2 Canada Article + our web page = http://pubwww.srce.hr/%7Eviziljak/VZbiografija/INDEX.HTM

#3 Galleries with Computer Graphics VŽ

#4 Žiljak, V., Pap, K.: "PostScript" Print &Publishing International Verlagsges m. b. H., Wien, 1999, ISBN: 3-9501090-0-5

#5 I. Adobe Systems: "PostScript Language Reference Manual", Addison-Wesley, 1990

#6 Fink, P: "PostScript Screening: Adobe Accurate Screens", Adobe Press, 1992

Communication and brand protection of consumer packages

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Abstract

New functional characteristics can be created to the customer packages in order to create value-added in the package itself by utilising the latest digital printing techniques. This means, for example, that personalised and up-to-date consumer information, announcements and advertisments can be as an integrated part of a package. Also totally new kinds of logistic and anti-counterfeit systems, based on the potentiality of digital printing methods, coding and detection systems, and information networks, can be developed for the optimisation of the delivery chain. Brand protection, safety and features ensuring authenticity are important features of packages. The packages of the future will thus be much more multifunctional, informative and demand-oriented than they are today. This is why companies in the packaging industry are interested in research and product development that is paving the way to the introduction of new business models.

VTT Information Technology has launched a project aimed at the development of a comprehensive system for new kinds of package production chains. The system pays attention to the special needs of consumer packages with regard to product information, identification, anti-counterfeit and appearance. Our project is being carried out under a larger VTT-driven theme, the main purpose of which is to develop and integrate active, communicative packaging with an effective logistics system for sensitive and demanding products. Intelligent coding, RFID and data networks are the technologies applied. In this paper we present different aspects of our packaging research regarding the communication needs of consumer packages and especially the utilization and potential of digital printing.

1. Introduction

Four VTT-wide themes were launched at the beginning of 2002, one of which is Intelligent Products and Systems. The Intelligent Products and Systems theme aims to make synergetic use of new technologies to develop intelligent products and systems which can be applied in future societal and

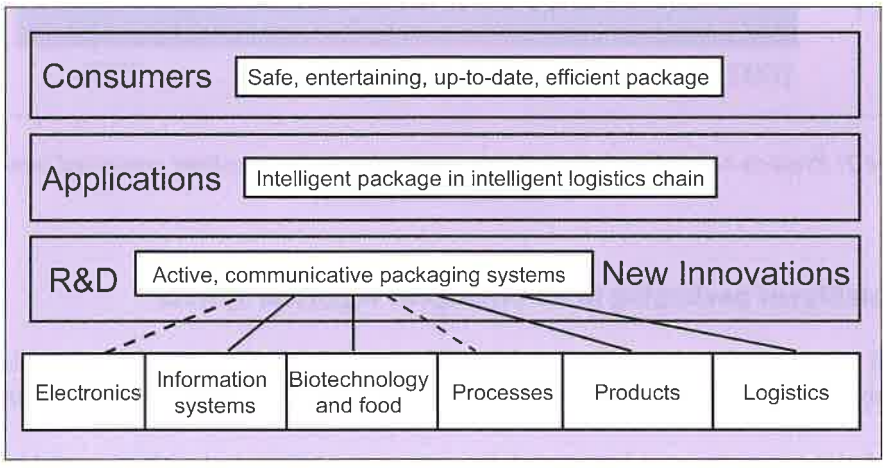

Figure 1: Active, communicative packaging - from research to finished products

business concepts. Intelligent products capable of observing, processing information, reacting and communicating will be able to adjust to different circumstances and communicate with their environment. A "smart" system adapts to expected situations in a predictable manner. An "intelligent" system is able adapt to unexpected situations as well (reasoning and learning).

One of the projects in the above mentioned Intelligent theme is Active, Communicative Packaging. Figure 1 shows the principle by which the multidisciplinary knowledge of VTT is combined to achieve innovations that will lead to applications that ultimately serve consumers.

2. Active, communicative packaging

The purpose is to develop packages that will give the product the required protection without additives. They will deliver information about the product (its condition and history in every phase of the logistical chain) and control the progress of packages, thus decreasing losses and mistakes. Packages will communicate topical information about the characteristics, usage and state of the product to consumers and consignees in entertaining ways. The idea is to increase the efficiency of the logistical chain while decreasing the use of packaging materials and packaging waste.

We have several other projects going on at VTT which support our development. Figure 2. shows the other projects related to the theme project, "Active, communicative packaging systems", and gives an idea of future development trends.

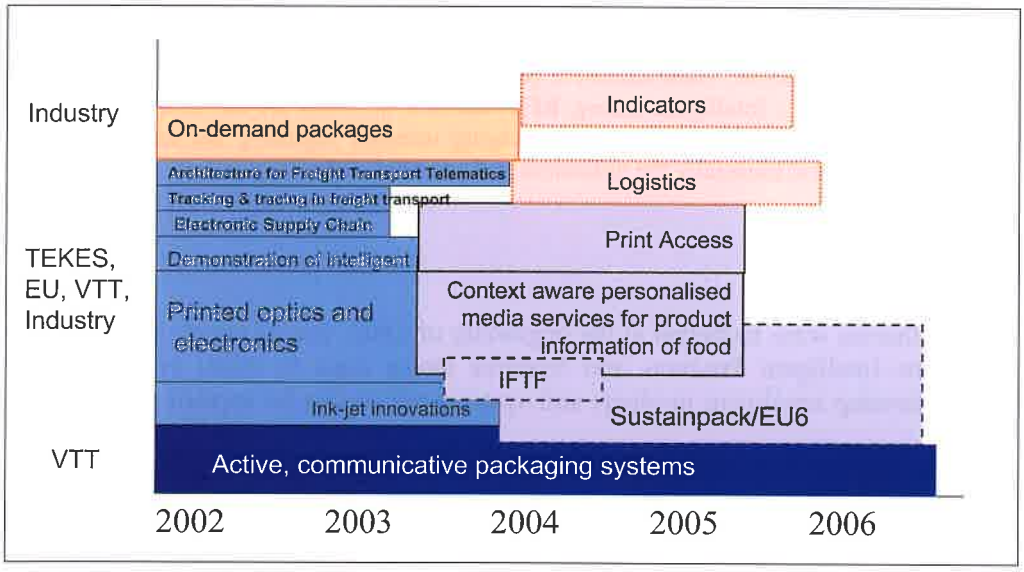

Figure 2: Projects related to Active, communicative packaging systems organised according to the financial structure

3. Target - intelligent packaging in an intelligent logistical system

The main goal is to develop a comprehensive, effective logistical system for sensitive, demanding products. The system is based on active, communicative packaging and mobile communications.

New functional characteristics can be created for customer packages in order to create value-added in the package itself (advertising, consumer information and education; edutainment, infotainment, etc.).

Value-added can also be created for the packed product (prevention of damage, freshness) or to produce savings for consumers (less waste, no overpacking) and/or suppliers (brand protection, traceability, theft protection, optimisation of the supply chain).

The project focuses on three sub-areas (see Figure 3) which interact with each other. These areas are:

1. Communication via consumer packages
2. Monitoring systems
3. Logistical chain

Although this paper focuses mainly on communication via consumer packages, it also deals with developments regarding the logistical chain.

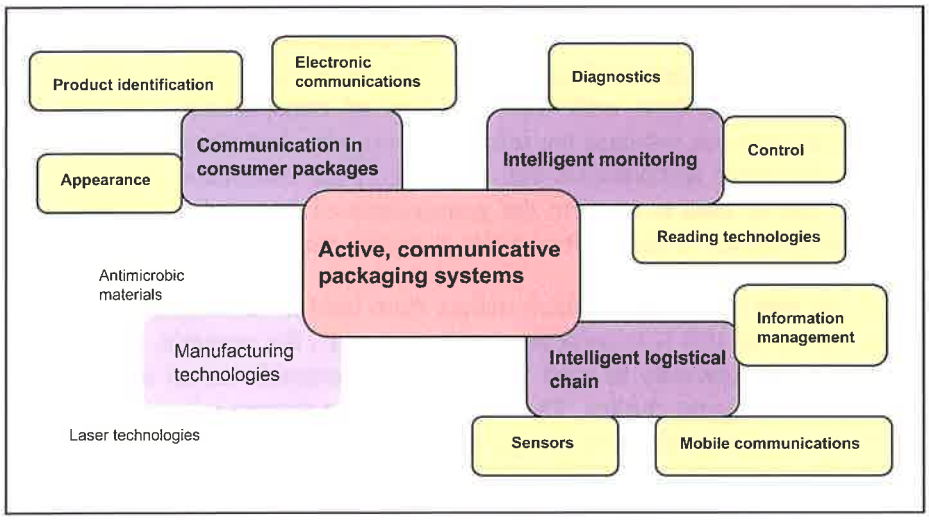

Figure 3: Technology map of Active, Communicative Packaging Systems

4. Improving information, traceability and brand protection of packages

The general trends in packaging production, such as shorter delivery times, larger selections and smaller product quantities, give an impetus to develop package production and packaging logistics. It is also important to develop packages so that they have better product information, a more visible trademark and a more selling appearance. More precise product specifications, better product traceability are today required by consumers and the authorities. There is the tempting possibility to use consumer packages as a medium for advertisements.

Nowadays, an increasingly important task of packaging is to provide greater brand protection, because forgers usually try to falsify the package rather than the product itself. Forgery is estimated to affect over 300 billion dollars of goods annually, which is about 10% of total world trade. The European Union has estimated that as many as 100,000 workplaces have been lost through forgery. Moreover, some forgeries (e.g. pharmaceuticals or spare parts for airplanes) can threaten the health and safety of consumers. Up to 50-60% of medicines can be bogus in some parts of Africa.

One way to increase the information on packaging is to use coding systems to compress data into a denser form. These methods can be optical, such as visual bar codes, or electronic, such as RFID tags. Usually these methods can also be used for brand protection and/or theft prevention. The most commonly used linear bar code system is the Universal Product Code (UPC) which is one of the most

successful standards ever developed. Originally this code was meant to benefit the retail trade, but over the years its use has also become common among raw material producers, manufacturers, wholesalers, distribution companies and consumers. This code makes it possible to control many activities of product supply chains and to track and identify products all over the world. The downside of the UPC bar code is that it carries only a limited amount of information, usually only twelve characters. For this reason, the normal bar code cannot include real information, but it is a link to a data base where the information is stored.

A two dimensional bar code can act as an independent data base. In this case, information can be read wherever a suitable scanning device for the code can be found. The other benefits of two dimensional bar codes are small physical size, scalability, big capacity of data storage and high data density, good correctness of information and high durability. Two dimensional bar codes can be attached to packages by using stickers or printing them straight onto the packages by means of an ink jet printer.

Two dimensional bar codes are usually used in the manufacturing sector, because more information, even over one thousand aphanumerical characters, can be included in the code. Every 2-D code includes an independent data base with total freedom of transportation. This is a great benefit compared to a landline network, because the information can be downloaded wherever the product is. Moreover, special encryption technologies can be used, if the information is confidential. Thus an encrypted 2-D code can be used to confirm the genuineness of the product. Multi-level confirmation technologies can also be added to the 2-D bar codes to ensure that the code will be read right.

Optical bar codes can also be invisible, which makes them hard to find and impossible to copy with a color copier. One way to do this is to print the word "original", for example, on a black box by using UV ink. After this the text can only be read in UV light. Thermochromical inks have also been used for pharmaceuticals and designer clothes. The best thing about thermo inks is that they do not require special reading devices, because they can change their color by touch, through body temperature.

Another developing coding system is Radio Frequence Identification (RFID). This technology allows information loaded onto a tag to be transferred wirelessly and without optical contact between a tagged product and an electronic reader. RFID tags use radio antennas which transmit information over a short range. Active tags include batteries so that they can actively send data over longer distances. Passive tags need power from the reader to be activated and to transmit data. Compared to optical bar codes, RFID tags can carry much more information. The biggest benefit of electronic tags is that they make continuous identification, tracking and communication of products possible, when they are connected to a reader network. RFID tags can also be used for theft prevention since they allow the continuous tracking of products. This was the motivation for Gillette to order 500 million RFID tags from Alien Technologies. Three of Gillette's products had been among the five most stolen items in department stores.

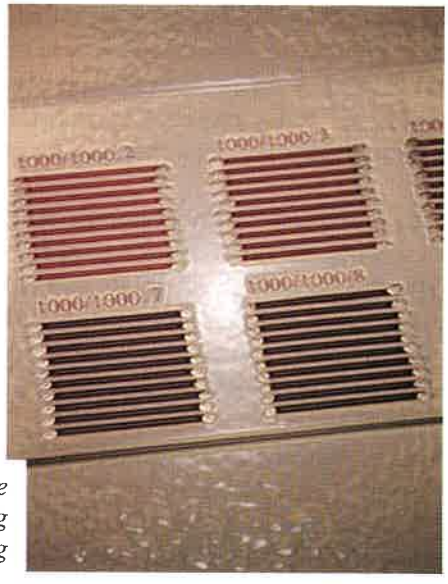

Figure 4: Ink jet printed conductors. Inexpensive electronic components can be manufactured by using conductive or luminous polymers and ink jet printing

The downside of RFID tags is that their price is much higher than the price of printed codes. Inexpensive electronic components can be manufactured by using conductive or luminous polymers and ink jet printing (Figure 4). For example, it has been forecasted that the price of ink jet printed RFID tags could be as cheap as half a cent in the future. Thus, electronics could be directly integrated with consumer packages. Working in co-operation with several companies and research institutes, VTT has launched a project called PRINTO (Printable Optics and Electronics) aimed at investigating the potential to fabricate passive and active electrical, optical and opto-electronic elements by means of roll-to-roll processes. The ability to successfully attach flexible and cost-effective electronics and displays to packaging and publication products would notably increase the number of applications and boost market potential.

5. Flexible package production

The key technology for flexible package production is digital printing. Because digital printing is masterless, i.e. there is no plate or cylinder that needs to be prepared in advance, it can produce small quantities of printed products cheaper and faster than any other printing method. Digital printing plays an important role in developing new operational and business models, because it provides a strong tool for the value addition of packages. Moreover, when digital printing methods are used, different work phases can be integrated and the transportation and storage of semi-finished products can be avoided, as can be seen in Figures 5 and 6 where conventional and integrated package production chains have been shown. Printing can also be decentralized and done in the locations where it is logistically most economical, as shown in Figure 7. The best tool to boost package communication is on-demand package production, in which the production of packaging or the whole product does not start until the order has been received, as shown in Figure 8. This brings extreme flexibility to the package production chain.

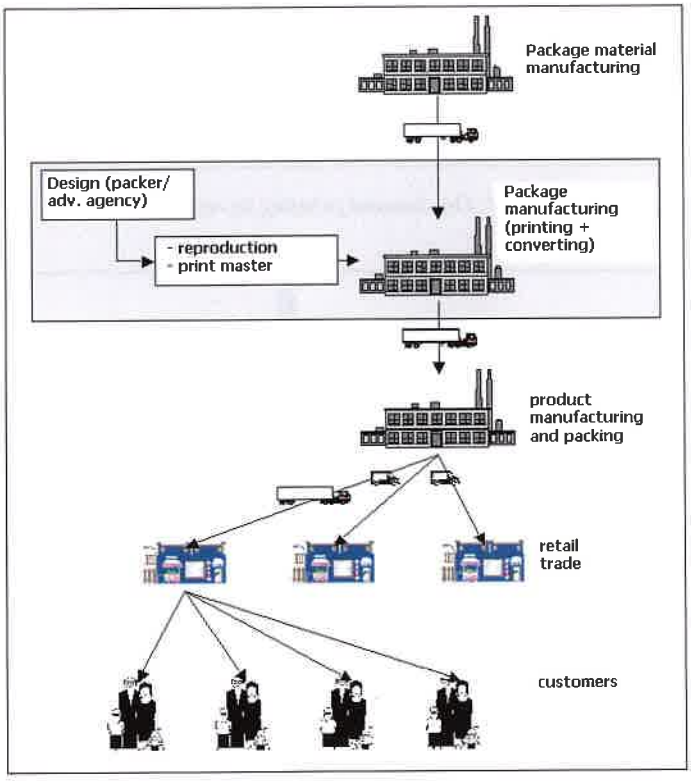

Figure 5: Conventional packaging process and delivery chain

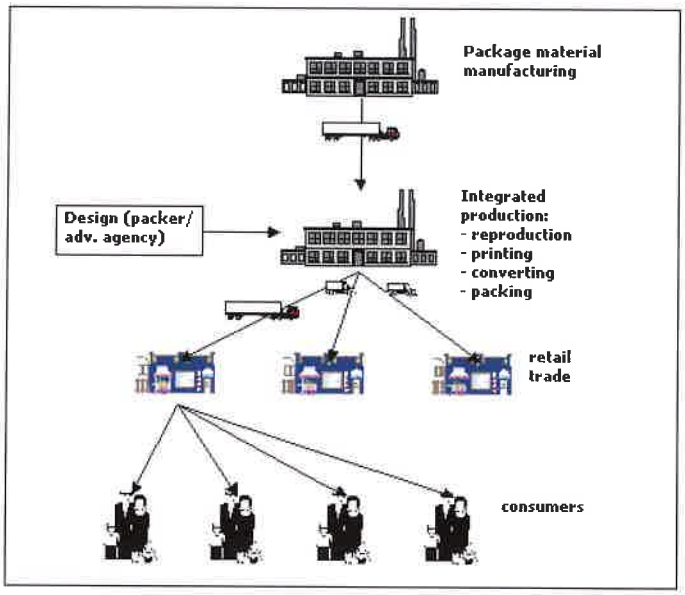

Figure 6: Integrated package production and delivery chain

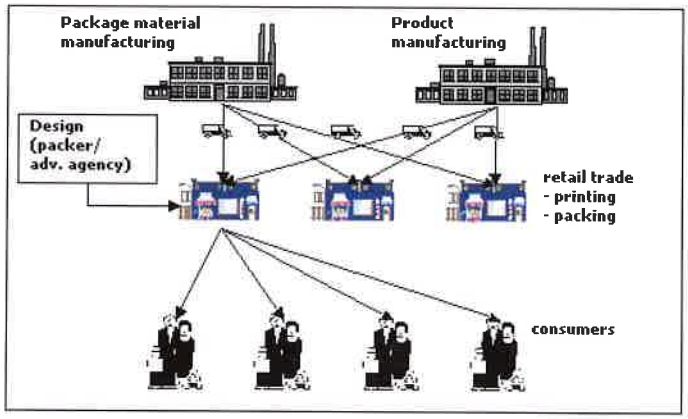

Figure 7: On demand printing in retail trade

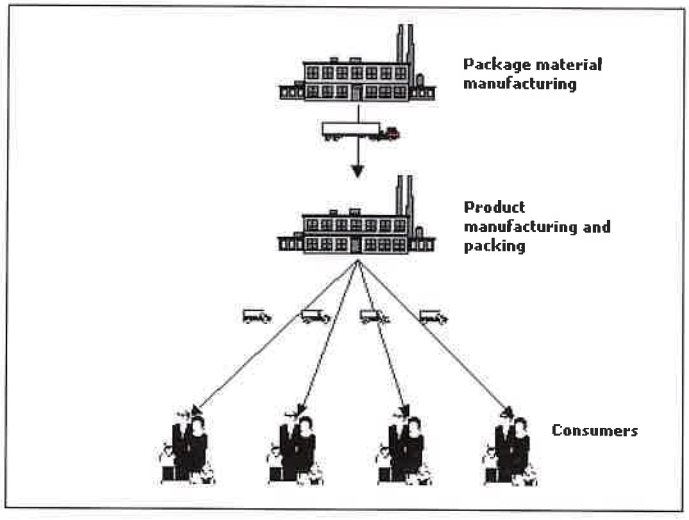

Figure 8: Integration of the whole packaging process

To sum up, the benefits of on-demand package production are that it:

- allows the production of customised and tailored packages
- means shorter delivery times, which helps to improve customer service
- decreases the waste of materials, which saves costs and nature
- decreases storage costs
- shortens production chains and accelerates production, which saves costs
- allows the production of packaging or even products to be started after order
- allows totally new kinds of products and business opportunities to be implemented

So, the main benefit of digital printing is that it opens up possibilities for new ways of marketing and creates logistical savings. VTT Information Technology has started several multidisciplinary projects to screen the possibilities and technical solutions of new digital package production chains.

6. Utilising digital printing in package production

There are two main utilisation areas, dictated by the present level of digital printing technology, in which variable information printing on packages can be implemented. In the first case, the whole package is printed digitally, so that every printed package can be 100 % different. Four-colour digital printing is usually done by electrophotographic means, but nowadays high-speed ink jet printers can also be used. During recent years, ink-jet printing technology in particular has developed rapidly and new applications have been created to produce documents, publications, personalised advertisements, security documents, textiles, cartons and packages. The method is suitable for a wide variety of materials, frequently updated information and for multicolour high-quality products.

Another way to utilise digital printing in packaging production is to use ink jets to add variable information onto pre-printed packages, which are often printed by conventional printing methods. Typically only black or one spot colour is added. The flexibility of ink jet technology makes it possible to place ink jet heads at the right location in the printing or packaging process. For example, the heads can be placed in the conventional printing press after traditional printing or they can be integrated in a packaging line before or after packaging. In any case, each interface and procedure must be carefully pre-organised so that the actual work flow will go smoothly.

In digital package production, it is important to understand that digital printing does not eliminate the need for graphic reproduction. In fact, variable data printing (VDP) adds complexity to an already complex process. The digital job must also be adjusted according to the target printer, so we still need to take care of reproduction of details, colour management, the right content of text, etc. In the digital workflow, these tasks are easier and quicker to accomplish, because many of them can be automated or semi-automated.

One bottleneck in the digital package process is converting. Many converting stages are needed for packages after printing, such as scoring, die-cutting, varnishing, folding, gluing and filling. These stages should be integrated as an inseparable part of the digital work flow to avoid expensive manual work and to gain the greatest benefits from digital package production. Because the digital manufacture of packages is a new concept, there are only a limited number of suitable alternatives for most packaging applications. For this reason, converting machines must often be developed or at least tailored as part of a digital manufacturing line development project. VTT has actively participated in projects to develop digital package production systems.

Another bottleneck in digital package printing is materials. Different demands are placed on materials in electrophotography and ink jet printing. Generally speaking, electrophotography is more material-

independent - as long as high quality paper and board grades are used. Ink jet printing sets stricter demands on the printing material, because the image is created directly onto the surface of paper, usually using solvent-based inks. The print quality will decrease dramatically, if ink flows on the surface of coated paper, as can be seen in Figure 9, or spreads in the capillary network of uncoated paper.

Figure 9: Test picture printed on two coated paper grades printed by the same printer. The print quality in ink jet printing is extremely surface-dependent

These phenomena are especially crucial in high-speed ink jet printing where there is no time for evaporation of solvent. A better knowledge of the basic mechanisms of the dynamic interaction between ink and paper is needed to produce more reliable and appropriate quality specifications for printing surfaces. A unique approach to this problem is the laboratory-scale testing environment developed by VTT Information Technology for the high-speed imaging of ink jet drops. Differences in spreading dynamics between paper grades can be noticed immediately after drop impact, as can be seen in Figure 10. The absence of any other method to detect these high-speed phenomena, this research environment

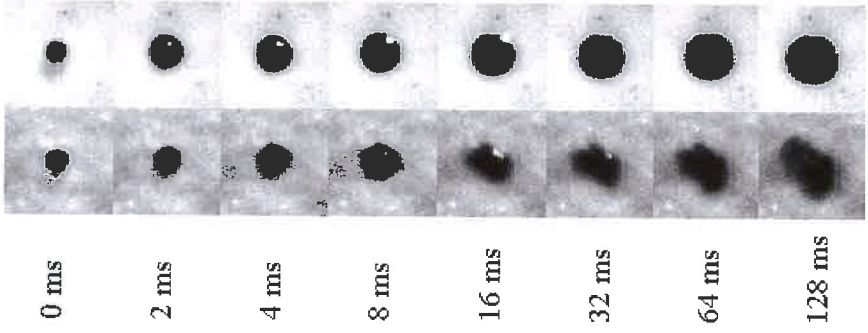

Figure 10: The behaviour of 3 pl ink drops on two different papers during the first 120 ms after impact

has proven to be a precise tool for the development of ink jet printing materials, inks and printers. To sum up, digital printing packaging applications require great care to find the right balance between the printing method, the material properties and the final print quality.

7. Conclusions

On one hand, general packaging production trends, such as shorter delivery times, larger selections and smaller product quantities, are setting higher and higher demands on package production and packaging logistics. On the other hand, developing communication and printing technologies are providing new tools for solving problems, boosting production and giving value addition to packages. An increasingly important task for packaging is to improve brand protection, because forgers usually try to falsify the package rather than the product itself. Methods such as visible or invisible printed bar codes and electronic RFID tags can be effectively used for brand protection and theft prevention.

VTT Information Technology has long-time expertise in these areas and several new activities have also been started. One of our projects, called Active Communicative Packaging, is being carried out under a larger VTT-driven theme and its main purpose is to develop and integrate active, communicative packaging with an effective logistics system for sensitive, demanding products. The aim is to develop a comprehensive system for new kinds of package production chain which pays attention to the special needs of consumer packages as regards product information, identification and appearance. VTT has also launched a project called PRINTO (Printable Optics and Electronics) aimed at investigating the potential to fabricate passive and active electrical, optical and opto-electronic elements for packages and printed products. The achievements of these projects will be reported in the near future.

References

Ahvenainen, Raija; Juhola, Helene, *VTT Strategic Technology Theme Intelligent Products and Systems: Active, communicating package. Nordic FoodPack. Helsinki, 4 - 6 Sept. 2002, 4 p.*

Heilmann, Jali; Juhola Helene; Linna Hannu, *New challenges of package-based communication. TAGA 2003 Conference, Montreal 2003. 11 p.*

Heilmann, Jali, *Measuring dynamic interactions between paper and microscale ink drops IS&T's NIP 17: International Conference on Digital Printing Technologies. 2001. 4 p.*

Heilmann, Jali; Lindqvist Ulf, *Effect of drop size on the print quality in continuous Ink Jet Printing. The Journal of Imaging Science and Technology. Vol. 44 (2000) No: 6, 491 - 494.*

Heilmann, Jali; Lindqvist, Ulf, *Significance of paper properties on print quality in continuous ink jet printing. The Journal of Imaging Science and Technology. Vol. 44 (2000) No: 6, 495 - 499.*

Linna, Hannu; Vallenius, Risto. *Printing of variable information on packages. Digital Printing for Packaging. London, 12 - 13 July 2000. Pira International. Leatherhead, Surrey (2000)*

4

Workflow and productivity

The stohastic model of simulation of a virtual printing-house

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Abstract

Modelling of graphic systems is introduced as a successful method for the improvement and optimisation of print production. Process flows have become open and complex, where every segment is attributed with a degree of probability and coincidences. Such approach completely changes the previous production management, with final results of more stable production, instant location of bottle-necks causing the stoppages as well as of increased productivity.

It is possible to integrate sucessfully the results of such an approach to the improvement of hybrid printing systems; it can also give a significant contribution to the development of CIP4 in the sense of the transparent following of graphic processes. Modelling and simulation are considered as the essential methods in designing the printing systems of the future, as well as a base for the research and development of reproduction processes.

1. Introduction

The paper creates and analyses stochastic models [2] that simulate a virtual printing house and its parts. The entire production process is being simulated in order to create extreme risk situations and thereby define maximum production capacities of the system. The simulation in the paper precisely determines bottle-necks. Optimal and highly balanced parameters of graphic production are being created on the basis of measurements and result analysis. Processes are transparent and complex, and each is accompanied by a level of probability and stochastic, thereby introducing modeling of a graphic system [6] [7] as a successful method for improving and optimizing production. There is a new approach to the observation and evaluation of graphical production processes, from preparation to finalization. In the long run, this is reflected in an increase in production, a more stable production line and better use of existing digital equipment.

2. Enhancement of graphic system by simulation methods

Simulation [1][5] enables the creating of extreme conditions in graphic production processes that would cause great damage in the real system. These borderline conditions are the ones in which simulation provides the insight and experience we use to create new ways of organizing production [10]. It is simulation that has showed us the bad sides of management and pure use of printing processes. In order to revive implementation CIP3, i.e. CIP4 in the graphic system [8] it is imperative to establish a more optimized production line. To establish such an approach in practice, it is necessary to reorganize the existing production plants entirely, especially in the sense of enhancing existing know-how and skills.

Hybrid solutions naturally spring to mind [9] for the creation of a competitive product, but the final realization is not possible as long as there is no definition of a stable production line. Significant steps have been made in that area, but for the idea of a hybrid system to take hold, further investigations and

adjustments of production processes will be necessary. Simulation methods can also penetrate and describe in detail the state of the graphic system and thus significantly improve and develop the existing know-how in that area.

Such an approach entirely changes previous methods of production management, which in the end results in a more stable production process, instant detection of bottle-neck that leads to delays and in enhanced productivity. The results of such observation can successfully be integrated in the enhancement of hybrid graphic systems and in aiding the development of CIP3 and CIP4 in the sense of a more transparent expansion of the graphic process.

The design of a new graphic product today incorporates several production technologies, which asks for a new approach in product manufacture. Printing-houses must be very flexible in regard to the market environment when it comes to offering quality solutions. Such a new understanding of the market leads to the introduction of new modeling and simulation methods, as well as having expert and consulting teams look for new solutions.

Expert teams are expected to define the flow of information making maximum use of the Internet technology linked to hybrid printing systems. As there is an unlimited number of solutions and unforeseen situations, the simulation method provides optimal solutions along with presumed problems in the real system. Thus one will not only try to foresee market demands on the one hand, but also create a dynamic system on the other hand that will shortly lead to a new graphic product.

Introduction of simulation into graphic systems enhances the flexibility and adaptability of new solutions in printing, finds production delays, critical spots that lead to deadlock and, most importantly, betters the education of production staff.

At the moment there is a very limited number of simulation applications in the market, which points towards the complexity and price of manufacturing such a virtual system. The solutions on offer enable us to learn and train for special situations just as with real graphic machines, only without the enormous cost in material and time. Furthermore, simulators can create extreme situations that can cause damage in the real environment. It is necessary to create as many various educational tools as possible to simulate the system, the printing process, specially ordered situations and individual production sequences. This will also create a new method of education on all levels.

The unpredictability and dynamism of the market brings printing-houses in a position in which they have to hire consulting and expert teams that will suggest new guidelines in information processing. If the printing-house discovers new situations independently within its own plant, it can easily lead to disorganization and jamming. In such a situation, simulators create solutions and suggest production processes that are definitely cheaper than activating the entire printing line. The area of modeling, simulation and virtual reality introduces a new education method for generations to come.

The next step is the organization of information flow and structure within the graphic system. The definite need to adjust to the Internet environment leads to the adaptation to new standards. XML is suggested as a standard, which linked with XSL provides filtered, targeted information [8]. It is also necessary to conduct further research into the behavior of a graphic system supported by such a model. Only after positive results on the stability of the system are obtained can one proceed with a complete implementation of the Internet environment into printing.

2.1 Defining stochastic models

Simulation of graphic production and the evaluation of its successfulness are practically just starting. Research is directed towards stochastic simulation [2] through data analysis [3] of real systems in

printing. Processes are open, and because of the level of probability and chance, models are defined as discrete and stochastic.

2.1.1 Experimental development of model of graphic prepress

This stochastic model tries to present and explore the problem on the level of prepress graphic production. For the analysis and evaluation of success special attention has been paid to the areas of digitalization of originals, editing originals, composition of the graphic page and platesetting. Depending on the output final size of the original and the category of editing and composition, every working place is dependent on various time intervals for editing. It has been defined that one third enters the production cycle every four (4) minutes, the second third every (5) minutes, and the rest every six (6) minutes. The digitalization of the original depends on the output file size, so that it takes three minutes for the first 25% of the originals, 3.5 minutes for the next 25%, and 4 minutes for the remaining 50%. The digitalization parameter for the original varies, so that the observation and research of the system will be guided by that very variable. To edit the originals it takes eight (8) minutes for the first third, nine (9) minutes for the second third and ten (10) minutes for the rest. Page composition takes twelve (12) minutes for 25% of the situations, fifteen (15) minutes for the next 45% and twenty (20) minutes for the rest. The model also takes into consideration errors that are unavoidable in editing, so that a certain amount undergoes re-editing defined by control within the production cycle (Figure 1).

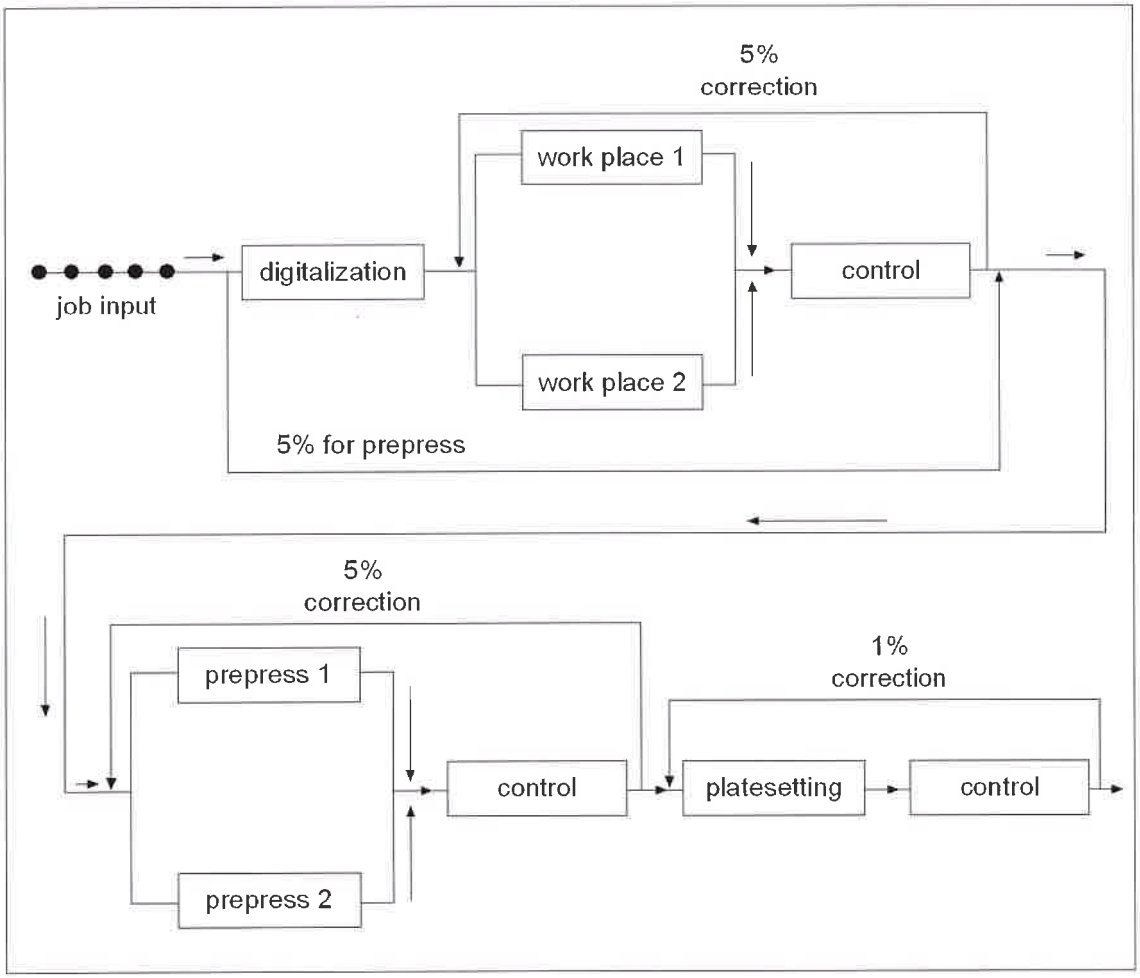


Figure 1: Model of graphic prepress

Variable digitalization parameter defined by times:

Time 1: 25% by 1 min, 25% by 1.5 min and 50% by 2 min = experiment A;
Time 2: 25% by 2 min, 25% by 2.5 min and 50% by 3 min = experiment B;
Time 3: 25% by 3 min, 25% by 3.5 min and 50% by 4 min = experiment C;
Time 4: 25% by 4 min, 25% by 4.5 min and 50% by 5 min = experiment D;
Time 5: 25% by 5 min, 25% by 5.5 min and 50% by 6 min = experiment E;
Time 6: 25% by 7 min, 25% by 8.0 min and 50% by 9 min = experiment F.

2.1.2 Experimental development of model of digital printing house

Within the real system there is an unlimited number of multifaceted work-influx variations. This stochastic model describes the printing part in the area of small press runs. Of the entire amount of printing jobs, 25% are runs of 50-150 sheets, 35% are runs of 151-250 sheets, and the remaining 40% are runs of 251-400 sheets. The time necessary for editing and printing preparation is 35 minutes for 30% of the jobs, 55 minutes for 40% of the jobs, and 80 minutes for the remaining 30% of the jobs. The editing parameter varies, so that the cost-effectiveness of the graphic system will be simulated by changing the parameter. The critical borderline area will also be shown, which is hard to reach within the real system, because of a possible crash-down of the entire production unit configuration. Along with the simulation model, there is also an amount taken into consideration that undergoes re-editing after the control process, not only after preparation, but also after printing. Printing speed is set to 150 sheets per minute. The model also takes into account errors during editing and printing, so that a certain amount, i.e. errors unavoidable in the production cycle, undergoes re-editing (Figure 2).

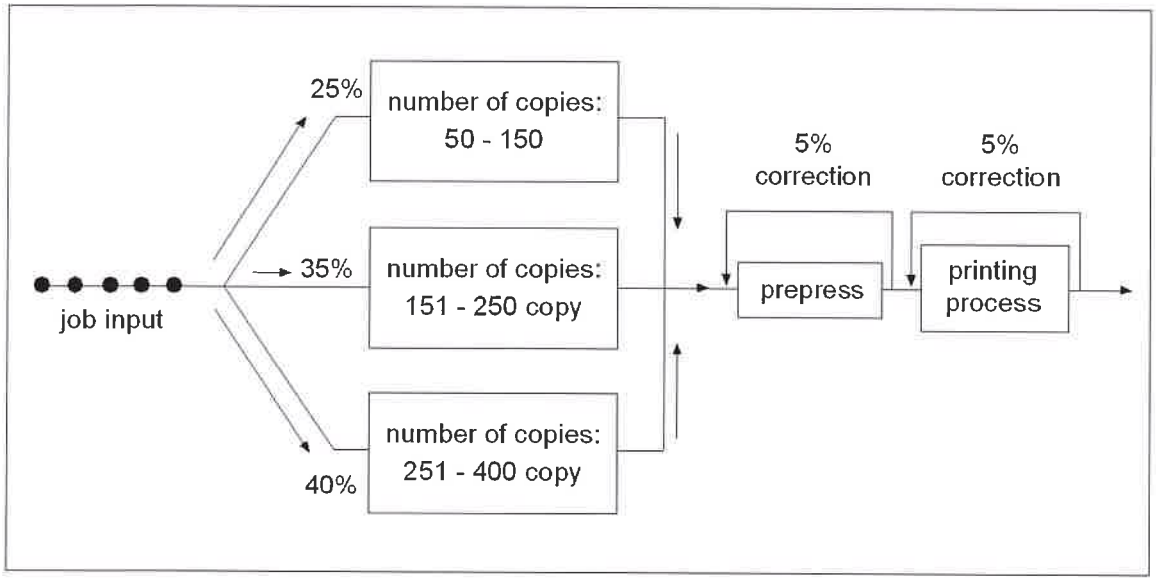


Figure 2: Model of digital printing house

The variable editing and printing parameter defined by times:

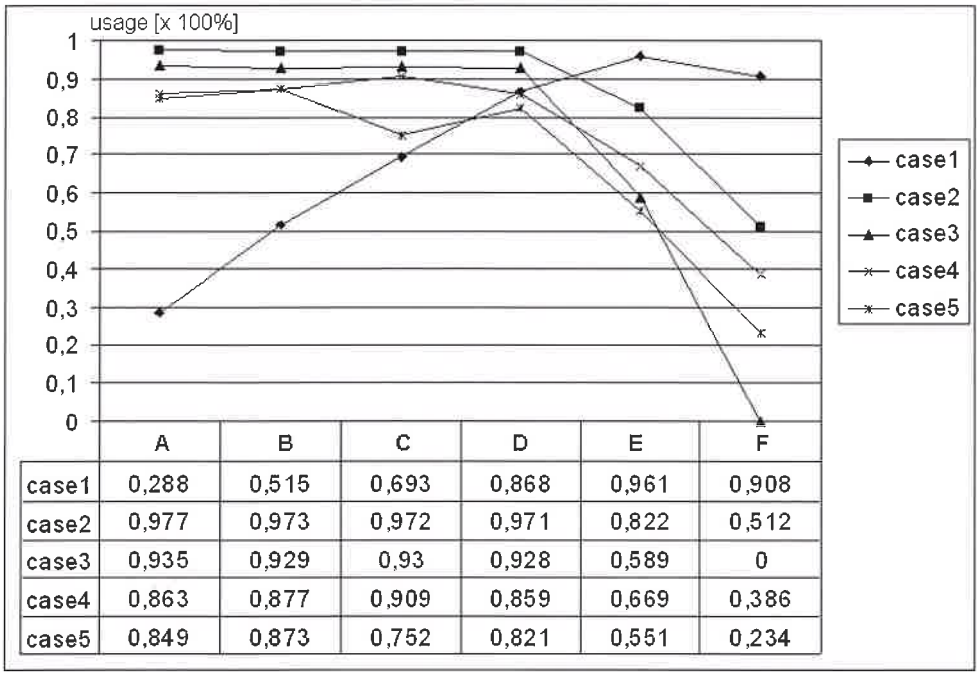
Time 1: 30% by 1 min, 40% by 3 min, 30% by 5 min = experiment A;
Time 2: 30% by 7 min, 40% by 10 min, 30% by 15 min = experiment B;
Time 3: 30% by 15 min, 40% by 20 min, 30% by 25 min = experiment C;
Time 4: 30% by 25 min, 40% by 30 min, 30% by 45 min = experiment D;
Time 5: 30% by 40 min, 40% by 45 min, 30% by 50 min = experiment E;
Time 6: 30% by 35 min, 40% by 50 min, 30% by 80 min = experiment F;
Time 7: 30% by 15 min, 40% by 45 min, 30% by 110 min = experiment G.

3. Experimental part

The resource has been used optimally if the utilization is between 70 and 85% [4]. Utilization exceeding 85% very quickly and abruptly leads to a complete deadlock. Digitalization time is taken as variable data in the model (Figure 1) and has been defined by times of 1, 2, 3, 4, 5 and 7 minutes for 25% of the input, by 1.5, 2.5, 3.5, 4.5, 5.5 and 8 minutes for the next 25%, and by 2, 3, 4, 5, 6 and 9 minutes for the remaining 50%. Digitalization times are distributed according to discrete function defined by the described set values. The first case of digitalization time distribution, e.g., is 1 minute for 25% of the jobs, 1.5 minutes for another 25% of the jobs and 2 minutes for the remaining 50%. The extreme case is defined by 7 minutes for 25%, 8 minutes for another 25% and 9 minutes for the remaining 50%. These times present data from the real system, where jobs are defined by several clients. Figure 3 shows simulation results obtained by the above data.

case1= utilization of digitalization;
case2= utilization of control after prepress;
case3= utilization of platesetting;
case4= utilization of editing work place;
case5= utilization of prepress.

Experiments A, B, C, D, E and F present defined times described by discrete function.



	A	B	C	D	E	F
case1	0,288	0,515	0,693	0,868	0,961	0,908
case2	0,977	0,973	0,972	0,971	0,822	0,512
case3	0,935	0,929	0,93	0,928	0,589	0
case4	0,863	0,877	0,909	0,859	0,669	0,386
case5	0,849	0,873	0,752	0,821	0,551	0,234

Figure 3: Utilizationof individual working place in model og graphic prepress

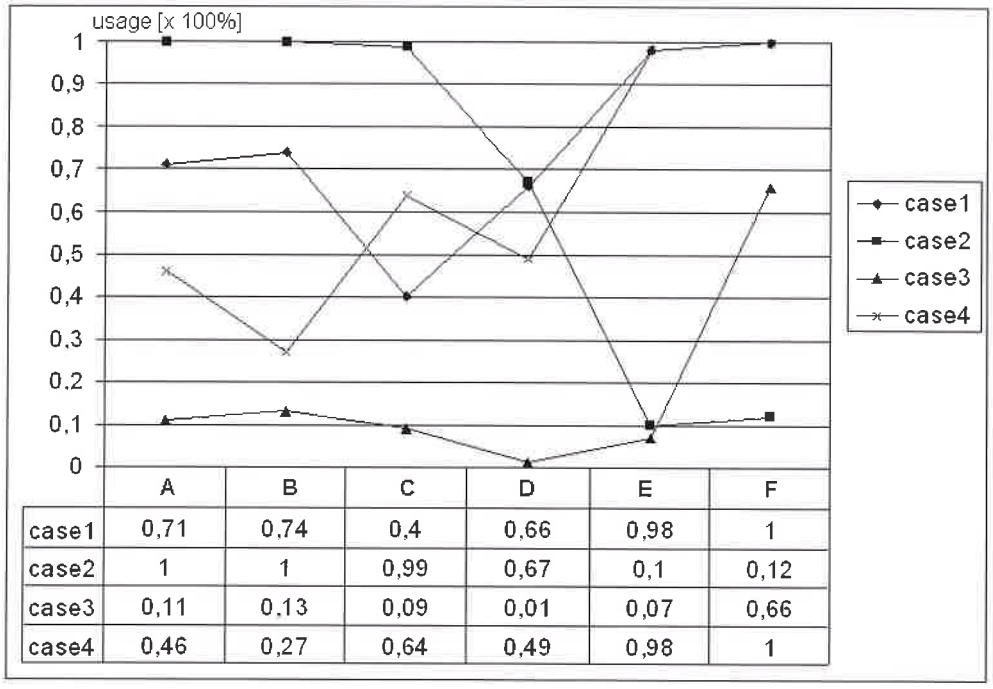
In time intervals the curve for case 1 shows utilization from 28.8% for the shortest digitalization time to 84.9% for the extreme digitalization time case as defined by discrete function. Control after prepress (case 2) was longest at short job in arrival intervals (1, 2, 3, 4, 5 minutes) between 97.7% and 97.1% and became shorter only in time intervals longer than 5 minutes. Control is defined by 9 minutes with 1-minute oscillation. Similarly, in case 3 during short time intervals there was utilization between 86.3 and 90.9%, which became shorter only in time intervals longer than 5 minutes. This point is defined by 15 minutes with 1-minute oscillation. Editing (case 4) was taking place in two

work places, because one was totally jammed. There is also a significant drop (38.6%) in time intervals longer than 7 minutes. Layout was divided among two work places (case 5) because of accumulation and queuing.

Optimal use of the digitalization point (case 1) are 69.3% and 86.8% in defined original input times of 3, i.e. 4 minutes for 25% of incoming jobs, 3.5, i.e. 4.5 minutes for another 25% and 4, i.e. 5 minutes for the remaining 50%. This is apparent in experiments C and D. Analyzing the editing working place (case 4), the optimum is achieved at a defined original input time of every 5 minutes for the first 25%, every 5.5 minutes for the next 25% and every 6 minutes for the remaining 50%. It can be said that the platesetting point (case 3) is under great job-influx strain (more than 90%). We suggest the installation of a new platesetter or a new RIP. In experiments C, D and E optimum results were achieved for the described model. In experiment F, when the digitalization is overloaded, one active work place is sufficient.

Figure 4 shows job inputs without a waiting period (percent of zeros). It regards jobs realized directly, without delay and sent to another point. Times used in the simulation are identical to the ones in Figure 3. Figure 4 shows simulation results obtained by that data.

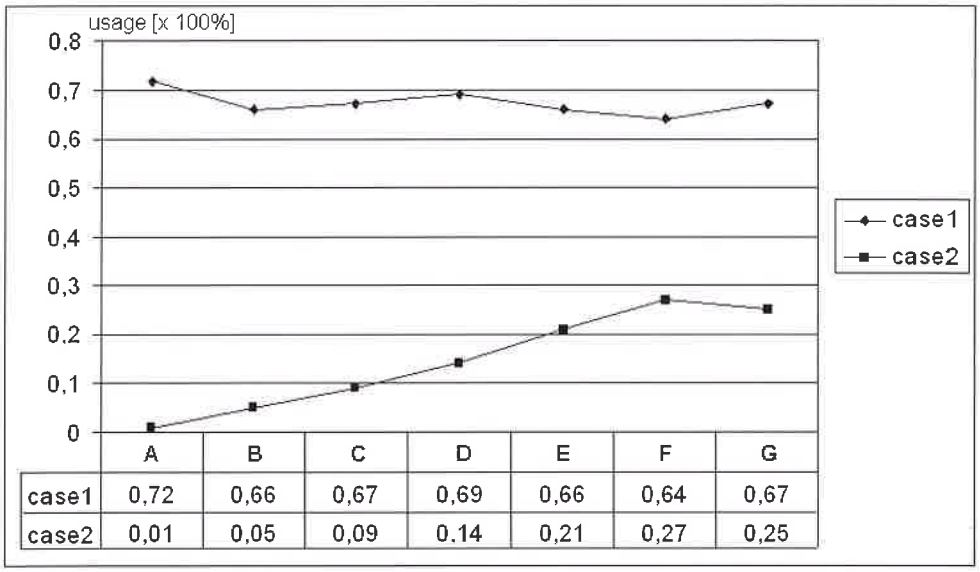
case1= percentage of jobs with no waiting period for editing;
case2= percentage of jobs with no waiting period for digitalization;
case3= percentage of jobs with no waiting period for post-prepress control;
case4= percentage of jobs with no waiting period for prepress.



	A	B	C	D	E	F
case1	0,71	0,74	0,4	0,66	0,98	1
case2	1	1	0,99	0,67	0,1	0,12
case3	0,11	0,13	0,09	0,01	0,07	0,66
case4	0,46	0,27	0,64	0,49	0,98	1

Figure 4: Percentage of job with no waiting period for individual working place in model of graphich prepress

In picture editing there was no waiting period only in time intervals exceeding 5 minutes (98% and 100%). In such situations, if constant, it is possible to have only one work place. This paper does not analyze such a situation in detail. As regards control, one work place is sufficient and 66% of jobs is the highest percentage of jobs realized with no waiting period in intervals of 7, 8 and 9 minutes defined according to described function.



	A	B	C	D	E	F	G
case1	0,72	0,66	0,67	0,69	0,66	0,64	0,67
case2	0,01	0,05	0,09	0.14	0,21	0,27	0,25

Figure 5: Utilization of individual working place in model of digital printing house

The variable of prepress time, was used as variable data in the model (Figure 2). Prepress times are defined through discrete function as 1, 7, 15, 25, 40, 35 and 15 minutes for 30%, 3, 10, 20, 30, 45, 55 and 45 minutes for 40% and 5, 15, 25, 40, 50, 80 and 110 minutes for the remaining 30%. For the first case of prepress time distribution, editing lasted 1 minute for 30%, 3 minutes for 40% and 5 minutes for the remaining 30%. Printing speed was defined at 150 sheets per minute. Figure 5 shows simulation results.

Case1= utilization of digital printing;
case2= utilization of prepress.

Experiments A, B, C, D, E, F and G present defined times described through discrete function.

Optimal utilization of printing (case 1) occurred when job arrival time was defined as 1 minute for 30%, 3 minutes for 40% and 5 minutes for the remaining 30%. Observing total case 1 utilization, we find that it was smallest at 64% in experiment F and largest at 72% in experiment A. The utilization of the prepress work-place (case 2) is so small that the work-place needs to given a higher job arrival frequency.

4. Suggested presentation of results for simulation experiment through XML technology

The researcher has to perform hundreds of simulation experiments with the program model. Each experimental simulation measurement result has little value in itself. Only after a larger number of experimental results can certain conclusions be made.

Every simulation research of parts of the model should have several experimental plans. All measurement results have to be placed in a relational database immediately after the experiment (SQL Server, Informix, DB2, Oracle or MSAccess). Each experiment presents one record in the table of experiments. Thus noted data can be obtained in XML format via a previously defined XML Scheme. Here we suggest a design of the XML document for the analysis of targeted resources for six experimental plans A, B, C, D, E and F:

```
<experiments>
        <A>     <digital n=1><util>0.288</util><perczero>1</perczero></digital>
                <plate n=1><util>0.935</util><perczero></perczero></plate>
                <workplace n=2><util>0.863</util><perczero>0.71</perczero></workplace>
                <prepress n=2><util>0.849</util><perczero>0.46</perczero></prepress>
                <contrprepress n=1><util>0.977</util><perczero>0.11</perczero></contrprepress>
        </A>
        <B>     <digital n=1><util>0.515</util><perczero>1</perczero></digital>
                <plate n=1><util>0.929</util><perczero></perczero></plate>
                <workplace n=2><util>0.877</util><perczero>0.74</perczero></workplace>
                <prepress n=2><util>0.873</util><perczero>0.27</perczero></prepress>
                <contrprepress n=1><util>0.973</util><perczero>0.13</perczero></contrprepress>
        </B>
        <C>     <digital n=1><util>0.693</util><perczero>0.99</perczero></digital>
                <plate n=1><util>0.930</util><perczero></perczero></plate>
                <workplace n=2><util>0.909</util><perczero>0.40</perczero></workplace>
                <prepress n=2><util>0.752</util><perczero>0.64</perczero></prepress>
                <contrprepress n=1><util>0.972</util><perczero>0.09</perczero></contrprepress>
        </C>
        <D>     <digital n=1><util>0.868</util><perczero>0.67</perczero></digital>
                <plate n=1><util>0.928</util><perczero></perczero></plate>
                <workplace n=2><util>0.859</util><perczero>0.66</perczero></workplace>
                <prepress n=2><util>0.821</util><perczero>0.49</perczero></prepress>
                <contrprepress n=1><util>0.971</util><perczero>0.01</perczero></contrprepress>
        </D>
        <E>     <digital n=1><util>0.961</util><perczero>0.11</perczero></digital>
                <plate n=1><util>0.589</util><perczero></perczero></plate>
                <workplace n=2><util>0.669</util><perczero>0.98</perczero></workplace>
                <prepress n=2><util>0.551</util><perczero>0.98</perczero></prepress>
                <contrprepress n=1><util>0.822</util><perczero>0.07</perczero></contrprepress>
        </E>


        <F>     <digital n=1><util>0.908</util><perczero>0.12</perczero></digital>
                <plate n=1><util>0</util><perczero></perczero></plate>
                <workplace n=2><util>0.386</util><perczero>1</perczero></workplace>
                <prepress n=2><util>0.234</util><perczero>1</perczero></prepress>
                <contrprepress n=1><util>0.512</util><perczero>0.66</perczero></contrprepress>
        </F>
</experiments>
```

Such an XML document containing all experimental data can easily be filtered and presented using XSL technology. Using XSL Transformation, e.g., one can obtain a new XML document containing only elements with util child element within interval (0.70, 0.85).

5. Conclusion

Research results lead to the conclusion that the simulation method of graphic processes gives both quality and quantity results which are of great use in solving production problems. Problems that occur are linked with insufficient use of individual components, impossibility of testing production in extreme conditions and worker education. The paper elaborates on the production situation of a virtual printing house, based on stochastic models and driven to borderline utilizations. A suggestion has been made for optimal use and new territory has been marked for further development in the graphic engineering domain, especially regarding the concept of virtual production components in printing. By experimenting in simulation, quantity results are obtained defining the use of the resource, pointing towards closing or opening new work places and investing in new hardware or software.

The results have shown that there is great discrepancy between components in graphic production workflows. Stochastic models provide highly useful results for solving such problems. A XML method has been suggested for the description of experimental results in order to facilitate future analysis with XSL technology, providing the use of a relational database.

Literature references

1. Zeigler B.P., (1976), *Theory of Modelling and Simulation, John Wiley & Sons, USA, ISBN 0-471-98152-4*
2. Maisel H., Gnugnoli G., (1972), *Simulation of Discrete Stochastic Systems, Science Research Associates Inc., USA, ISBN 72-807-61*
3. Kleijnen J.P.C., (1974), *Statistical Techniques in Simulation, Marcel Dekker, New York, ISBN 0-8247-6157-X*
4. Pap K., Žiljak V., (2000), *Model simulacije dinamičkog konfiguriranja grafičkih sustava, IV simpozij Modeliranje u znanosti, tehnici i društvu., Rijeka 2000. UDK 519.8(082), ISBN 953-6065-00-2*
5. Žiljak V., (1982), *Simulacija računalom, Školska knjiga, Zagreb*
6. Žiljak V., Pap K., (1999), *Optimization of individualized reproduction in long-run digital printing, IARIGAI 26th research Conference, Munich*
7. Žiljak V., Pap K., (1999), *Production Management for the Long Run Digital Print with Individualization based on Dinamic Modular Print, 30 th annual Conference of the IC, Stockholm*
8. Žiljak V., Pap K., Agić D., Žiljak I., (2002), *Modelling and Simulation of Integration of Web system, Digital and Conventional Printing, 29th International Research Conference of IARIGAI, Lake of Lucerne, Switzerland*
9. Žiljak V., Simovic V., Pap K., (2002), *Simulation of Stohastic System of Printing Procedures, The International Conference on Modeling and Simulating of Complex System, ICMSCS 2002, Chengdu, China*
10. Nježić Z., Žiljak V., Pap K., (2002), *Design of Digital Graphic System, International Design Conference DESIGN 2002, pp 876, Dubrovnik, Croatia*

Publishing workflows with XSL-FO

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Abstract

XML and XSL-FO are used more and more often as media neutral formats in current electronic and print publishing workflows. Advantages of an XML-based approach are above all the possibilities of integrating back-end systems, such as Enterprise Resource Planning Systems and databases. On the basis of this integration, individualized and customized publishing products can be produced in a simple manner and on-the-fly. Therefore, the main area of XSL-FO-technology application lies with the dynamic generation of publishing products. Particularly in online applications, where users expect an immediate digital PDF-response to their web query, the response document is often generated from an XML-database. So far XML-FO has been especially interesting as a starting point for PDF-print make-up when there are limited quality requirements regarding layout and typography. Technical documentations or legal texts are typical print products in this context. The application of XML-FO in prepress is further restricted by the lacking support of high-end PDF-features in current Formatting Object (FO) processors. An extended support for fonts, an Open Prepress Interface (OPI) mechanism, and colour management functions are some of the optimisations that are still to be found.

In the presentation, basic possibilities and current areas of application of XML-FO will be systematically demonstrated and advantages over alternative workflow concepts will be pointed out. The thematic emphasis will be on PDF generation. Additionally, the state-of-the-art of XSL application in more general production processes for any media and output formats will be illustrated.

Various implementation projects carried out in cooperation with publishers and universities as well as academic research on publishing with XML/XSL will serve as basis for the presentation. The demonstrated results in mind, new business models on the basis of XSL-FO-based workflows in professional prepress will be discussed in detail. Finally, requirements for the next generation of FO tools as well as for XSL-support in DTP products will be deduced and future applications explored.

1. Introduction

For many years publishing has been subject to constant change. The introduction of computers to printing rationalized production processes whereupon the dissemination of PCs and the internet produced a new medium. This new medium developed into a serious alternative for the publication of information for many traditional printing products. Electronic publishing has since established itself. Despite frequent prophesies to the contrary, however, paper has not yet been replaced. What has occurred is rather an integration of the various types of media. Today, "content" is being individualized, personalized, and cross-media published with respect to target groups and applications.

Portable Document Format (PDF) and Extensible Markup Language (XML) have been important milestones in this development. While PDF is especially powerful as format which is "true to the original layout" and as exchange format in prepress workflow, XML stands out due to the higher potential in the exchange of structured documents or data. In publishing workflows, especially in cross-media publishing, a combination of formats can often be beneficial. The use of XML as media-neutral source format and PDF, along with other format types, as output format for screen and paper is

both typical and reasonable. The W3C recommendation Extensible Stylesheet Language (XSL), including the specifications and processing rules for Formatting Objects (XSL-FO) provides rules for a standardized formatting workflow from XML to PDF documents.

2. From XML to representation

The conceptual potential of XML lies in the strict separation of content, logical structure, and document layout. However, this advantage also means that, without additional formatting rules, the representation of XML documents is not defined. The missing rules can be specified as XSL style sheets. Software that is compatible with XSL (XSLT and XSL-FO processors) can then be used to represent XML documents with different formatting and on various media.

It is commonly known that the XSL recommendation is organized into two main parts. In accordance with the title, rules for the transformation of XML documents, namely for restructuring, resorting, and renaming XML elements, are defined in the section XSL Transformations (XSLT). Formatting of XML documents on the basis of so-called Formatting Objects (FO) is defined in the main section of XSL.

In agreement with the two XSL sections, the publishing workflow of an XML document is also organized into two main processes. Figure 1 illustrates that first of all a transformation, in which a new XML document is produced, is carried out. The logical structure of this new XML document might be valid against a Document Type Definition (DTD). The case which is most often found in practice is the HTML- or XHTML-DTD, i.e. the transformation of the original XML document into an HTML or XHTML document.

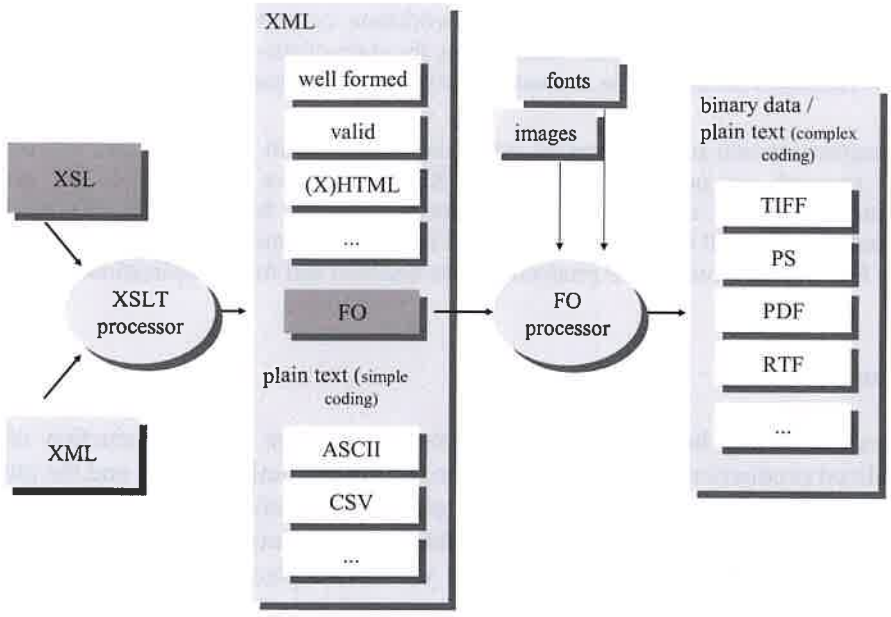

Figure 1: XML publishing workflow

In order to publish a PDF document it is first of all necessary to transform the original XML document into a FO document, i.e. a well-formed XML document, attributes and elements of which derive from the XSL-FO namespace. The FO elements and attributes describe the desired formatting of the output. ASCII or binary formats with complex encoding, such as PDF, can then be generated by means of an XSL-FO processor.

An FO document describes the formatting of an XML document on the basis of an area model. Within the model, the representation area (for example, an A4 page) is divided into block and inline areas. Block areas are destined for paragraphs, illustrations, etc.; inline areas are primarily used to place signs and words.

To all areas layout characteristics, such as margin, font-size, font-family, etc., can be assigned. The complete set consists of all the characteristics that are already defined by the W3C recommendation for Cascading Stylesheets (CSS) and additional novelties with regard to the extended field of XML applications. An important CSS supplement is the introduction of areas for page-oriented formatting. Areas and regions for headers and footers as well as for the layout of columns are available in XSL for this purpose. Another novelty is the orientation towards international application. XSL-FO therefore supports writing in any direction, for example, from right to left as in Hebrew and top down as in Chinese.

With regard to the use of XSL in high-end printing, qualified handling of colour is important. Colours which are predefined and known from CSS can be correlated with the different areas of an XSL-FO document or explicit RGB values can be set by means of the rgb-function in order to facilitate qualified colour management. Since printers do not work with RGB colour definitions but need CMYK values for printout, ICC colour profiles can also be integrated into an XSL-FO document. Colour space transformations, which are necessary for colour accuracy in print, can be performed on the basis of these profiles. In the XSL-FO document, the single values of an ICC colour profile can be referenced with the icc-color-function. Altogether different colour-functions are specified, however, the possibilities for colour-management-workflows based on XSL depend on the respective implementation in the available FO-Processors.

3. Potentials for print service providers with XSL-FO

Several DTP products, each of which has different specific advantages, are used in producing publishing products. On the one hand, there are professional DTP products on the basis of WYSIWYG, which are primarily suitable for the creative, manual layout process. On the other hand, established layout systems with rule-based controls, which are predominantly used for large, structured documents, are available. So, the question is: Where can XSL-FO-based workflows be placed?

Stephan Deach (Deach, 2002) sees a possible application of XSL-FO primarily in batch processes, in which structured documents are formatted on-the-fly. He identifies "financial-planning guides", "owner and maintenance manuals", and "legal agreements and contracts" as specific examples of contemporary XSL-FO application. Conventional layout systems might already generally support such processes; in the following it shall be demonstrated, however, that yet more efficient publishing concepts were introduced by the XML philosophy.

In contrast to the controlling technologies of conventional rule-based layout systems, XSLT offers a standardized, easy-to-use, and widespread programming language, which does not only allow formatting but also structural transformations. Conceptual and technical separation of transformation and formatting supports a correspondingly modularized production flow. In addition, it provides a basis for publishing projects with different user groups and output systems.

Figure 1 illustrates how the strict separation of content and layout is reflected directly in separate production processes. Core competences of all service providers engaged can thereby be used in the publishing workflow to the greatest advantage possible. The customer or publisher can devote him- or herself to the content of a publishing contract, a design agency takes care of the layout, the print service provider does the printing, and a web service provider publishes the content online.

Apart from presenting possibilities for optimized product quality, the depicted division of responsibilities also offers a potential for new, efficient workflows. As customary in many data-based applications today, the customer does not need to worry about layout every time data is updated but rather reuses layout parameters that are separate of any content.

As described above, conceptual and technical separation of production processes can generally also be achieved with proprietary approaches. The application of XML/XSL, however, has two advantages. Firstly, it supports more flexibility in the integration of backend systems, such as merchandise management, document management, or other systems, and thereby ensures, as does any other standardization, medium- and longer-term investment safety. Secondly, the use of standardized DTD/XML schemes provides an XML-specific advantage: The exchange of documents with standardized structure, which, for example, comply with one of the widely spread DTD for booklice publications (e.g. DocBook, ISO 12083 or TEI), enables the use of XSL style sheets for publishing orders from different customers instead of for one specific order only. Individual adjustment of customer layout, which is generally necessary, remains feasible and can be realized by gradually changing the overall style sheet. Technically, the included mechanism for XSLT style sheets provides a possible way to do so. Customer-independent transformation rules of the DTD can be administered independently of customer-specific ones.

In order to recognize suitable printing products for XSL-FO a starting point is dividing the production workflow of documents firstly into layout intensive versus uncritical processes and secondly into manual versus automated processes (see Figure 2). Independent of the workflow organization, a number of areas of application suitable for XSL-FO can be specified. These shall now be characterized briefly:

Structured printed matter

Structured print products have content that is characterized by clear, logical structure and rather functional and informative character (content-driven applications). These products can have great page volumes, such as product catalogues, technical manuals, and loose-leaf-collections, but they can also be brochures, labels, classified advertisement, etc.

Data base publishing / Personalization / Individualization

XML has already proved to be an easy-to-use and efficient exchange format for data bases and is therefore also suitable for application in publishing processes with integrated backend systems. Typical applications are the integration of merchandise management data or personalization data, which are of special interest in the publishing of individualized product proposals or business reports, for example.

Cross-media publishing

Media neutrality of XML and the XSL workflow directly supports the publication of content into different media. However data management which is really free of redundancy can only be achieved for text and vector graphics. Device-dependency of halftone images, which is a result of image resolution, continues to exist even if the image is embedded in an XML document.

Web printing

In his Seybold article, Ken Holman (Holman, 2002) draws attention to the fact that XSL-FO could help to improve the often inadequate quality that results when longer HTML pages are printed out. What he refers to is a special cross media application: The online reader who wishes to print out an HTML document does not simply use the print function of the browser. Instead, he or she generates a document in PDF or another print specific format. This document can be generated on the basis of the original XML data either on the web server or on the user client by means of XSL-FO.

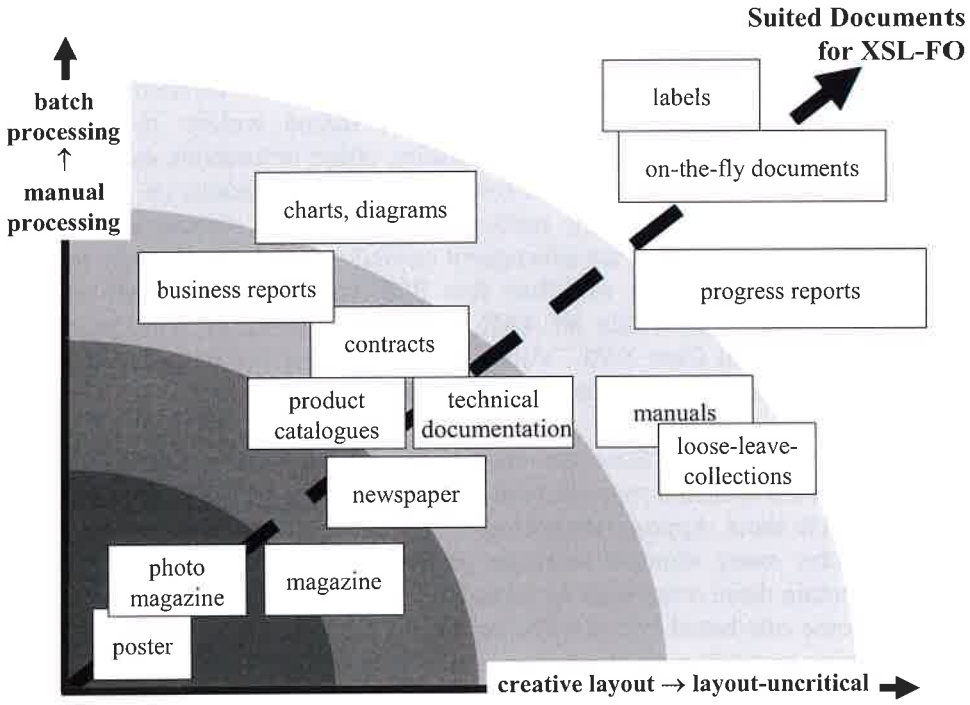

Figure 2: Suitability of documents for XSL-FO-workflows

Adaptive documents

Personalization and individualization of documents on the basis of intelligent automatic processes is the subject of contemporary research in the field of conventional and electronic publishing. In this context, XML is not simply a format for structuring documents but also one that contributes to the necessary semantic description of reusable document units. Among other things, the semantic data can be described in XML-coded meta-data. The meta-data can also be transferred directly into XSL-FO format (as values of role attributes). Thereby an FO processor is given direct access to the semantic of the layout objects. Specific examples of application are scripts for teaching which are compiled automatically of reusable teaching modules, a context specifically composed newsletter, or an individualized travel guide, etc.

Exchange of functional charts

The integration of charts, such as pie or bar charts, is often useful in business print matter. Illustrations of that kind have a strong functional character and are often generated on the basis of spreadsheets. XSL-FO supports the integration of external format, such as vector graphics, and especially the integration of XML data, such as Scalable Vector Graphics (SVG/SVGP). XSL-FO therefore enables the use of vector graphics without the necessity to apply separate technologies for text and graphic data. Furthermore, XSL-FO documents can be utilized to exchange vector graphics within formatted documents without loss of data structure or semantics.

XSL-FO enables the exchange of visual data that, on the one hand, contains all layout information necessary for printout onto paper or display on screen and, on the other hand, can also be used further for data processing in backend systems. Possible applications are business documents with visual data in table form, such as a quarterly report that contains sales figures with respect to type of branch, the evaluation of a product with extensive numerical series, or charts of stocks with the various days' rates, etc.

4. XML and XSL-FO as data exchange format in the print production workflow

PDF has developed into the standard format for exchanging and processing layout data in prepress. From a pragmatic point of view on the production flow, it is primarily the integrity and straightforward use of the format that caused PDF to spread widely. In addition, important characteristics, such as platform neutrality, compressibility, object orientation, etc. have reinforced the use of PDF. Typically, PDF is generated as the result of the layout process, i.e. the final stage of the creative design process. Depending on the particular print product, several steps, such as colour management, trapping, and imposition, are subsequent carried out in the technically oriented prepress. It is predominantly for this technical workflow that PDF has established itself as data exchange format. Hence, one of the tasks within an XML publishing workflow with paper output is the generation of a PDF document from XML. Various strategies that can be differentiated in terms of technical framework and business model can be employed to master this task.

From a technical point of view, there are two basic alternatives: standardized or proprietary conversion. Standardized conversion requires both an XSLT and an XSL-FO processor, which run on the basis of an XSL style sheet. Appropriate processors are available either as commercial or as public domain products. Today many standard software products (office packages, DTP tools, data base systems, etc.) also contain those processors as embedded modules. Proprietary conversion into PDF is mainly possible in some rule-based layout software into which XML can be imported and, by means of an internal formatting concept, printed out in various formats afterwards.

With regard to the respective business model, the following workflows are of interest for a print service provider:

The customer delivers PDF

Currently conversion of the XML document prior to delivery to the print service provider is the most common case. The customer provides the PDF document and the print service provider does not face any changes in comparison with conventional workflows. On this basic level, every print service provider therefore also supports XML publishing workflows.

The customer delivers XML content and XSL style sheets

In this case conversion is performed by the print service provider. The customer, however, remains responsible for generating the style sheet. This proceeding is especially interesting if the print service provider offers specific services which are based on the quality or on the characteristics that the employed FO processor supports.

A special processing of bar codes or the embedding of special sets of characters can be offered, for example. Quality of FO processors primarily differs in the support of different XML name fields, which can be embedded as instream foreign objects in XSL-FO. A print service provider can therefore offer first-rate support of DTDs, such as XForms, SVG, MathML, etc., as an additional service.

The customer delivers XML content without XSL style sheet

In addition to the services in the previous case, the print service provider also produces the XSL style sheet when XML is delivered without it. Both the drafting of a style sheet, which is generally done by specialized designers, and the application of style sheets from an available XSL data base should be viewed as services in this context.

In practice, this proceeding is interesting when the customer uses a generally known DTD (Open E-Book (OEB), DocBook, etc.). The print service provider can offer various XSL style sheets for the respective DTD. Ideally, the customer can test and choose the style sheets online via the Internet.

The customer delivers XSL-FO content

In practice, there will also be cases in which a customer, who publishes content for various media, does part of the publishing process him- or herself. The customer can, for example, independently carry out the transformation of XML documents, the related publication of HTML documents, and also the transformation into XSL-FO. He or she leaves the formatting by means of an FO processor to the print service provider, who is specialized in FO and PDF. As in the above case, the print service provider offers specific services on the basis of an extended XSL-FO processor.

5. Summary and outlook

By now, XML and XSLT have proved themselves in many online publishing applications. Many of the HTML pages that can be accessed today are already generated by XSLT processors without the users knowledge. The spread of XSL-FO and the realization of XSL-FO workflows are still in their early stages. While generation of PDF documents is already being applied for electronic use, production of premium printed matter on the basis of XSL-FO is still an exception.

The possibilities for XSL-FO business models in prepress, which have been presented above, and the manifold products demonstrate, however, that there is also a great potential for XSL-FO in printing industries. Moreover, we can count on XML/XSL gaining in importance as exchange format between customer and print service provider as FO processors are further optimized.

In addition, future spread of XSL-FO technologies certainly depends on the extent to which future XSL-FO extensions also serve "layout intensive" applications and to which degree support of printout onto paper in various XML standards is advanced. The SVG Printing Requirements (SVGP) are an important and interesting initiative in this context.

Considering that XSL-FO has been adopted as recommendation only in October 2001, it is too early to deliver any extensive prognoses. An observable trend is, however, that many producers in DTP apply XSL-FO not only in marketing but also in development departments.

References and further reading

Stephen Deach, (2002), *What Is XSL-FO and When Should I Use It?, The Seybold Report, Analyzing Publishing Technologies, Vol. 2, No. 17, 2002*

Dave Pawson, (2002), *XSL-FO. Making XML Look Good in Print. O'Reilly*

Ken Holman, (2002), *XSL-FO for Web Services and end-to-end book publishing, The Seybold Report, Analyzing Publishing Technologies, Vol. 2, No. 18, 2002*

XSL - Extensible Stylesheet Language, W3C recommendation and information: www.w3.org/Style/XSL/

SVG - Scalable Vector Graphics, W3C recommendation and information: http://www.w3.org/Graphics/SVG/

Customised information on packaging - production flow and logistics for hybrid printing solutions

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Abstract

In order to efficiently produce packaging with customised information the design of the system for logistics and production flow is critical. With a pre-set base layout for a packaging there are several print technologies that can be used depending on the required print quality and cost limitations. Using conventional technologies, long series give a low cost for a single packaging, due to cheap reproduction once the printing forme is produced. If customised messages are to be added and printed on the packaging, the preferred technology is digital printing.

In an ongoing research project, the purpose is to investigate the possibilities of obtaining both high quality and economically viable customisation using hybrid solutions, where conventional flexography printing technology is combined with digital printing. The purpose is to find out where in the value chain a digital printing task can be inserted and what the associated benefits and obstacles are. Three possible scenarios with different ways of applying customisation are described.

1. Customised information added on the packaging directly after the conventional printing.
2. Customised information added on the packaging when it is filled with content.
3. Customised information added on the packaging at the wholesale dealers/retailers.

There are however many parameters to consider in order to have a complete picture of the costs and benefits for the whole value chain. In this paper, two of the parameters that today restrain the trend toward shorter product series are investigated: changeover costs and cliché costs at a flexography printer. This gives necessary knowledge for the continuous research towards a complete evaluation of the different scenarios. The study is based on quantitative research through case studies at companies including a producer of packaging (printer) and a filler (producer).

By using a hybrid printing solution one basic design printed by conventional technology can be customised into several variants of packaging using digital printing. The results show that the differences in cost for the two parameters are considerable for small volumes. The analysis indicates that the second scenario is advantageous in some aspects but more research is needed to map out the whole value chain in order to get a complete comprehension of the cost and added value from a hybrid printing solution.

1. Introduction

A general trend today is that the quality of similar products from different brands is becoming more and more uniform (Olsmats, 2001). This means that a strong brand and the packaging design are of paramount importance. One way to make the product competitive and adapted to market forces is to tailor the information on the packaging specifically for customers or retailers. This is in line with the new trend, which, according to Loutfy (2002), is to sell products prior to production, as opposed to the traditional way where products are first produced and then marketed. According to Olsmats (2001) packaging can function as a very cost effective marketing tool.

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Kotler (2001) defines two extreme methods of marketing: massmarketing and micromarketing (complete segmentation). Between these two extremes are segment marketing and niche marketing. To better reach the customers, companies can divide a large heterogeneous market (where massmarketing can be applied) into smaller segments and thereby offer products adapted for each segment. Segments normally consist of large identifiable groups based on for example geographic or demographic variables. A subgroup within a segment is called a niche and the idea behind niche marketing is to more precisely satisfy the customers' needs. The most extreme method of marketing is micromarketing, where products and marketing are tailored to fit specific individuals (Kotler, 2001).

In order to hold small-scale campaigns in different countries and different markets, there is a considerable need for personalized packaging (Sarelin, 2001). An investigation focused on the food and pharmaceutical industry, within the business to consumer sector, showed that the driving force behind the use of customised information on packaging is the possibility to increase a product's consumer and market value (Viström, 2003). This possibility could be of great importance in order to win a position on the market, especially since the competition between companies continues to increase (Viström, 2003).

The business-to-business sector is also very interesting and challenging for customised packaging printing. Business markets are similar to consumer markets as the same people are involved in both types of markets and make purchasing decisions to satisfy different needs. However, a business marketer normally has fewer but larger buyers than the consumer marketer, but the business customer's demand often derives from the demand for consumer goods. Many of the same variables are used to segment both business markets and consumer markets (Kotler, 2001). Fewer buyers in a business-to-business value chain probably implies, however, that the market demand for different variants will be smaller than in a business-to-consumer value chain. This means that the logistics system, the handling and updating of information in databases, should be less complex and thereby less expensive.

If packaging is to be customised it can for small volumes be economically viable to only use digital printing, since there is no cost for any printing form. However, for larger volumes the biggest perceived limitation is that the cost is too high (Gillboa, 2002). A combination of different printing technologies could however be a way to minimize the increased cost per piece. As some of the information is general to all packaging, there are only certain parts that lend themselves to customisation (Dante, 2000). This means that the major part of the printing can be performed in advance. If a conventional technology is used for this pre-print, large-scale advantages can be achieved when high volumes are produced. If digital print is added afterwards, we get a hybrid printing solution that has both the potential to achieve large-scale advantages and the possibility to customise the information on each packaging. Since the cost of ink for ink jet and electro photography (two main digital printing technologies) accounts for a high percentage of the total cost of ownership (Kipphan, 2001), the total cost of pre-printing with conventional technology and thereafter adding smaller customised prints could be much lower compared to printing the whole packaging series in a digital press.

One interesting hybrid solution is flexography combined with digital printing. Flexography can be used for a wide variety of materials (paper, cardboard, plastics, metal), which means that this technology is well suited for the packaging industry (Johansson, Lundberg, Nyberg, 2001). Flexography is predicted to remain one of the major printing technologies and is especially suitable if flexible materials such as plastic film are used as substrates (Kipphan, 2001). The trend indicating that plastics will be used to an increasing extent within the packaging industry (Riley, 2003) is yet another argument for the use of flexography.

A digital printing task can be performed at different parts of the value chain. One option is to let the addition of digital print follow directly after conventional print. However by adding the digital print further down the value chain, advantages such as flexibility and the postponement of information binding can be achieved. Depending on the point in the value chain where the digital print is inserted,

the logistics and the production workflow of the whole system may be affected in different ways. These issues are analysed in an ongoing research project, where the purpose is to investigate the opportunities offered by a hybrid printing solution and to evaluate the optimal point in a value chain for the customisation task.

2. Research objectives and methods

In this paper, three possible scenarios in which the digital print is inserted at different positions in the value chain are described, which will give a comprehensive understanding of the research. However to evaluate the value and costs for hybrid printing solutions and to find the optimal location for the customisation task (digital printing), many parameters have to be investigated. This paper focuses on two particular parameters (changeover and printing forme costs for conventional printing) that today are limiting the development for shorter series. The purpose of this study is therefore to:

investigate if and how changeover costs and printing forme costs can be reduced when using a hybrid printing solution instead of conventional printing

Both the business-to-business segment and the business-to-consumer segment are interesting but in this paper, I have chosen to focus on the business-to-business aspect. There are several actors in a business-to-business value chain, who could gain advantages from tailored packaging. Middlemen could improve their marketing and make short run campaigns on the fly. There are also possibilities to increase the customer value of the product.

Within the business-to-business sector I have chosen to focus on the production of packaged paper reams in the paper industry. Paper producers are increasingly competing with products of uniform quality, which makes other factors such as logistics and branding decisive for whether the customers will make a purchase or not. Within this segment it is possible to identify specific niches. It could for example be interesting to adapt the information on the packaging for different geographical areas and specific printer equipment or offer to print customers' logos on the packaging. Many of the paper producers' customers are today asking for their own packaging design, but for small customers this is today considered too expensive.

Hence, this study will use the production of wrapping paper for reams in the paper industry as a case in studying the benefits and limitations of hybrid printing for packaging. The study is mainly based on primary sources (respondents at the selected companies). In addition, secondary sources (books, articles, Internet) are used to obtain information about related research and to collect interesting theories for use in the analysis.

Quantitative research using case studies performed at companies in the value chain, including the packaging producer (printer) and the filler (producer), was carried out during 2003. The collected data are based on interviews with respondents at the packaging producer and the filler. The price figures quoted are indicative, collected in 2003 and converted to euros. Observations of the production workflow also took place and wholesale dealers have been interviewed in order to have a comprehensive overview of the value chain.

Respondents:
Flexography printer: CEO, production manager, 2 operators
Paper producer: stock control supervisor, 2 production planning assistants, group product manager home & office, packaging line responsible, sales manager office paper
Wholesale paper dealer: division manager office paper
Wholesale office equipment dealer: CEO
Printer manufacturer: controller/purchasing manager

3. Scenarios for digital print

Three scenarios are presented here, illustrating the different points in the value chain where digital print can be added. Based on these scenarios it is possible to evaluate the opportunities and consequences of having a digital printing task placed with the different actors in the value chain: the packaging producer, the product producer (the filler) and the wholesale dealer/retailer. Other possible scenarios where new middlemen are introduced could also be defined but here, the number of scenarios has been limited to three, S1-S3.

S1: Customised information added to the packaging, directly following conventional printing at the *packaging producer (c1)*.

S2: Customised information added to the packaging when it is filled by the *producer (the filler, c2)*

S3: Customised information added to the packaging at the *retailers (c3)* on the local market.

According to Dante (2001), the most flexible platform for product customisation is integration of the printing and packaging operations. This corresponds to the second scenario and means that the printing could be changed during an ongoing process, which is the prerequisite for an on demand printing system. However, such a system carries a risk of interruptions in the production line, should printer problems occur. If the printing process is separated from the packaging line there is no risk for interruptions, if printer problem arises (Dante, 2003). There is also a need to verify the output in real time in order to ensure the integrity of the print (Dante, 2001).

Dante also discusses offline-printing close to the final packaging operation as well as integration of a digital printing task within the flexography press (corresponds to scenario 1). In my approach, I have also chosen to consider the possibilities of having a digital printing task at the wholesale dealers (scenario 3) since these actors are closest to the customers at the end of the value chain.

S1: Customised information added on the packaging directly after conventional printing

In the first scenario a digital printing device is installed directly after the conventional press. This means that the speed of the conventional press and the digital printing device have to be synchronised, if the digital printing is performed in-line. After the printing is made the packaging is transported to the filler, who will use them to pack his products. Flexo presses can at least reach speeds up to 300 m /min but many times they run at a speed of around 150 m /min. Several production steps and transports before the customised product reaches the customer would likely imply a higher risk for delays.

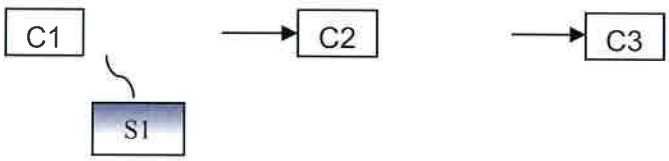

Figure 1: Scenario one

S2: Customised information added on the packaging when it is filled with content

In the second scenario the packaging producer is producing pre-printed packaging that are delivered to the product producer (the filler). For S2 the digital print can be added in-line before the packaging is filled or after the product has been packed. The latter alternative will most likely be more complicated since a packaging filled with content is 3-dimensional. Cubic packaging has six sides for printing, as opposed to a flat packaging substrate that in most cases only has one side that is of interest for printing. After the products are packed they are delivered to the wholesale dealers /retailers. As for scenario 1 the

speed of the digital printing unit has to be synchronised with the speed of the packaging line, unless customisation is made off-line in another press. The packaging lines is normally much slower than flexography presses, which means that the demand on the digital printing device is not as high. At lower speed it would also likely be easier to assure the integrity of the print and depending on the chosen equipment the print quality would likely be better.

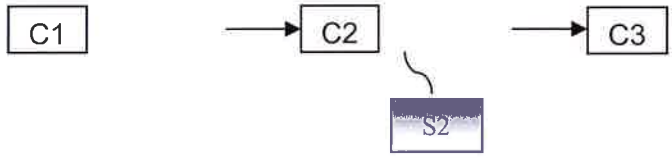

Figure 2: Scenario two

S3: Customised information added on the packaging at the retailer on the local market

In the third scenario the packaging producer is producing pre-printed packaging, which thereafter are delivered to the filler, who fills the packaging with content. The packaging are then sent to the retailer. At C3 information is added on the packaging by digital printing before the products are sent to the customers.

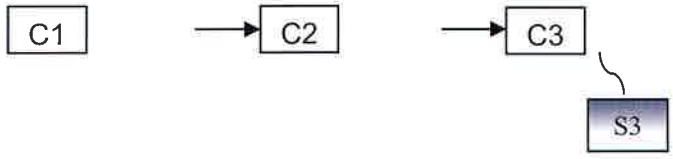

Figure 3: Scenario three

Adding the digital print at the wholesale dealer or retailer is maybe the most flexible way of customising a product. It could however be very expensive to print on packaging that is stored in a warehouse or at a retailer. There would likely be a lot of manual handling and if some kind of system for feeding packaging is to be installed to print inline it could be very expensive. For a high value product, with a good margin, it could be motivated to make a customised print at the wholesaler, but for a high volume product (with a low sales price) the cost for making the print has to be very low. It would accordingly be hard to motivate customisation of high volume products at (C3), especially since the products most likely also have to be unpacked from a delivery container before printing.

If the products are located and customised closer to the customers the deliveries could be more precise and faster. The wholesale dealer would most likely have better contact with the customers than the producer and be rather sure about their needs. One production step and transport to reach the customers instead of several would likely make the delivery faster and minimise the risk for delays. This will however depend on the printing equipment used for the customisation and the present workload at the wholesale dealer. It would likely take more manual handling to customise the products at a wholesale dealer or a retailer, whereby the capacity to handle a large number of customers would be limited. This could however be regulated by focusing the customisation task towards the most valuable customers, whereby micro marketing could be applied.

Technical aspects

According to Ashley (2003), ink jet technology is rather suitable for printing directly onto packaging materials. One advantage is that the imprinting unit does not enter into contact with the substrate, which might not be completely dry following conventional printing (Kipphan, 2001). As ink jet print-

ing is a non-impact technology, the thickness of the substrate is irrelevant (Moncarey, 2003), which also means that it is possible to print on packaging after the product has been packed, which is a pre-requisite for scenario 3.

The speed of electrophotography (around 60 m/min) is generally lower than ink-jet (120 m/min), which also has the possibility of operating at different speeds (Kipphan, 2001:2). Since speed is a very important factor in inline printing, and electro photography has a more limited variety of printable substrates, ink jet would seem to be the most interesting alternative.

One major problem in setting up a hybrid printing system is that the top speed of the different printing units varies a great deal. For single colour printing, the fastest non-impact printing technology reaches speeds of between 0.3 - 5 m/s. (electro photography, magnetografi, ink jet), while multi colour printing normally reaches speeds of between 0.1 and 0.5 m/s (electro photography, ink-jet). These differences in speed can make it impractical to build an inline hybrid printing system (Kipphan, 2001). A prototype inline variable data imprinting unit, based on drop on demand technology was developed by Heidelberger Druckmaschinen AG. This unit can print variable data in full colour at a speed of 1.6 m/s, providing quality prints in 600 dpi (Zhou, 2001). There are also other print heads (for example from Scitex) that can manage to print 300 dpi at speeds of over 150 m/min. These examples and the continuous development of ink jet technology gives a clear hint that print heads would be fast enough to set inline with a flexopress running at speeds over 150 m/min or a packaging line running at 20 m /min, which is a requirement for scenario 2 and 3.

4. Theoretical framework

In this section some theories about logistics and differences in requirement and aims between production and consumption are introduced.

Logistics is about getting the right product to the correct place at the precise time to a minimum of costs. Through logistics most companies want to increase their profitability or at least retain it. There are three different ways to increase the profit and to improve the profitability, the best method is to work with all three ways (Lumsden, 1998).

- Reduction of costs
- Increasing of the receipts
- Decreasing the capital tied to different types of stock

Business is created through marketing while logistics is needed to complete the sales process. The effectiveness of logistics can be described in terms of delivery service, costs and binding of capital. These terms are dependent on each other whereby all of them have to be considered to know the complete effects when one factor is changed. An improvement of the delivery service may for example give a higher binding of capital.

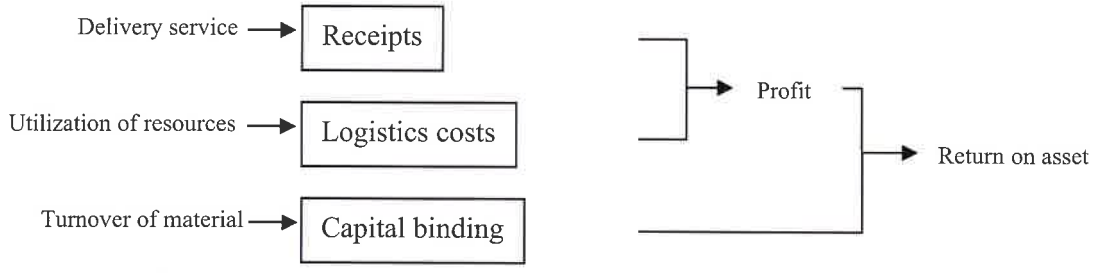

Figure 4: Connection between logistics and return on asset (Lumsden , 1998)

There is a strong connection between marketing and logistics, foremost through the conception of service. Customer service includes everything concerning the relation to the customer (Lumsden, 1998). However according to the marketing channels literature it is possible to define a number of gaps that illuminate that the producer and the customer have different requirements and aims (Abrahamsson, 1992).

Time gap - The producers are producing continuously in order to achieve large-scale advantages, but the customers are buying the products in discrete intervals.

Geographical gap - The customers are scattered over a large geographical area, while the producers are located on a small number of places.

Quantity gap - The consumers often like to buy small quantities, while the companies are producing large volumes.

Variant gap - The customers have different needs and are demanding many variants, while the producers has a limited numbers of variants of a product.

Communication and information gap - The producers do not always know who and where the potential buyer is to be found. At the same time the desired products are not always accessible for the customers.

Intermediaries are expected to create benefits and bridges between gaps in a more effective way than the selling company (Lambert, 1998). In this paper it will be discussed whether hybrid printing solutions also could be a way to bridge over some of the existing gaps between producers and customers.

Another factor, which is of crucial importance in order to meet the market demand for shorter series and faster updating, is **lead time** which is defined as the time between order and delivery. The lead time includes activities such as receiving of orders, handling of orders, planning, (if necessary) construction, manufacturing and distribution (Lumsden, 1998).

5. The case study value chain

The flow of reams studied applies to a segment where most buyers at the end of the value chain are companies who need office paper in their daily activity. A very small amount is sold to private purchasers (2000 tons per year). The reams are produced and packed at the paper producer (c2) using wrapping paper produced by the flexography printer (c1). They are thereafter shipped to different middlemen (wholesale paper dealers, wholesale office equipment dealers and printer manufacturers) who sell the reams to end-users. In the flow (illustrated in figure 5) data has primarily been collected from c1 and c2.

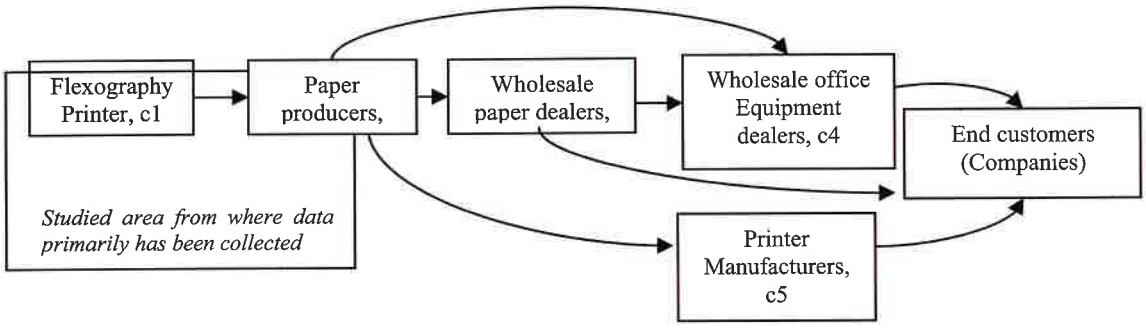

Figure 5: The product flow in the value chain

The Swedish market is consuming 90000 tons of office paper each year and 45000 tons of the total volume of office paper (90000 ton) is sold by (c2). The paper producer has to produce large volumes in order to cover the cost for the production and to make a good profit. In order to achieve this a certain amount of paper is often sold at a lower prize. In order not to damage their own brand the paper producer can sell less expensive products through the private brands of the wholesale dealers. There are about 1000 outlets where one can buy reams (including the wholesale paper dealer, the office equipment retailers and other shops). The end customers are purchasing around:

- 50 % of the volume from the retailers of office equipment
- 30% of the volume from the paper retailers
- 20% of the volume from the printer manufacturers

Wholesale paper dealer (c3)

The role of the wholesale paper dealer is sales, the coordination of deliveries from different manufacturers (thus providing effective logistics) and to offer a wide range of different types of paper. C3 are the largest wholesale paper dealer in Sweden and 95% of their volume is sold to wholesale office equipment dealers and 5% directly to end users. Around 20% of the reams sold by (c3) (white A4, A3) are delivered from stock, while 80% are delivered directly from the paper producer(c2).

Wholesale office equipment dealer (c4)

There are around 500 wholesale office equipment dealers in Sweden but today amalgamations into larger chains are an ongoing trend. When smaller companies become part of larger chains they can place higher demands on the paper manufacturers and wholesale paper dealers. Smaller wholesale office equipment dealers have to buy their paper from the wholesale paper dealers while the chains, due to their size, can buy paper directly from the producer and thereby obtain better prices. Today in Sweden there are 5 large chains of amalgamated office equipment retailers and each of them has developed their own brand. (c4) is the largest chain in Sweden with an annual turnover of 160 million Euro.

Printer manufacturer (c5)

Company (c5) is one of the largest printer manufacturers in Europe and has several own brands. They buy large quantities of office paper from several paper producers worldwide and can thereby cut prices and at the same time minimise the risk of running out of stock, in the event that one paper producer is unable to meet their demand.

5.1 The flexography printer

The printer studied in this case (c1) uses two flexography presses to make wrapping paper for customers within the food-, paper- and florist industry. One of their main products is wrapping paper for reams that are used by (c2). The substrate used for this product is laminated with polyethylene, which functions as a moisture barrier. The average operating speed is around 150 m/min for both presses.

When (c2) decides to develop a new design for a wrapping paper, an advertising agency produces a design based on c2's ideas. The design is then sent back and forth until approved by (c2). Afterwards a cliché manufacturer makes a proof, which is sent to both (c1) and (c2) within 7 days. After the proof is approved, the clichés are delivered to (c1) 5 days later.

The average lifetime of a cliché (112 * 39 cm) is 70 tons of printed paper (102 g/m^2), which means that it is possible to produce wrapping paper for around 3100000 reams before the cliché is worn out. The lifetime is shorter for fine raster clichés, which are needed to produce good quality pictures. The

cost of one cliché is around €800. The average number of changeovers in the course of a year is around 1748. According to the operators, the average changeover time (including cleaning, colour mixing, insertion of new clichés, colour adjustment) is 75 min.

The average sales price is €1.8 /kg, the average cost of paper is €1.09 while the cost of colour is €0,094. This means that the press generates €0.612 for every kilo produced. Since the average paper weight is around 100 g /m2, the average cliché length around 1 m and the average speed 150 m/min, the press generates €9.18 per minute. Hence the changeover time of 75 minutes is equivalent to €688.50. If the changeovers during the course of a year are added together, they correspond to a figure of €1.2 million.

5.2 The paper producer

The filler (c2) studied is one of the largest paper manufacturers in Sweden, producing pulp and thereafter making paper for copiers and printing devices. They produce more than 200,000 tons of paper (A4, A3) annually, which is packed as reams, using wrapping produced by (c1). About 10% of the volume is converted to A3 while 90% is converted to A4. The packaging area consists of three double and one single packaging line. Four different products can be packed at the same time (it is not possible to have two different variants on the double lines). The speed of each packaging line is around 18 m /min and all lines together can pack 350 reams /min (7 *50 reams/min).

C2 produces and markets five own brands, and 80-85% of the customers for these products are middle-sized companies. Besides their own brands they produce around 20 brands for printer manufacturers and office equipment retailers. There is a total of 84 different variants of wrapping paper. Five are completely blank, which means that there are 79 sets of clichés and a total of 215 clichés when the number of colors for each set is taken into account. Today there are several variants of wrapping paper for each brand, depending on the specifications of the paper (format (A4/A3), perforation, weight). Only a few design details distinguish these wrapping papers from each other, although different weights of paper (80g , 90g, 100g, etc.) require different sizes of the wrapping paper.

Sometimes products for specific orders have to be tagged with particular information. For example some countries insist on the information "Made in Sweden". When the volume is too small to purchase additional clichés for a new design, pre-printed labels are attached to the packaging. 8% of the annual volume sold consists of labelled packaging. There is however a desire to minimise the use of pre-printed labels, since they are problematic. The roll of labels has to be changed every hour (after 6 tons of paper is produced). The price of a pre-printed label is around € 0.011 and two application units (€ 7000 each) are required for each production line.

Today (c2) buys 48 different labels. Eight of these are pre printed to a basic design, which means that the information is printed on them before they are attached to the packaging. Today (c2) has 52 items of different information stored in a database for the customization of labels. There is a total of 165 variants of wrapping paper: 79 designs + 92 labels - 6 designs that need a label attached.

The incoming orders are between 1 and 500 tons, although on some occasions orders as small as 500 kg have been distributed. About 40% of the orders are delivered directly from stock (covers the Scandinavian market) while 60% can only be delivered after the products have been manufactured. The average stock of finished products is around 1800 tons (€1440000), and the average stock of wrapping paper is around 35 tons (€ 58000). If (c2) receives an order at the end of a week, a request for wrapping paper is sent to (c1), who produces the wrapping paper webs and delivers them to (c2) on the following Friday. This means that it will take at least one week before (c1) can start the production of the ordered reams.

When there are not enough products in stock to complete an incoming order or when the stock has to be replenished, an order is sent to (c1), who produces the desired amount of wrapping paper and delivers it to (c2). For the Scandinavian market the goods are delivered by lorry directly from stock, with a delivery time of around 2-3 days. For other countries products are shipped by sea, which takes around one week, depending on the destination.

C2 often receives enquiries from retailers who are interested in having their own design on the packaging. But since the costs of producing new designs and clichés are high, a customer has to buy at least 1500 tons per year in order to have their own packaging. This has actually led to a decrease in the amount of customised packaging ordered by customers. The number of packaging designs used by (c2) has decreased (world wide) from 160 to 79 since 1995.

6. Results

As described in the introduction, a general trend on the market today is a demand for more variants and faster updating of products. This trend also involves the paper industry. The handling of labels at c2 is one example.

The procedure for creating new designs in the studied value chain indicates that this process can be rather expensive, especially as the cost for designers and copywriters is high (Viström, 2003). Therefore the paper ream producer tries to minimise the number of different packaging designs. Today, the frequency for updating packaging designs is very low (once every 3-4 years). However if the updating frequency and the number of different designs were to increase (in line with the general market trend), the costs involved in updating and/or creating designs or text information could be immense.

If packaging is to be tailored to fit specific regions or other market segments, it is possible to have one basic design that can be customised for each region by the addition of digital print. This implies the possibility of only needing one set of clichés instead of a set of clichés for each region. Table I illustrates the difference in cost between one set of clichés and six sets of clichés (a typical situation in the studied case) when the design is updated after the production of 3 100 000 packaging units. As stated in the description of the value chain, the cost per cliché is €800 and for a three-colour design (the average number of colours used at c1) the cost trebles to €2400. This figure corresponds rather well to the average number of colours used by (c2), which is 2.72 (215 clichés divided by 79 designs). However, if the demand for more colours on packaging were to increase (c1 had to buy a new press to produce 7 colours jobs), the average numbers of clichés will increase and thereby also the cost. The cliché cost per ream (3 colours) is around €0.00077 if the cliché wears out after 3100 000 packaging units, which is the figure used in the example. By using hybrid printing it will be possible to wear out the clichés even if a basic design is updated more frequently in the future.

Every new order at (c1) means a changeover in the press that according to the calculations above amounts to a cost of around €688.50 (assuming that the press could have been running during the changeover time). Even if the cliché is used for a large volume of packaging or wears out, new market orders with shorter series will result in a high changeover cost per packaging unit, unless the same cliché is used for different segments during the same printing process (as shown in table I). If the information in the basic design is less detailed, it is also easier to update the packaging without the need for updating the clichés. Packaging for 20,000 reams corresponds to around 500 kg paper, which are the smallest orders produced today by (c1) and the smallest orders delivered by (c2). According to the example in table I, a digital printing task for this order size could cost €0.033 per ream in order to break even with the first alternative, where conventional printing is used. However, when the number of variants increases and the series become shorter, the advantages of having one set of clichés for a basic design that can later be adapted by means of digital printing will become greater.

Table I: Comparison of changeover and cliché costs per packaging unit between one and six sets of clichés, for different order sizes

Alt. 1: Separate clichés for each of the 6 regions	**50 kg**	**500 kg**	**2 ton**	**10 ton**
Cost per design & cliché (112*39cm) (€)	800	800	800	800
Number of colours (nb. Of clichés)	3	3	3	3
Total cliché costs(€)	**2400**	**2400**	**2400**	**2400**
Number of packaging before change of design	515768	515768	515768	515768
Cliché cost / packaging (€)	**0.0047**	**0.0047**	**0.0047**	**0.0047**
Changeover costs (€)	688.5	688.5	688.5	688.5
Number of packaging per order	2000	20000	80000	400000
Changeover cost / packaging (€)	**0.34**	**0.034**	**0.0086**	**0.0017**
Total cost / packaging (€)	***0.35***	***0.039***	***0.013***	***0.0064***
Alt. 2: One basic layout for all 6 regions				
Cost per design & cliché (112*39cm) (€)	800	800	800	800
Number of colours	3	3	3	3
Total cliché costs(€)	**2400**	**2400**	**2400**	**2400**
Number of packaging before change of design	3094607	3094607	3094607	3094607
Cliché cost / packaging (€)	**0.00078**	**0.00078**	**0.00078**	**0.00078**
Changeover costs (€)	688.5	688.5	688.5	688.5
Number of packaging per order	2000	20000	80000	400000
Changeover cost / packaging (€)	**0.057**	**0.0057**	**0.0014**	**0.00029**
Total cost / packaging (€)	***0.058***	***0.0065***	***0.0022***	***0.0011***
Alt 1 - Alt 2 (€)	0.29	0.033	0.011	0.0053

As stated previously (c2) has 79 sets of different clichés, of which 6 lack specific information, meaning that the wrapping paper thus produced has to be customized in the packaging line by the addition of a label. Since the number of designs has halved since 1995, the number of labels has increased. Hence, labeling is a way of customizing the products inline. It is however, desirable to minimize the use of labels since the label roll has to be changed after 6 tons of paper is produced and according to two people in charge of packaging at two large food producers in Sweden, a label does not look as professional as information printed directly on to the packaging. While some of the labels are pre-printed, additional information needs to be included before they can be used.

The production of reams could work out less expensive if a hybrid solution is used (as shown in table I). However, if the cost exceeds the logistical gains the value of adding the digital print must at least compensate for this extra cost. Digital print can for example lead to improved marketing, a higher product value and thereby increased sales. Figure 6 illustrates these two alternatives.

It is difficult to estimate precisely how the total costs within the value chain will be influenced by an implementation of a hybrid printing solution. In addition to the cost involved in the actual digital printing task, there are other costs that may be affected. The cost of administration and the handling of information and goods will more than likely increase when the products are customized and the number of variants increases. A greater variety of packaging also means extra handling costs and ensuring the accuracy of an increased number of products. Hence more detailed observations of the whole value chain are necessary in order to obtain an accurate estimate. Further research on the cost of implementing a hybrid printing solution and how this cost will relate to the added value from customization would thus be interesting.

When it comes to lead time, in order to be in a position to make rapid deliveries directly from stock, there is a need for large inventory. However, if a company stocks an extensive range, the inventory costs could be considerable (Stol, 2003). In order to reduce the inventory, orders can be produced on

demand, which means a longer time to market. Since lead time is a very important element of competition, it is preferable to try to keep it as short as possible.

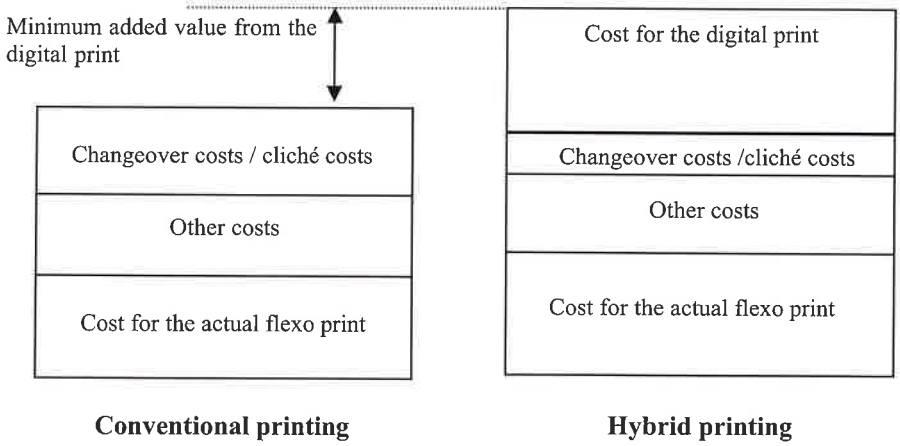

Fig 6: Costs for conventional and hybrid printing solutions

One possible solution is to try to predict demand and keep the corresponding webs of wrapping paper in stock. This means that the extra week of waiting for wrapping paper to be delivered from (c1) could be eliminated. However, besides the high costs of keeping a large stock of preprinted paper (necessary to ensure the availability of every single variant) is very difficult to make accurate predictions. However, delayed orders lead to unsatisfied customers. One possible solution would be to reduce the number of different variants of pre-printed packaging to a few basic designs ready for customization, thus minimizing both the stock and the risk of delayed deliveries. In other words, one basic design would be sufficient for several variants. This also implies that (c1) can produce continuously, even if customers purchase different variants at discrete time intervals. Hence, the time gap decreases. However, the customers' demand and the number of basic variants required will determine the size of the stock needed. The corresponding cost has to be compared to the expected gain from a shorter lead time. Among the scenarios described above the second or third would be possible alternatives if this solution were to be applied. For a high volume product such as reams (in the event that every ream has to be customized) the customization should take place inline at the producer's premises, since the cost of retailer customization without a large scale production line will most likely be too high. This leaves us with the second scenario.

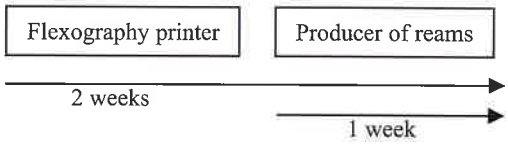

Fig 7: Possibility of reducing lead times if pre-printed webs are kept in stock by the ream producer

7. Discussion

Hybrid printing solutions could make customisation and shorter series possible at a lower cost, even if many factors have to be considered before a hybrid printing solution can be deemed successful. Conventional printing can be used to gain large-scale advantages while digital print can be added in order to customise the packaging. This means that it would be possible to bridge several of the gaps defined in the frame of reference. In particular, it would be possible to reduce the quantity gap and the variant gap. When the gaps are minimised the production will better meet customer demand.

If a paper producer can offer tailored packaging for medium and small customers due to a successful production flow, it goes without saying that these customers most likely will choose him as their supplier (assuming that the price, logistics and product quality are comparable with those of his competitors).

Only one flexography printer and one paper producer were included in the present study. However, since the paper producer supplies half the Swedish market with reams, it is no doubt the most representative company in Sweden. This study should be of interest to value chains which include a flexography printer making wrapping paper for producers that have a packaging line, although the exact figures and the demand for customization will however most likely vary according to the line of business.

As mentioned previously, more research is needed to investigate the cost of implementing a hybrid printing solution and whether the cost is justified by the added value from customization. According to a large print head manufacturer, every new installation of in line ink jet printing involves a great deal of specific testing. Many parameters have a bearing on the print quality (e.g. speed, substrate, type of print, ink jet technology, type of ink). This makes it more difficult to provide a general answer to the question of how much a hybrid printing solution will cost.

8. Conclusions

The study shows that, by using a hybrid printing solution combining flexography and digital printing, it is possible reduce or at least maintain existing changeover- and cliché costs should future market trends favour shorter series and more frequent updating. This can be achieved by decreasing the number of basic designs on packaging and have them customised instead, for example on the producer's packaging line, before delivery to the customer. This could also result in a reduction in lead-time. However, these decreased costs, the additional customisation costs and the added value from providing customised products have to be evaluated in relation to each other in order to ascertain whether or not a hybrid solution for providing customised information on packaging is economically viable.

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References

Abrahamsson M., (1992) *"Tidsstyrd direktdistribution", Studentlitteratur, Lund; pp. 44-47*

Ashley T, Willis M., (2003) *2003 International Conference on Digital Production Printing and Industrial Applications, Barcelona, Spain, 2003; pp. 116-117*

Dantes H, Karles G, Basak A., (2000) *"Digital Printing in Industrial Packaging Applications" IS&T's NIP16 Vancouver; pp. 519-522*

Gillboa Ron, (2002) *"The production Digital Printing Market: Opportunities and Trends", IS&T's NIP18: San Diego, California; pp. 134-138;*

Impact Marketing Consultants, (2002) *"Flexo ink profits flow", Flexo (Ronkonkoma NY) December 2002;pp. 10-13*

Johansson K, Lundberg P, Ryberg R., (1998) *"Grafisk kokbok" 1st ed, Arena & Kapero, Värnamo; pp. 217*

Kipphan, (2001) *"Print Media" Springer Verlag Berlin Heidelberg New York; pp. 761-771*

Kipphan, (2001:2) *"Print Technologies and Design Concepts for Hybrid Printing Systems", DPP 2001: Eye on the Future, Antwerp, Belgium;May 13, 2001; pp. 33-38*

Kotler P, Armstrong G, Saunders J, Wong Veronica, (2001) *"Principles of marketing" Pearson Education Limited, Edinburgh Gate, Harlow; pp. 314-333*

Lambert D, Stock J, Ellram L., (1998) *"Fundamentals of Logistics Management", McGraw-Hill Higher Education, USA; pp506-513*

Lumsden K., (1998) *"Logistikens grunder", Studentlitteratur; Lund pp221-230*

Moncarey K, Van den Hole G., (2003) *2003 International Conference on Digital Production Printing and Industrial Applications Barcelona, Spain; pp. 164-165*

Olsmats C., (2001) *Packaging Foresight Packa Futura, Packforsk, Stockholm; pp. 90*

Riley A., (2003) *"The threats to my packaging" Speech at the conference "The future role of packaging 25-26 March 2003" (organised by STFi / Packforsk) Stockholm*

Sarelin P., (2001) (Research manager at Walki Wisa) *Press release PacTec 2001 http://w3.walkiwisa.upm-kymmene.com/*

Viström M., (2003) *"Customised Information on Packaging - Business Opportunities and Consumer Value", TAGA 2003 Montreal (to be published).*

Zhou Y, Rensch C., (2001) *"Applications of page wide Piezo Inkjet printing to commercial and industrial market", DPP 2001: Eye on the Future, Antwerp, Belgium; May 13, 2001; pp. 50-53*

5

Computer-to-plate technology

CtP PDF quality control

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Abstract

Modern graphic processes demands greater reduction of production time in prepress. This especially applies to platemaking phase. CTP systems today are capable to perform this reduction of time but they require a whole new approach in preparation of print production.

In this paper are presented the experiences and the results of measurements, quality control and standardization of the first CTP workflow in Vojvodina. It contains software prepress, especially the compability of PDF files with PDF/X and other standard file formats.For measurements were used digital control strips of various vendors. Different procedures were developed according to demands of working environment in compliance with corresponding standards.

1. Introduction

There are a few inventions which have changed the civilization: the wheel, the clock, the steam machine, the computer, ... Most of these inventions have derived from a developed technical environment and previous knowledge and experiences. Computer to Plate technology has a significant basis in the development of emulsions, light sources, engineer constructions of imaging devices and, what is the most important, in intensive computer development. Measuring and control methods for the standardization and quality assurance in graphic processes make up the foundation of the quality control in CtP technology with its own characteristic properties.

In this paper the researchers from the Department of Graphic engineering and design at the Faculty of Technical Sciences in Novi Sad have tried to apply international experiences in the specific environment of domestic print shops. In Serbia, from the middle of 2002 until the middle of 2003 four CtP imaging devices and 2 CtCP's had been installed, which makes the total number of all available installations. The small number of devices and short device exploitation time had just narrowed the area of work. Quality control of the production workflow from the incoming digital files to the final printed material on the CtP installation has been conducted in Birografika, Subotica. Presented here are the procedures of control which are suitable for production conditions, and which enable a continual effective and efficient production process control.

2. Statement of the problem

Digital workflow process control demands a coordinated and well-directed control system, from the incoming digital file to the final print. Mistakes or omissions cause the increase of production time and the inevitable rise in production costs. On the other hand, the customers and the market demand a shorter production runs and, what is the most important, high quality. Transition from the conventional plates on the CtP offset plates brought a change in the control conception. A CtP imaging device, as a compactly built system, consists of more subsystems which are interrelated, and every offset from the tolerance limits result in certain consequences. The beforehand control of the information transfer from

the film to the plate could easily be observed with the control wedge which has been exposed at different exposing levels. This has been done successfully also on CtP imaging devices, but the level of exposition is just one of the myriad of factors which are vital in working with CtP. The linearisation of halftone dot percentage ratio is the function of the imaging device and the size of the laser spot, and not just the exposition level. Different surface asperity of the aluminum substrate of the printing form can make matters more complicated. The variations in quality of the copy layer emulsions can affect the quality of the plate, but the copy layer on the plate is not critical, especially not on the thermal plates. The employees at the print shops cannot influence the quality of the plate. Their communication with the plate manufacturer goes through the batch number of the faulty plates.

The quality of the imaged and chemically processed CtP plate is also influenced by: the insufficient calibration of the platesetter/RIP, change in the system status due to changed environmental influences during production (humidity, temperature), too low laser intensity due to a defect, ageing, or dust and dirt contaminating the laser or optical paths, temperature fluctuations in the plate processor, activity (level of exhaustion) of the developer in the plate processor, washing quality of the plate surface.

3. CtP workflow quality control

CtP workflow quality control consists of different components, and the most important ones are:

1. Digital PDF file preflighting
2. Plate quality
3. Plate control after imaging and processing
4. Print control
5. Plate control after printing

The definition of the critical control points in the process is the most important thing to get a complete and compact overview of the state of the task. The most significant parameters of the control points are shortly discussed.

3.1 First control point: digital PDF files preflighting

The transition on a full digital workflow has changed the used file types, namely the masters for data exchange. The control process has moved more to the beginning of the digital workflow because bad incoming information is causing problems throughout all production phases. Contemporary workflows are demanding digital compact, robust files, which conform all computer systems. The PDF file format, and especially its standardized versions, bring a necessary reliability and consistency to the digital workflow.

Although the master file (in our case PDF) has no effect on the quality of CtP plate processing, the integrated workflow makes it indispensable to check the conformance of the incoming files with standards. Preflighting is already a standard option and a process step in all CtP PDF workflows. Every company chooses the most suitable PDF/X version depending on their production profile.

The family of PDF/X standards (CGATS, 2002), currently consists of:

PDF/X-1 and PDF/X-1a (ISO 15930-1) (which permits only CMYK and Spot colors) for complete exchange using CMYK data;
PDF/X-2 (ISO 15930-2) for partial exchange;
PDF/X-3 (ISO 15930-3) (allows device independent color spaces like ICC RGB or Lab);
for complete exchange suitable for color managed workflows.

Measuring procedures

Software applications which are available on the market and which are a principle part of the preflight process were used in the measurements. On the installation Enfocus PitStop 5.02 was used to preflight the incoming PDF files. The preflight profiles for PDF/X which were used are incorporated in the application. For the verification and comparison of preflight reports as an alternative, Callas PDFX3 Inspector was used.

The measured variables were:

file size, version and compliance with PDF/X standards;
for preflighting PDF/X-1a PLUS Magazines v.2; PDF/X-1a:2001 v.2 Verification;
and PDF/X-3:2002. profiles were used.

Results

48 PDF files were preflighted. The average file size was 2.95Mb (the largest file was 7.11Mb, the smallest 0.67Mb). All files were in PDF 1.3 version. None of the preflighted files was compliant with PDF/X-1a:2001 or PDF/X3:2002 standards.

Table I: Exhibits the deficiencies that implied the noncompliance with PDF/X standards

Deficiencies	OPI	Output Intent	Trapped Flag	Effective resolution of single bit black and white resolution less than 600 dpi
Number of files	15	48	48	1
Percentage (%)	31.25	100	100	2.08

Although the preflighted PDF files did not conform with the standards, none had the so-called rough mistake which would cause significant editing or production delay. All shortcomings have had procedural mistakes, namely that they have been created without the necessary procedures that PDF/X standards state.

3.2 Second control point: plate quality

At the beginning those critical points were determined that can influence the quality of plate processing and which are measurable during the production, without disturbing the continuality of the production process. The application notes and recommendations from FOGRA/UGRA and IFRA were used.

The first critical point is the plate quality. The quality of the printing plate is related to its manufacturer. In the printing process the control adds up on writing the batch number and recommended plate handling and storage.

3.3 Third Control point: plate control after imaging and processing

The next step is the assessment of Raster Image Processor. Calibration and tonal transfer characteristic curve are assessed with a digital control wedge and a plate measuring device. Regular calibration and linearisation is a necessity, and dot gain compensation can be done when it is required.

On the CtP system there are two main critical points to observed:

- Imager (laser and drum)
- Processor

Laser is the most important part of the imager that influences the quality of platemaking. Continuous laser control is required due to a myriad number of factors affecting it: loss of intensity due to ageing or contamination and mechanical changes (IFRA, 2001). Additionally, different plate types have different sensibility level, so it is necessary to regularly control the intensity. We have included this control step in the measuring protocol, but we have not done it on the observed installation.

A test with a gray plate (plate that is covered completely with a 50 percent dot area screen) verifies that the plate is exposed and developed in a uniform manner. We suggest that this test should be part of the protocol, although we had not done it.

The next test was the test with nine control wedges (Junglas, U, 2001), which has two objectives:

- To determine the laser precision across the full exposure surface
- To give information for calibration

The measurements were made on RIP and imager that was calibrated and had adjusted dot gain compensation curve. For the purpose of this analysis only the 50% dot area patches were measured. For the calibration assessment a standardized digital control wedge was used.

Results

Tables II to V display the result of calibration values.

Table II: Linearisation values or cyan plate

RTV(%)	1	2	3	Mean value /%/
2	1.4	1.4	1.4	1.40
10	8.2	8.1	8.5	8.27
20	18.3	18.5	18	18.27
30	24.2	24.6	24.2	24.33
40	35.6	36.4	36.6	36.20
50	43.3	44.8	44.2	44.10
60	55.8	55.8	56.5	56.03
70	65.3	64.7	65.3	65.10
80	75.2	76.0	75.7	75.63
90	88.6	88.9	88.2	88.57
100	100	100	100	100

Table III: Linearisation values of magenta plate

RTV(%)	1	2	3	Mean value /%/
2	1.4	1.4	1.4	1.40
10	9.5	9	9.4	9.30
20	18.7	18.2	18.5	18.47
30	23.4	23.9	23.8	23.70
40	33.7	32.7	34.2	33.53
50	45.3	43.9	43.4	44.20
60	57.5	56.4	56.4	56.77
70	65.7	67.3	66.1	66.37
80	74.8	74.8	76.0	75.20
90	89.1	89.1	89.0	89.07
100	100	100	100	100

Table IV: Linearisation values of black plate

RTV(%)	1	2	3	Mean value /%/
2	1.3	1.3	1.2	1.27
10	8.5	8.4	8.4	8.43
20	17.9	18.1	18.1	18.03
30	24.8	23.5	24.9	24.40
40	35.3	35.2	35.2	35.23
50	45.2	45.3	45.3	45.27
60	55.5	55.2	55.6	55.43
70	64.8	65.4	65.4	65.20
80	76.3	76.0	76.7	76.33
90	88.1	87.7	88.0	87.93
100	99.6	99.5	99.3	99.47

Table V: Linearisation values of yellow plate

RTV(%)	1	2	3	Mean value /%/
2	1.2	1.2	0.8	1.07
10	8.3	8.2	8.3	8.27
20	16.9	16.7	16.6	16.73
30	21.8	21.9	22.2	21.97
40	31.3	33.8	33.0	32.70
50	47.4	46.6	45.9	46.63
60	55.6	55	53.1	54.57
70	67.0	67.4	68.2	67.53
80	73.4	76.1	72.7	74.07
90	88.9	89.5	88.7	89.03
100	100	100	100	100

Measuring procedures

Nine control wedges were made on two plates for parallel comparison. The values of the 50% dot area patch and the single halftone dot size on 50% dot area were measured. A Vipcam 116 plate measuring device was used for the measurements.

Results

Tables VI-VIII display the results. Figure 1 shows the position of the used control wedges on the plates.

Table VI: Values of 50 % halftone (first plate)

Position	Measuring number 1	2	3	Mean value /%/
1.	43.0	43.5	45.6	44.03
2.	46.9	45.5	44.3	45.57
3.	45.4	44.4	45.8	45.20
4.	44.4	46.5	46.5	45.80
5.	46.8	46.9	46.9	46.87
6.	43.3	42.7	44.4	43.47
7.	45.6	44.8	46.1	45.50
8.	45.6	45.6	43.3	44.83
9.	46.1	46.8	45.1	46.00

Table VII: Values of 50 % halftone (second plate)

Position	Measuring number 1	2	3	Mean value /%/
1.	44.3	45.4	44.0	44.57
2.	45.0	47.2	47.1	46.43
3.	43.0	41.8	44.9	43.23
4.	46.9	46.9	46.9	46.90
5.	42.7	45.0	46.9	44.87
6.	44.4	46.7	43.9	45.00
7.	43.9	46.7	42.8	44.47
8.	45.0	45.4	43.5	44.63
9.	46.2	46.2	46.2	46.20

Table VIII: Mean value of single halftone dot of 50% in nine positons (59 l/cm)

Position	Measuring number 1	2	3	Mean value /μm/
1.	130	131	128	129.67
2.	130	130	127	129.00
3.	129	130	130	129.67
4.	130	130	128	129.33
5.	129	130	127	128.67
6.	129	130	127	128.67
7.	126	131	129	128.67
8.	130	128	126	128.00
9.	128	130	129	129.00

The values of dot area patches and single halftone dot size were checked for exposure consistency. The difference between the mean value of the nine 50% values and the largest offset from that value was calculated.

Results

On the first plate the largest difference was at position six with the value of 1,78 and the smallest at position three with the value of 0,05. On the second plate the biggest difference was at position three with the value of 1,91 and the smallest on position six with the value of 0,14. The largest difference from the mean value of halftone dot size was in the first and third areas with the value of 0,71.

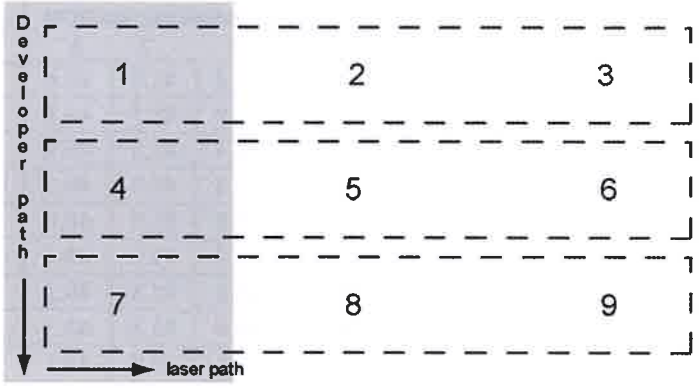

Figure 1: The position of nine used control wedges

A Vipcam 116 plate measuring device was used to measure the single halftone dot size on a 40 percent dot area and an 80 percent dot area with control wedge on every separation of one printing form. Table IX shows the results.

Table IX: The dot size values on 40% and 80% halftone value patch

Dot size in /μm/	Magenta				Cyan			
	1	2	3	Mean value	1	2	3	Mean value
80 /%/	166	166	166	166.0	166	165	166	165.7
40 /%/	113	116	114	114.3	114	114	114	114.0
Dot size in /μm/	Black				Yellow			
	1	2	3	Mean value	1	2	3	Mean value
80 /%/	167	165	166	166.0	164	161	162	162.3
40 /%/	115	112	111	112.7	103	106	102	103.7

All the imaged and processed plates had a clearly rendered 2 percent dot area, and the 98 percent dot area was not clogged.

The assessment and measurement were made on Screen Plate Rite 8600 CtP system, the used plates were Fuji LH-PIE thermo plates. It should be noted that the environmental conditions and the variables in chemical processing of the plates (the developer temperature, pH and conductivity) were held constant during the whole process.

3.4 Fourth control point: print control

Based on the linearisation of the CtP plate (Tables II to V) it is clear that the dot gain in the print will be smaller. The print control was conducted visually, because for the purpose of this analysis, the dot gain in print was no consequence. The corresponding procedures and standards are used in every department in the print assessment; therefore conventional densitometric measurements were not made.

3.5 Fifth control point: plate control after printing

Measuring procedures

10 samples were taken for this experiment. The samples were taken from the same positions on both plates (Figure 2). 5 samples were taken from a processed plate that was not used in printing (Figure 2a) and 5 samples from the plate that was processed and that was used in production (Figure 2b). The samples were processed, measured and visually analyzed on a JEOL JSM-35 electronic scanning microscope.

Results

Figure 3a and 3b displays the results of a samples surface picture. The wornness of the surfaces of the printing areas can be sighted after 60.000 impressions.

The wornness size of the printing elements can be measured at the magnification of 1000x and 5000x.

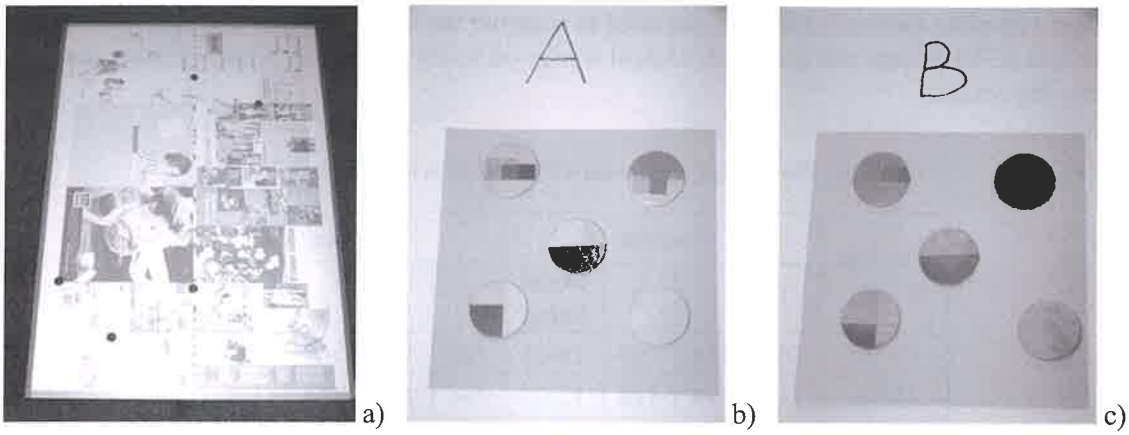

Figure 2: Positions of the taken sample and taken samples from the plates
a) Positions of the taken sample, b) Samples from the imaged plate that was not used in printing
c) Samples from the imaged plate that was used in printing

Results

Figure 3a and 3b displays the results of a samples surface picture. The wornness of the surfaces of the printing areas can be sighted after 60.000 impressions.

The wornness size of the printing elements can be measured at the magnification of 1000x and 5000x.

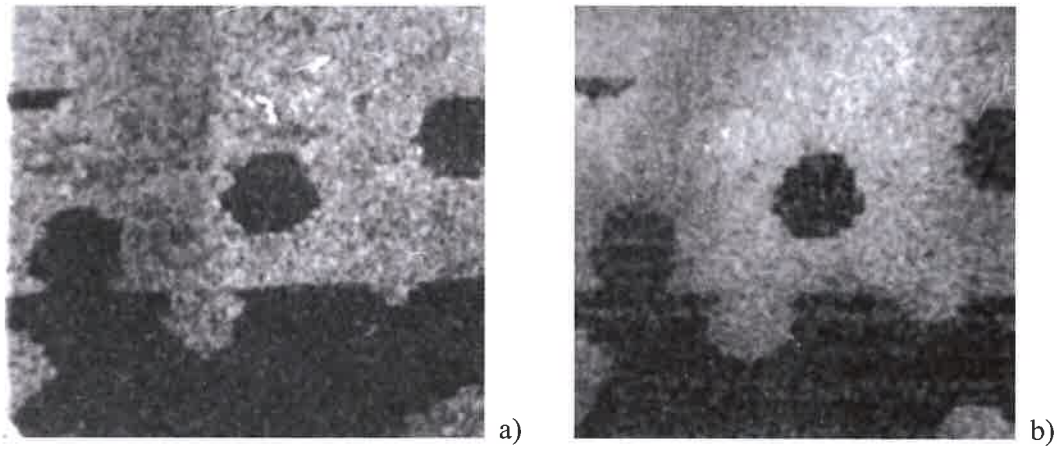

Figure 3: The results of a samples surface pictures
a) The printing surface of the plate that was not used in printing
b) The printing surface of the plate that was used in printing

For data processing a software application was developed. It contains control measurement assesment tables. This will be a basis for further comparation of future results from different plates and platsetters.

4. Conclusion

The processes of measuring and control are in particular important in the introductory phase of the CtP system appliance. It is a mixture of hitherto applied measuring procedures, modified and completely newly introduced ones, that are compliant with the newly applied technology-digital PDF files

preflighting, imager calibration and linearisation. The gained experience and the measurement results are significant in the inauguration of reliable workflow parameters that are giving good production results. The measurements were made on only one CtP plate (thermal). For more significant analyses it is necessary to consider results gained from imaging of different plate types in different CtP systems.

Literature

Callas Software Gmbh, (2002), *PDF/X-1a and PDF/X-3:Conversion and verification in pdf Inspektor2 and PDF/X-3 Inspector (Freeware), technote*

CGATS, (2002), *Application notes for PDF/X standards Version 3*

IFRA, (2001), *Automated process control in CtP production, IFRA Special report 2.32*

Junglas, U., (2001), *Calibration and CTP imagesetters, International Newspaper Color Quality Club 2002-2004*

Karlović, I., Pešterac, Č., (2002), *Ctp PDF Workflow, Proceedings GRID '02, First scientific symposium, Novi Sad, pp. 135-142*

Pešterac, Č., Novaković, D., 2002, *Offset plates for Computer to Plate technology, Proceedings GRID '02, First scientific symposium, Novi Sad, pp.123-130*

CtP system assessment with resolution and vignette patterns

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Abstract

For many companies quality assurance for CtP plates is a problem area. Small sized test patterns like those of the Ugra/FOGRA Digital Plate Wedge are commonly used to document the actual output resolution in a variety of target configurations. Such patterns, however, do not suffice if image rendering is not uniform throughout the format. Loss of density, streaks and stripes generated by the plate setter frequently appear only in limited areas of a plate. Furthermore, drawn-out, large vignettes cannot be accommodated in small control devices. In a FOGRA research project a test forme for testing the output performance of plate setter and processor combinations was developed. Tint strips, various vignette designs and a number of resolution patches were used to calibrate and adjust the laser beam spot size and imaging accuracy in a full size printing plate. Vignettes with defined screens and default screens are used to document advantages and shortcomings of different screening methods and their impact on printing. The parts of the CtP test forme and the results achieved with them are discussed for various CtP systems and plate types. The practical use of the test forme in a production environment is shown.

1. Introduction

With the wide spread use of CtP systems the once segmented workflow from design to print has been reduced to a two-step workflow. Today digital prepress includes plate making and therefore prepress and press room people have to communicate to assure optimal print quality. Any error or misunderstanding can result in product rejection and compensation claims.

In any workflow for plate imaging the user does not have many options to choose from. Once an investment is done the software components and the plate setter are selected. The wavelength of the image beam used by the plate setter consequently defines which plates can be used. Variations in output results still can happen as many parameters in digital workflow have an impact (for example file type and format, file resolution, colour management, screen definition and raster image processing). The capabilities of the plate setter (like spot size, wavelength, spot accuracy, focus) and the sensitivity of plate define the possible plate imaging results. Furthermore the plate development type (pre-heat-, non-pre-heat-, silver halide and process-less plates) and the dwell-time-temperature combination of chemical developer are critical for the print quality.

Quality control in the workflow requires a clearly defined data management, definitions for data exchange, pre-flight and error corrections for incompatible output files [1]. Process control of plate making requires adjustment and calibration of the plate setter, correct plate material, measurement on plate and digital control devices for control. In pre-press and pressroom the need for this is accepted and at least for pre-press a common practice. For quality control of a CtP it has to be decided:

Should there be a quality control on each plate and off each print job?

Or

Should there be only a periodical quality control (like once per day)?

2. Quality control on each plate and with all print jobs

Quality control that follows the requirements of ISO 9000 (2000) demands that any production job has a documented quality assessment. Most commonly this is done with digital control devices. These are considered reference files where a certain outcome is predictable and serves as the "okay" criteria.

Production needs and available resources require that digital control devices

- are easy to use and easy to be implemented in the workflow
- should not require lots of space
- should not delay output speed of production jobs
- should not require a lot of data storage capacity
- are easy and quick to evaluate
- do not need special equipment for evaluation

These demands resulted in miniaturized test targets, which consist of test patterns in conjunction with measurable areas. These test targets are usually placed in border and cut-off areas of print jobs, the gripper area of plates or on special pages of document files.

Common practice in pre-press is that a quality control of colour and resolution is done during digital proofing and print form assembly. Therefore resolution and colour dependent digital control devices (like the Ugra/FOGRA-Media-Wedge CMYK and the Ugra/FOGRA-Plate-Wedge) are used for PostScript and PDF workflow as well as output control [1] [2]. In addition a print control strip is needed for print run evaluation.

Figure 1: Indicator patches of the Ugra/FOGRA-Plate Wedge

CtP system evaluation and plate control is done by visual inspection of the indicator patches of the Ugra/FOGRA-Plate-Wedge (figure 1). The indicator patch consists of resolution dependent micro lines. This means the lines are generated according to output resolution of the plate setter. For example a plate setter which is imaging at 2540 dpi resolution should be capable to create micro lines of a width of 10 µm. The actual resolution used is documented in the information patch of the plate wedge.

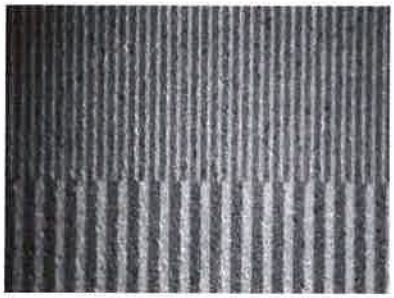

Figure 2: Multiple micro lines

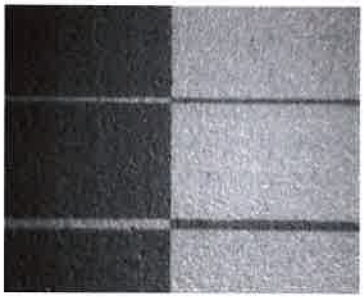

Figure 3: Single micro line

In general an optimal output quality is achieved when the

- four patches of the multiple micro lines (figure 2) all appear uniformly,
- the positive and negative micro lines (figure 3) are of equal width and
- the checkerboards 2x2 and 4x4 (figure 4) are of the same intensity.

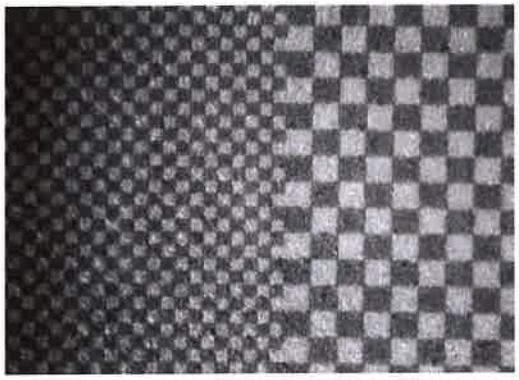

Figure 4: 2x2 and 4x4 checkerboard

Any de-adjustment of the laser beam (like out of focus, incompatible spot size to chosen resolution) will become clearly visible as the indicator patches change instantly. In figure 5 the multiple micro lines are distorted because the spot was too large for the selected output resolution (example here is a silver halide plate). In figure 6 the multiple micro lines are distorted due to an optical and focus error (example here is a thermal plate).

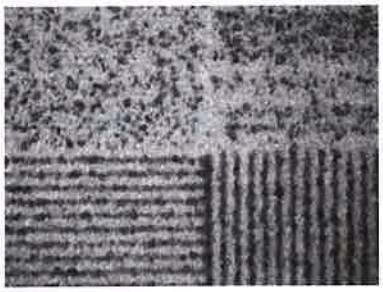

Figure 5: Distorted micro lines due to spot size error

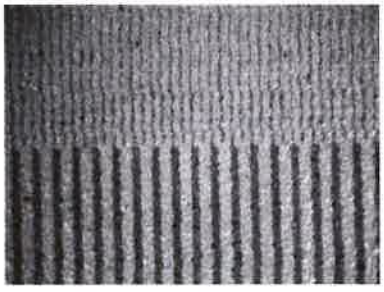

Figure 6: Focus problem cause for distorted micro lines

The indicator patches are also quite helpful when the beam energy levels need to be corrected to prevent over or under exposure. In a production environment it is a common situation that the optics gets foggy due to environment dust as well as plate ablation. But the beam energy adjustment can also be necessary when a new plate delivery is used and the plate coating is of different sensitivity. Figure 1 showed the optimal energy level in its appearance of the indicator patches for positive acting thermal, silver halide and computer imaged conventional plates. Over exposure creates a solid appearance in the multiple micro lines, the single micro lines and the checkerboard patches as shown in figure 7.

Figure 7: Over exposure of positive acting plate

Research projects completed at FOGRA confirmed that the micro line patches respond to changes in plate setter, plate sensitivity and chemical development much faster than the print dot. It can be stated that measurements on plates with densitometry readings or image analysers do not document changes in plate imaging and development as precisely as the indicator patches. For print runs done with traditional screening (60/cm to 100/cm screen ruling) this is not too much of a problem as the large print dots are much more stable. For these plates changes of the resolution dependent generated micro lines can be regarded as an early warning and are used in this respect. For non-periodical screen and for screen ruling of more than 100/cm is has been noticed that these print dots respond to changes of imaging parameters just as intensely as the micro lines.

3. Periodical quality control

In the production environment it is not always possible to place test target or a plate wedge on each plate or have it combined in all productions jobs. In this instance quality control has to rely on periodical evaluations done on test plates. Here the test results are the activity point when problems are detected. Therefore they define a time during which the production was okay. Individual jobs still can go wrong undetected and the risk of customer complaint without a possibility to prove a correct production is immanent.

Another important reason for a periodical quality control is the fact that small size digital control targets only represent correct results for a local area where they are situated on the plate. A plate wedge locate in the bottom left gripper area cannot guarantee uniformity through out the plate. Micro size structure created by the imaging beam, by rollers and brushes in the chemical developer or by unevenness of the plate coating are detected with a plate wedge only in those instances where it is immanent that area. In addition, different plate imaging technology had an effect on the imaging uniformity on plates. Due to this situation there was an apparent gap in quality assurance. On request by the German printing industry FOGRA launched an investigation and the FOGRA-CtP-Testform was its result.

The main aim of the FOGRA-CtP-Testform is to prove correct imaging by visual as well as m easurable inspection in all areas of a printing plate. Any deviation from an optimal or best possible result of a CtP system needs to be detected before plate production is started.

The test forme (Figure 8) consists of:

- output device resolution dependent uniformity patches,
- output device screen dependent uniformity patches,
- several output device screen dependent vignette patterns,
- several fixed screen vignette patterns,
- positive and negative typographical patches,
- several output device screen dependent half-tone wedges,
- a solid bar covering the plate width.

The device resolution dependent uniformity patch is a L-shape element on the left and the topside. It consists of a 1x1 and a 4x4 checkerboard segment. The size of the squares is calculated at time of output and based on the used output resolution. At 2400 dpi resolution the 1x1 checkerboard has a size of 11 µm x 11 µm. This patch helps detecting vertical and horizontal micro size structures (like banding) as well as macro structures (like streaks and large size inconsistencies) created on a plate. Micro size structures usually need instant corrections. Sources are de-adjustment of focus, optical errors, and dust in the optical path e.g. Micro size structure which appear only in specific areas on plates

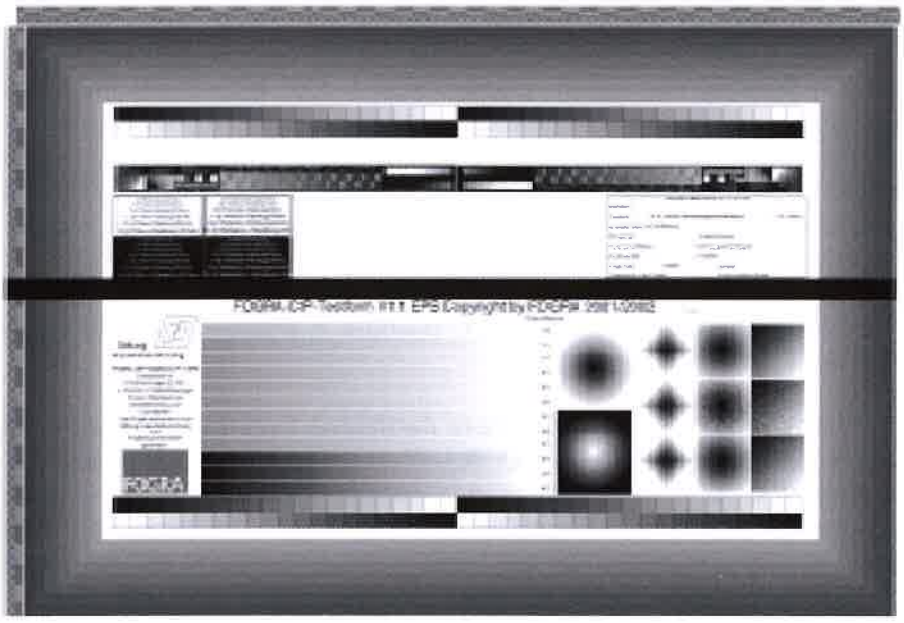

Figure 8: FOGRA-CtP-Testform - layout for 50 cm x 70 cm sheet size

can be caused by unevenness in coating, incorrect flatness of plate on drum, problem in chemical developer, pre-heat e.g. In some plate setters a micro size structure appears through out a plate and can not be corrected by the user. In these instances it is caused by the beam design. Since these structures can have a significant impact when non-periodical screening is used it has to be carefully evaluated. Macro structures also are most commonly caused by beam or laser diode design in a plate setter. Since these structures can have a significant impact on the print quality. Quite often they are mistaken for press problems. For this reason they also have to be carefully evaluated before these plates are used.

The screen dependent uniformity patch is designed as a frame covering the full plate size. Here uniformity of the used screening parameters is evaluated by visual inspection as well by measurements. Structures, which are detected in the resolution dependent uniformity patch, might not always show similar structures in the screen uniformity patch. Extensive tests at FOGRA have shown that visible structure in the screen uniformity patch will become visible in the print results.

Additional important features are the two-dimensional and linear vignette patterns. Most of these linear patterns are used with a fixed screen set of non-periodic screening. The dot sizes of the screen sets are ranging from 16 µm to 40 µm. Standardization for commercial printing requires that the dot size should not be less than 20 µm and for news printing the dot size be not less than 40 µm. Evaluation of these vignettes is done by visual inspection in some case picture analysis can be employed as well. Deviation in imaging due to beam focus problems can be detected in banding or even streaks. Incorrect chemical development has also a significant impact in the appearance and change the evenness of the fades.

The two-dimensional vignette patterns are defined with fixed screen sets of 20 µm non-periodical screen and in data set that allows the application of the default screen set as used at time of output. Evaluation is done in the same way as the linear vignette patterns. Two-dimensional vignettes support the human eye in detecting unsteady appearances and reveal structural elements due to incorrect rendering. They also document imaging and development problems.

A solid bar is added to the CtP-test for evaluation of plate coating and for use in print.

4. Conclusion

The German printing industry has rapidly changed over to CtP systems for plate making. Quality assurance of CtP plates was an obstacle to successful utilization of this technology. A project was launched to specify, develop and test possible control tools for better production control which are suitable for production environments. It turned out that quality assurance on CtP systems requires micro line elements and vignette patterns to secure correct output throughout a plate. Test results showed that this way the best possible print results could be achieved. The FOGRA-CtP-Testform is used in conjunction with Ugra/FOGRA-Plate-Wedge to detect problems during RIP processing, imaging and plate development. The FOGRA-CtP-Testform is available for different plate sizes and file formats (PDF and PostScript).

Today over 200 FOGRA-CtP-Testforms have been distributed. Feed back showed that they are used daily (mostly in conjunction with the Ugra/FOGRA-Plate-Wedge). Most commonly the test forme is used at start-up time of a CtP system. This gives a company the ability to prove that the plates are produced under identical conditions and with optimal uniformity. Feed back from industrial users is absolutely positive. In a current project the test forme is under revision to add more functionality and extent usability.

Literature

[1] Schmitt, U.:
Rationeller Einsatz von qualitätssichernden Werkzeugen in Produktion und Archivierung
München: FOGRA, 2000 (68) - Praxis Report. Currently only available in German language

[2] Schmitt, U.:
Qualitätssicherung der Ausgabesysteme bei Computer-to-Plate
München: FOGRA, 2002 (73) - Praxis Report. Currently only available in German language

[3] Schmitt, U.:
Qualitätssicherung im PostScript- und PDF-Arbeitsablauf
München: FOGRA, 2003 (72) - Praxis Report. Currently only available in German language

Mechanical and optical differences in long run printing in conventional and CTP offset systems

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Abstract

In the recent years there has been a significant growth in the area of platemaking. The development of electronic hardware and software, data manipulation, image and platesetters, has resulted in systems that image directly from computer to printing plates. From the commercial point of view the usage of CTP technology is not in question. The elimination of the film making phase and direct copying on printing plate has resulted in saving materials, less operators handling, as well as in significantly shorter graphic workflow time. The aim of this article was to compare the mechanical and optical properties in the conventional offset platemaking system to CTP offset platemaking system. In both cases the same original was reproduced in specified systems in optimal conditions. The focus was on possible mechanical and optical differences on plates and prints in the long run, which come as a result of different platemaking systems.

1. Background

The offer of CTP systems and back up material has diversified in the last few years. Thermal and visible light technologies have overflowed the world market. The workflow digitalization by installing the CTP system demands adjustment and conversion of the whole work environment in the printing house. Such changes represent new technical and organizational challenges for the firms investing in CTP technology. Nevertheless, the installation of CTP is viewed upon with some skepticism due to high costs of the digitalization of the production. Additionally there is a significant need for the adjustment in the qualifications of the employees. A CTP operator must be skilled with computers and he/she must be familiar with the whole production process. In order for the new technology to be accepted and adjusted to the new literature the ambition of the employees is also required. The lack of information about the trends of technological development leads to longer period of transformation from conventional to digital surrounding. This lack of information is the main reason why the conventional platemaking system still prevails. Holding on to the conventional platemaking system ensures the consistent quality of the reproduction. Nevertheless, those graphic firms whose production must not be influenced and who are forced to keep up with trends set up by the market are more likely to make the decision to transfer to the CTP technology.

2. Introduction

There are lots of factors which influence the quality of the production. Besides the working conditions in the prepress and printing department, the significant role also plays the platemaking conditions.

In the conventional reproduction there is a greater possibility of errors in the platemaking process, due to larger number of steps in the process. The factors which influence the transfer of coverage values are the film and the printing plate quality, the type of photosensitive layer, the exposure conditions, the contact between the film and printing plate and the processing conditions (Richter, 1978). The main

reason for the impossibility of the standardization of production is the human factor. Human precision in the film assembly and imposition directly influences the reproduction quality.

The possibility of error becomes much smaller with the elimination of film making and with the introduction of electronic imposition. The quality of printing plate and photosensitive layer, the source of radiation used for exposure and the conditions of printing plate developing can have influence on the occurring of errors (Seydel, 1996). The quality of the printing plate depends on the individual phases of the platemaking as well as on the characteristics of CTP system, the exposure time and the resolution (Adams, Romano, 1996). The maintenance of the above mentioned parameters is to a greater or smaller degree automatic.

The aim of this article is to explore the mechanical and the optical differences of screen elements which are the outcome of the various platemaking systems. Two procedures of the platemaking have been observed. The first one is the conventional system and the other one is the CTP system. In the CTP system there is much less deformation of printing elements due to the elimination of the film making phase. In the conventional system the copying and developing cause the size deformations of the printing elements, which in effect cause the change of the form of the characteristic reproduction curve. In this article the mechanical and the optical differences of the prints which are result of the different platemaking systems have been observed. The changes of printing elements on the printing plates which derive from the long run print as well as their influence on the prints have been examined. The printing process has been led in controlled conditions concerning ink and fountain solution, and the printing substrate has not been changed.

3. Experimental

Computer generated the original and the control wedge with patches from 10% to 100% of the surface coverage and ruling of 155 l/in have been conventionally reproduced on printing plates and than printed in offset. The same original has been reproduced by the computer led CTP system directly onto the printing plates and has been printed out in the same conditions.

The experimental part consists of film making for the conventional procedure of the platemaking. Through the copying and developing the information from the film has been transferred to the printing plate, which will ensure the making of the colored print on the paper in the further reproduction. The printing plate for the conventional reproduction consists of aluminum base with the light sensitive diazo layer. The photochemical reaction in the layer is caused by the radiation of the metal halide lamp between 380 and 420 nm, with the power app. 5000W. The sensitivity of the conventional printing plates is approx. 50 mJ/cm^2 (Diamond, 1991).

For this paper the CTP system with the internal geometry designed platesetter and violet laser diodes (400 nm) with the power of 5 mW has been used. Digital printing plates for this platesetter are silver halide with the aluminum base sensitive on violet light and with the technical capacity up to 350.000 prints depending on the press conditions. The sensitivity of the silver halide printing plates is 0.01 mJ/cm^2 (Van hunsel, Van Damme, Vermeersch, Elsässer, 1998).

The device with the CCD camera for measuring the mechanical deformations and the densitometer for measuring the optical deformations of screen elements has been used. The characteristics of the surface coverage on the conventional and CTP printing plates have been determined by the experimental measuring. The dot gain has been calculated as the result of the measured values. The changes at the edges of the printing elements on the printing plates, resulting from the long run printing and their influence on the prints have been followed. The differences are shown in the figures with measured values on 40% coverage.

4. Results and discussion

In the conventional system the dot loss arises during the copying of the positive film on the offset printing plate. The dot loss (negative deformation) is expressed as the percentage of the coverage. The deformations of the printing elements, which are caused by undercopying, are avoided by the direct computer platemaking. The reverse phenomenon, that is, the increase of the screen elements (positive deformation) arises during the printing process. This deformation is caused by the construction of the offset device, the blanket cylinder, the rotation of the impression cylinder, the transfer of the foundation solution and ink from the plate, the surface manipulation of the printing plate, the ink and paper, screen, press speed and the working conditions. It is expressed as the mechanical increase of the dot coverage (Riedl, Neumann, Teubner, 1989).

The optical increase which is registered with the densitometer arises on the surface of the paper as an addition to the mechanical differences. Due to the light scattering between the screen elements and unprinted surfaces, there is a reflection of the light underneath the screen elements and the partial absorption of the light. This effect causes the optical increase of the screen elements and they seem larger (Born, 1983).

The mechanical differences of the printing elements of the printing plates in the conventional and CTP procedure have been measured on the 40% coverage and are shown in Figure 1.

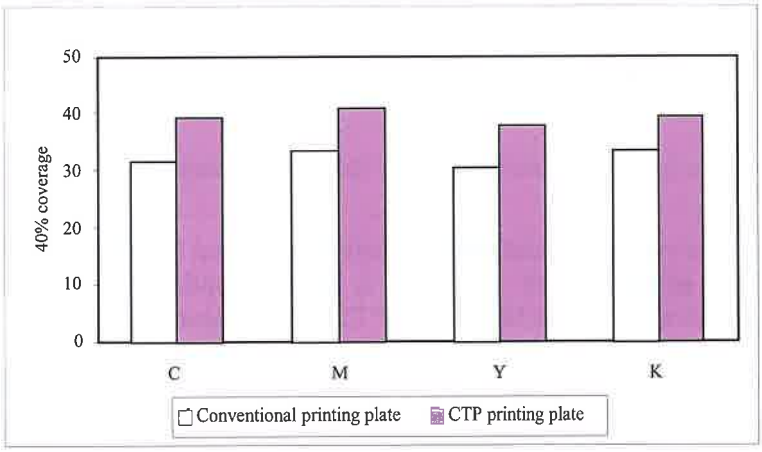

Figure 1: 40% coverage measured on printing plates

With the measuring of the printing plates it can be seen that on the 40% coverage in the conventional procedure there is a decrease of the coverage from 7% to 9 %. On the CTP printing plates the values on the 40% coverage have decreased for 2%. The conventional and CTP printing plates on the 40% coverage have been observed under the microscope and are shown in the Figure 2.

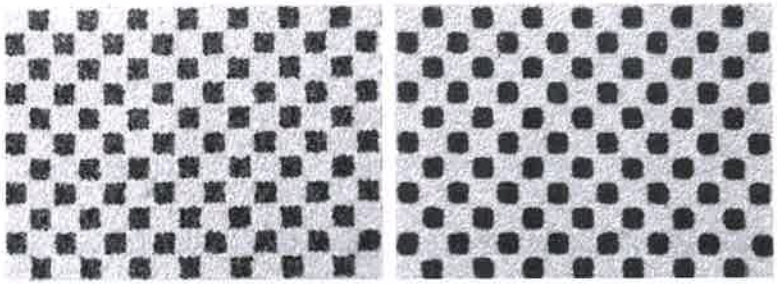

Figure 2: Conventional and CTP printing plates

One can see correctly shaped printing elements on the CTP plates whereas the edge of the printing elements of the conventional plates is unbalanced.

The press with conventional and CTP plates has been led under the same controlled conditions. The print-run has been defined according to extended standard conditions (200.000 prints/conventional plates, 350.000 prints/CTP plates). The prints on app. 10.000 have been measured on 40% coverage and the values of the mechanical and optical differences of the screen elements are shown in the Figure 3 and 4.

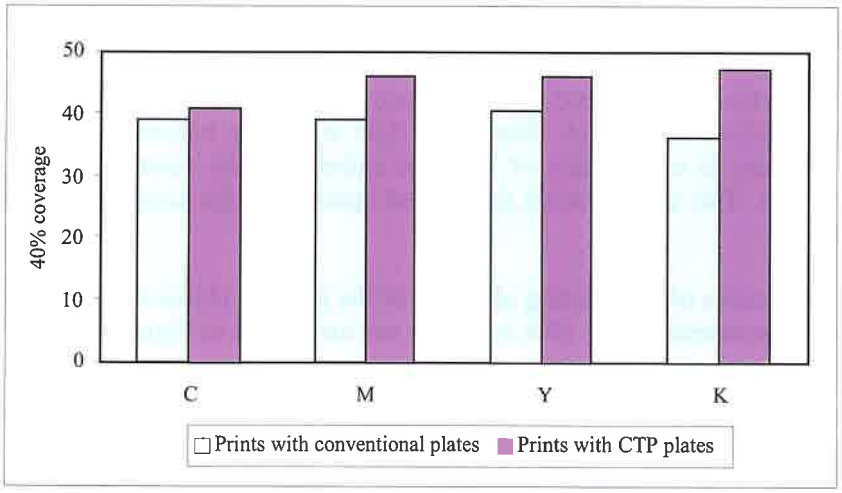

Figure 3: Mechanical differences of the screen elements on the prints

One can see that there is a mechanical deformation between 5% and 8% on the conventional prints and about 6% on the CTP prints (Figure 3). There is also an optical deformation of 12% on the conventional prints and about 10% and 14% on the CTP prints (Figure 4).

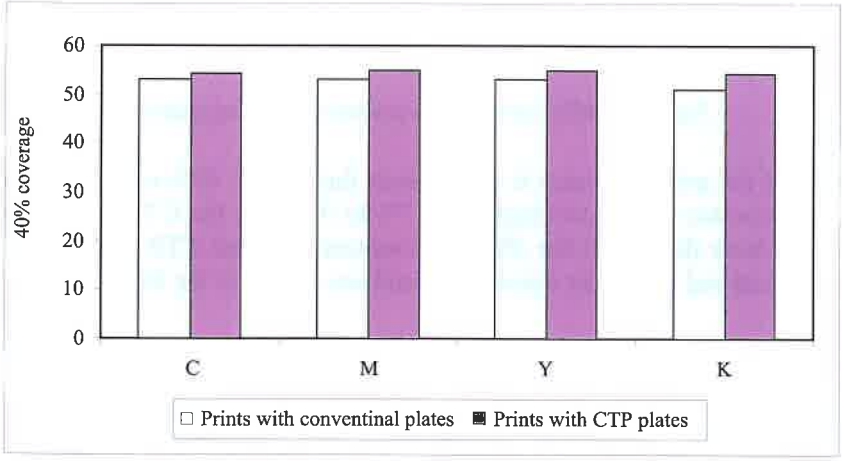

Figure 4: Optical differences of the screen elements on the prints

On the basis of the measured values the dot gain which is shown in the Figure 5 has been defined. The dot gain on the conventional prints is between 8% and 14% and on the CTP prints it is between 15% and 18%.

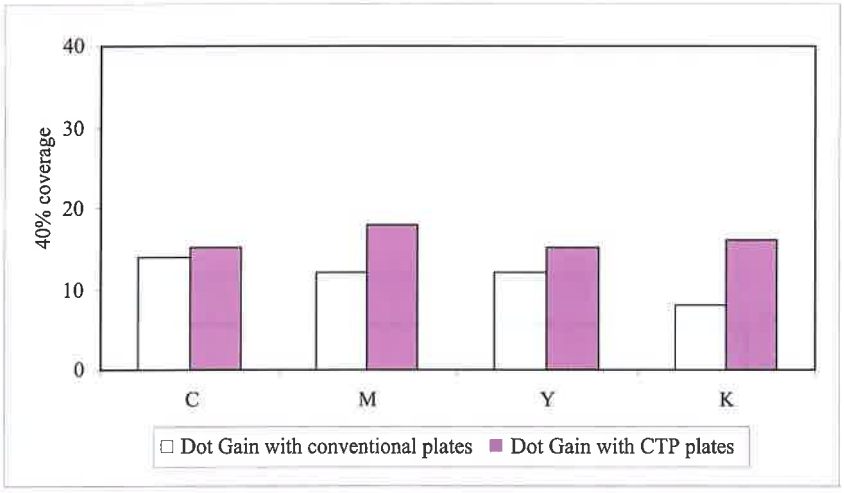

Figure 5: Dot Gain at 40% coverage

The changes on the printing elements of the printing plates, which derive from large print-runs, have been followed. The change in the coverage value on the prints after a certain number of prints depending on press conditions and material used has been noticed.

As a consequence there are changes on the edges of the printing elements which result in decrease of the ink transfer from printing plate to the paper. This demands a change of either the whole set of printing plates or one of the separations during the reproduction. The coverage of 40% on the printing plates has been measured before the press. The coverage value on 40% has been measured after the print-run of 200.000 prints for the conventional plates and 350.000 prints for CTP plates. The results are shown in the Figure 6.

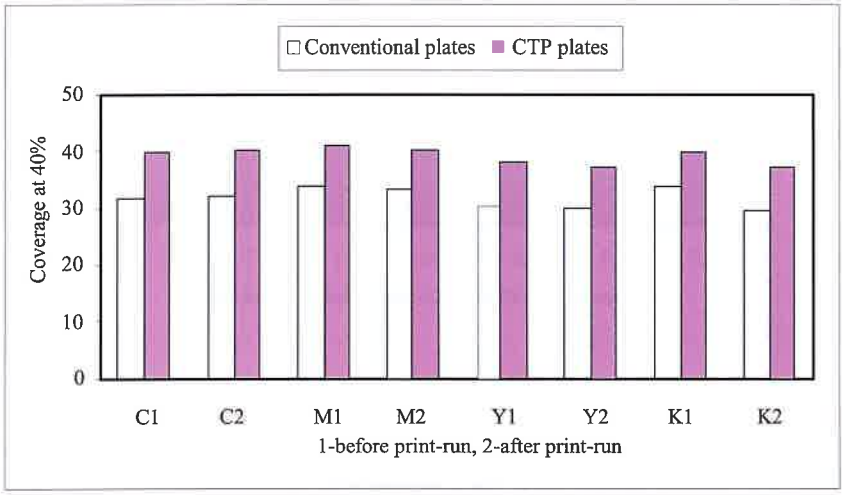

Figure 6: Coverage at 40% measured on printing plates

One can see that there is the decrease of the coverage of the printing elements in both cases with the same press conditions and extended standard conditions. The decrease of the surface coverage is about 4% with the conventional plates and about 1% with the CTP plates. The decrease of the coverage is the result of the changes of the edges of the printing elements which have lost their shape and oleophilic characteristics. Due to that there is a lesser transfer of ink from the printing plate to the

paper which results in the smaller coverage. Deformations become bigger with the increase of the print-run which also has the effect on the reproduction curves.

After the extended print-runs of the conventional and CTP printing plates the values of the mechanical and optical differences of the screen elements on the prints (Figures 7 and 8) have been measured.

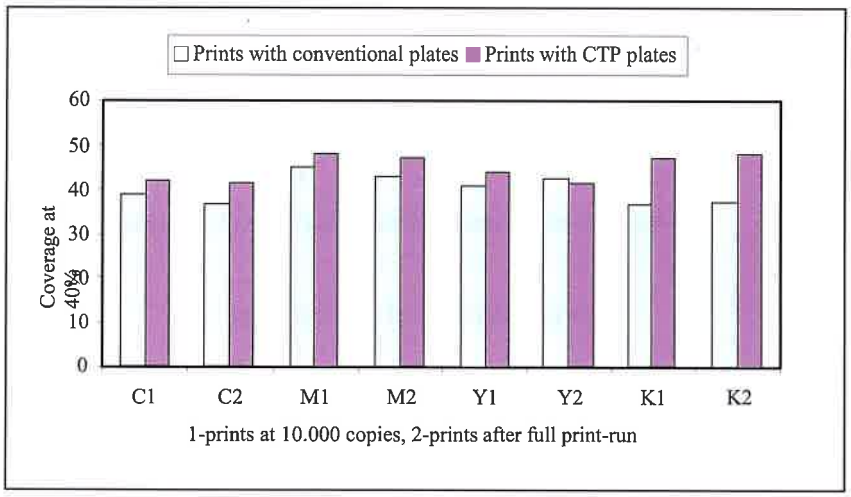

Figure 7: Mechanical differences on the prints

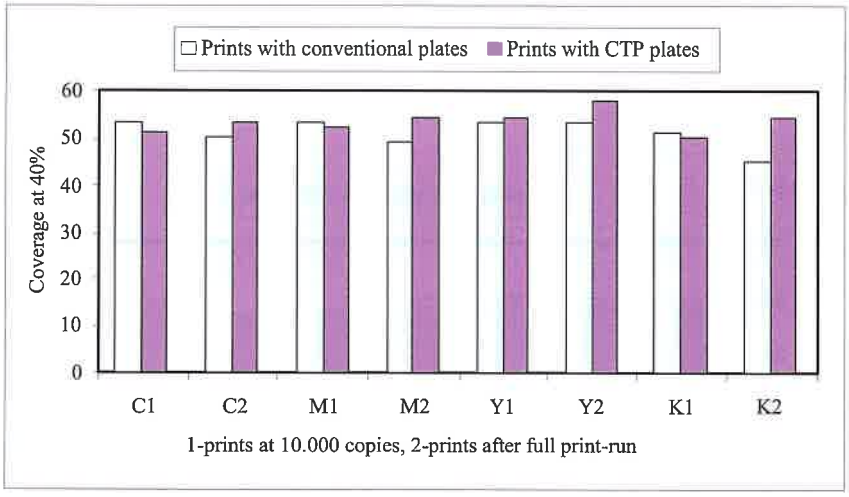

Figure 8: Optical differences on the prints

From the Figure 7 one can see that there are mechanical changes on the screen elements of the conventional prints after the print-run of 200.000 prints. These changes are relatively balanced. There is a decrease of about 2% with cyan and magenta and increase of 2% with yellow and black. The mechanical changes on the CTP prints are significantly smaller and are about 1%. Large print-runs caused optical decrease of 10% of the coverage of the conventional prints and increase of 7% of the coverage on the CTP prints (Figure 8).

The changes in the density on the conventional and CTP prints have also been followed. In the Figures 9 and 10 the relation between the density on the 40% and the size of the print-run can be seen.

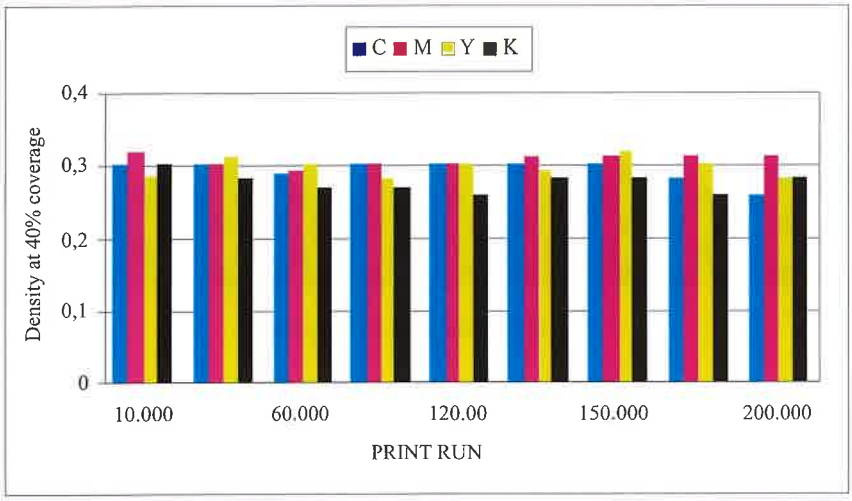

Figure 9: The density of the conventional prints

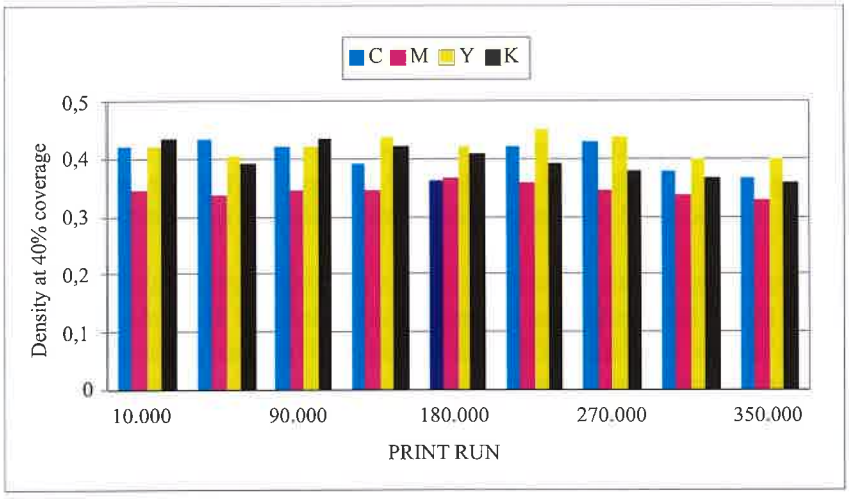

Figure 10: The density of the CTP prints

From the figures one can see that the density of the 40% of the coverage in both cases is balanced and moderately decreased. It means that both conventional and CTP plates would endure even larger print-run than extended conditions, but the quality of the prints slowly decreases due to visible damages on the edges of the printing elements. The microscopic images of the conventional prints at 10.000 and after 200.000 print-runs, and of the CTP prints at 10.000 and after 350.000 prints can be seen in Figures 11 and 12.

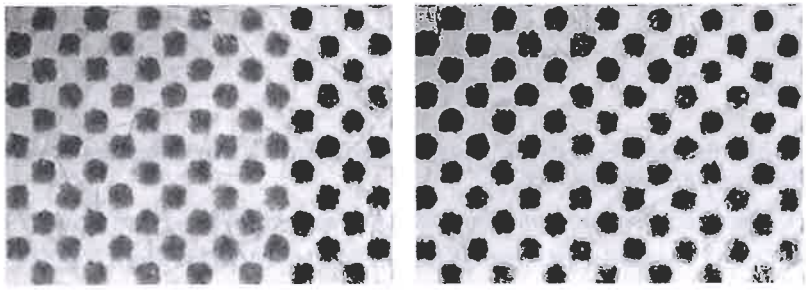

Figure 11: Images of conventional prints

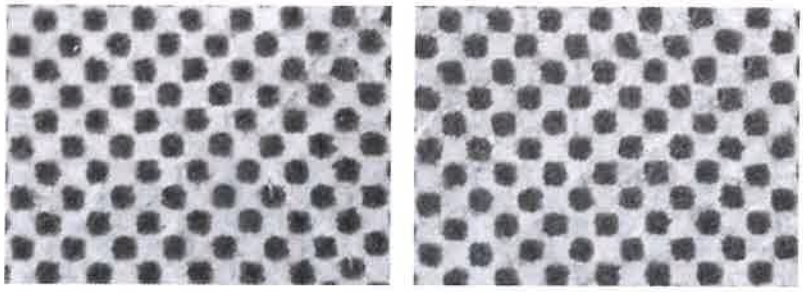

Figure 12: Images of CTP prints

5. Conclusions

The mechanical and optical characteristics of prints also depend on the platemaking system. The CTP system is a big step forward in the platemaking process. The coverage defined on the original is correctly transferred on the CTP printing plate. The shape of the printing element corresponds to the computer defined element. On the conventional printing plates there is a decrease of the coverage and the form of the printing element deforms due to undercopying and developing processes (Figure 2). The dot gain is slightly bigger in the CTP printmaking system. The dot gain on the conventional prints will be smaller than on the CTP prints under the same condition of the press. These results show the need for the adjustment of the printing process in the systems with the CTP platemaking, in order to achieve the satisfying tone reproduction curves. The changes in these reproduction curves can be compensated by using the specified profile inherent to the system in question.

Observing the changes of the printing elements on the printing plates which come as a result of the large print-runs leads to the following: the controlled conditions of the press and the same paper will bring more consistent results with the CTP printing plates. The changes in the density of the middle tones in both cases are insignificant. Certain mechanical deformations and damages on the edges of the printing elements of the conventional printing plates point to the possible loss of the quality due to the increase of the print-run. The expectations have been confirmed with the CTP printing plates. There have been no significant changes on the printing elements nor differences in density in spite of large print-runs. Such results show greater stability of the CTP system. By introducing the CTP technology in the printing houses it is possible to simplify the information flow in the production, the time required for the prepress and the whole production becomes considerably shorter. The printing elements on the prints with the CTP printing plates are more correctly shaped which makes more accurate reproduction. By adjusting the conditions in the printing department with the CTP printing plates, one can achieve the correct tone reproductions curves and the decrease of the ink and fountain solution quantity. By eliminating of the film making process it is possible to achieve more positive economic effect in the context of saving graphic material and chemical substances. From the ecological point of view this technology contributes to maintaining the quality of the environment (Mittelhaus, Wilkesmann, 1997).

Literature references

Adams Richard M., Romano F., (1996), *Computer to Plate: Automating the Printing Industry, Graphic Arts Technical Foundation, USA*

Born E., (1983), *Handbuch der Rasterphotographie, Verlag Ambripress Basel, Basel, 13-19*

Diamond, A. S., (1991), *Handbook of Imaging Materials, Marcel Dekker, Inc., NY, 61-157*

Mittelhaus M., Wilkesmann C., (1997), *Computer to Plate Technologie aus ökologischer Sicht, Deutscher Drucker 30-31, 15-17*

Richter S., (1978), *Lichtempfindliche Diasoschichten auf Offsetplatten, Fachhefte Bulletintechnique 4, 178-186*

Riedl R., Neumann D., Teubner J., (1989), *Technologie des Offsetdrucks, Fachbuchverlag Leipzig, Leipzig*

Seydel M., (1996), *Computer to Plate: Digital Workflow and Integration into Quality Offset Printing, TAGA Proceedings, Rochester (NY), 634-648*

Van hunsel J., Van Damme M., Vermeersch J., Elsässer A., (1998), *Thermostar: A new Thermal Litho Printing Plate Technology for CTP Recording, TAGA Proceedings, Rochester (NY), 395-409*

Pyrromethene dye derivatives sensitized photopolymers and the application to visible laser direct imaging

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Abstract

We found that a three-component positive-tone printing plate which consists of pyrromethene dye, N-trifluoromethylsulfonyloxy-1,8-naphthalimide (NAI 105, photoacid generator) and a 0.86:0.14 copolymer of methylmethacrylate and 2-methyl-1-propyl oxypropyl methacrylate (Mw:16000, Mn/Mw:1.4) exhibited a high sensitivity to 488nm light of an argon ion laser and We could apply the plate to computer-to-plate technology. The image formation mechanism is as follows. The pyrromethene dyes excited by the argon ion laser react with NAI-105 to release trifluoromethylsulfonic acid. The sulfonic acid induces the cleavage of the acetal bond of the copolymer. The cleavage of the acetal bond converts the copolymer to the alkaline soluble and therefore the copolymer acts as a positive tone photoresist. In this mechanism, the efficiency of the acid generation by the interaction between the pyrromethene dye and NAI-105 is very important.

Based on the spectroscopic study in a solution and a polymer matrix, the fluorescence quantum yield of the pyrromethene dye was found to be very high. In addition, the fluorescence quenching of the pyrromethene dye by the NAI-105 proceed efficiently indicating 9.2 x 109 $M^{-1}s^{-1}$ as the fluorescence quenching rate and -11.7 kcal/mol as the ΔG value. The transient species due to the interaction between the pyrromethene dye and NAI-105 in polymer matrix was observed by nanosecond laser flash photolysis. A transient species was observed at a few nanoseconds after the pulse irradiation. It was assigned as a species originated from NAI-105. This fact suggests that the static quenching proceed in the polymer matrix while in solution, the dynamic quenching is dominant. Finally, various properties of the positive-tone printing plate obtained from computer-to-plate technology were investigated.

1. Introduction

In recent years, with the rapid development of visible laser direct imaging technology such as Computer-to-Plate (CTP) and dry film resist for printed circuit board (PCB), much attention have been paid to photofunctional materials. One of the most important researches is to find a photopolymer which can afford a high sensitivity. In case of printing plate, the photopolymer basically consists of a binder polymer, an acrylate monomer, a radical generator, and a sensitizing dye (negative working). In the initial reaction, the sensitizing dye absorbs the light of the laser, then reacts with the radical

generator to generate a initial radical, therefore the combination of the sensitizing dye and the radical generator is very important and there are lots of reports about the good combination, photochemical behavior in the initial reaction, or new sensitizing dye for the violet, Ar ion, FD-YAG laser (N. S. Allen, 1987, Y. Bi, 1994, Z. Kucybala, 1996).

In this paper, we present a novel photopolymer based on chemical amplification. The photopolymer consists of the sensitizing dye, a photoacid generator, and a polymer which contains acetal group. Chemical amplification has been widely applied to the field of photoresist, and the light sources of UV or VUV region are mainly used (H. Ito, 1982, 1983, J. M. Frěchet, 1983). The image formation mechanism is as follows. The photoacid generator excited by a laser or lamp decomposes and generates acid. The acid induces a cleavage of the acetal bond of the copolymer in the post exposure baking (PEB) process. The cleavage of the acetal bond converts the copolymer to the alkali developer soluble, therefore the copolymer acts as a positive working photopolymer (Figure 1). In case of visible laser direct imaging by this mechanism, sensitizing dye is required as a matter of course, but compared with the radical polymerization, there are not so many reports about the good sensitizing dyes and the combinations (G. M. Wallraff, 1992).

We synthesized pyrromethene derivatives as the sensitizing dye and found that the combination of the dyes and a photoacid generator, *N*-trifluoromethylsulfonyloxy-1,8-naphthalimide (NAI-105), could afford the high sensitivity. The dyes originally synthesized for dye laser, so they can show high fluorescence quantum yields and lots of reports about electroluminescence materials including the pyrromethene dye exist (J. M. Brom Jr., 2002). One of the advantages of the novel photopolymer are that overcoat layer is not required because the initiating species are not radical but acid.

Various combinations of pyrromethene derivatives and phoacid generator or radical generator were tested in the experiment, then the best combination was applied to the printing plate and dry film resist.

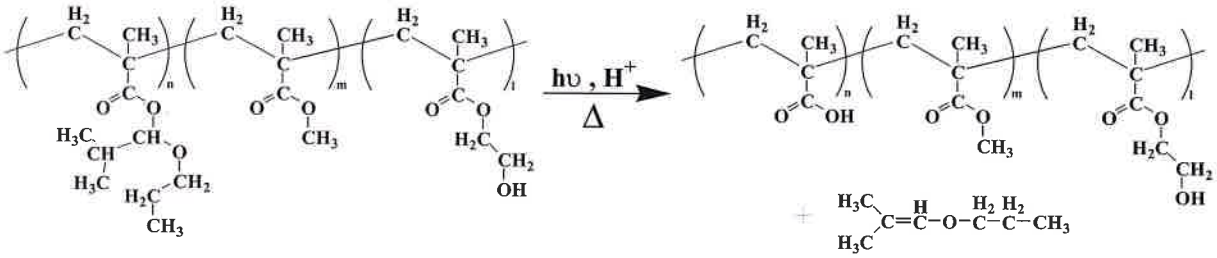


Figure 1: The mechanism of positive working photoresist

2. Experimental Section

2.1 Materials

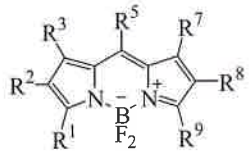
Photoacid generator, *N*-tosyloxy-1,8-naphthalimide (NAI-101) and NAI-105 was provided by Midori chemical Co. and recrystallized twice from chloroform. 2(2',4'-dimethoxystylyl)-4,6-bis(trichloromethyl)-1,3,5-triazine (TAZ-114) was also provided by Midori chemical Co. and used as received. Diphenyl-iodonium trifluoromethanesulfonate (DPI-OTf) and triphenylsulfonium trifluoromethanesulfonate (TPS-OTf) were purchased from Tokyo Kasei Kogyo Co., Ltd. Radical generator, 2,2'-bis(2-chlorophenyl)-4,4',5,5'-tetraphenyl-1, 1'-bi-1H-imidazole (HABI), 2,4,6-tris(trichloromethyl)-1,3,5-triazine (TCT), 2-

mercaptobenzthiazole (MBT), Ethyl-*p*-dimethylaminobenzoate (EPA) were provided by Mitsubishi Chemical Corporation and used without further purification. The pyrromethene derivatives, 1,3,5,7,9-pentamethyl pyrromethene BF_2complex (HMP), 2,8-diethyl- 1,3,5,7,9-pentamethylpyrromethene BF_2 complex (EMP), and 2,8-diethyl-5-phenyl- 1,3,7,9- tetramethylpyrromethene BF_2 complex (EPP) were synthesized according to the procedure in the literature (M. Shah, 1990). 0.14:0.76:0.10 terpolymer of 2-methyl-1-propyloxypropyl methacrylate, methylmethacrylate and 2-hydroxyethylmethacrylate (P-8003) (Mw:12500, Mn/Mw:2.2, AV: 80) was provided by Kyowa Yuka Co., Ltd. 0.75:0.25 copolymer of methylmethacrylate and methacrylic acid (Poly (MMA-*co*-MAA)) was synthyesized (Mw:16800, Mn/Mw: 1.6, AV: 149). Pentaerythritol triacrylate monomer was purchased from Aldrich and used as received.

Their corresponding structures are shown in Chart 1.

Chart 1

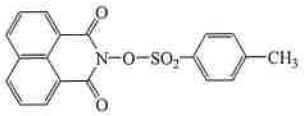
Sensitizing Dye



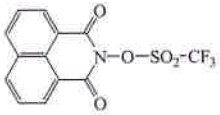
Pyrromethene derivatives

	R^1 R^3 R^7 R^9	R^2 R^8	R^5
HPB	CH_3	H	CH_3
EPB	CH_3	CH_2CH_3	CH_3
EPP	CH_3	CH_2CH_3	C_6H_5

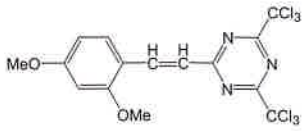
Photoacid generator



NAI-101



NAI-105



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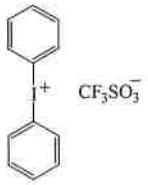
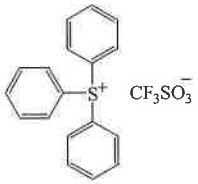
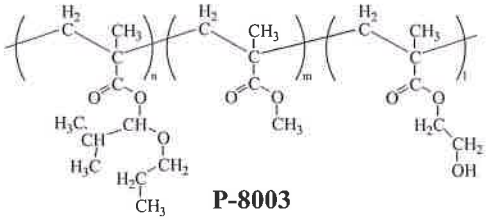


DPI-OTf



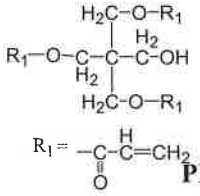
TPS-OTf

Polymer



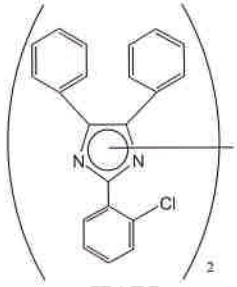
P-8003

Monomer

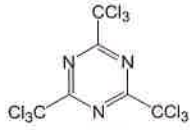


PETA

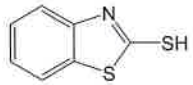
Radical generator



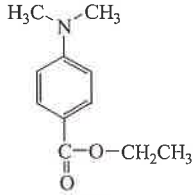
HABI



TCT



MBT



EPA

2.2 Sensitivity measurement

2.2.1 Negative working photopolymer (radical polymerization)

Pyrromethene sensitizing dye was typically used in formulations consisting of MMA-MAA copolymer, monomer, radical generator, sensitizing dye, combined in a weight ratio of 100:100:10:1 and dissolved in cyclohexanone solvent (11.1 % by weight of solids). The photopolymer solution was deposited on a grained Al plate and pre-baked at 100°C for 10 minutes (1.2 μm thickness), then 10.0 wt% polyvinyl alcohol (PVA) aqueous solution was coated on the photopolymer to avoid the oxygen inhibition of polymerization (2.0 μm thickness). The photosensitive layer was flood-exposed by the Ar ion laser (1.2 mJ/cm^{2}sec, 488 nm or 514.5 nm) with step tablet. Following the exposure, PVA over coat layer was removed, and then the photosensitive layer was developed in a 2.38 wt% aqueous solution of tetramethylammonium hydroxide (TMAH) for 1 minute. The sensitivity was determined from the step tablet image on the developed photosensitive layer.

2.2.2 Positive working photopolymer (chemical amplification)

The photopolymer solution consists of P-8003, photoacid generator, pyrromethene sensitizing dye was combined in a weight ratio of 100:5:1 and dissolved in cyclohexanone solvent (18.0 % by weight of solids). The following pre-bake and exposure process was the same as the case of the negative working type. After the exposure, the photosensitive layer was baked at 120 °C for 2minutes for the purpose of the acid diffusion, and then developed in a 2.38 wt% aqueous solution of TMAH for 1 minute. Lastly, the sensitivity was determined from the step tablet image.

3. Results and discussion

The photosensitivity of the negative or positive working photopolymer including pyrromethene derivatives and various initiators were summarized in Table I and Table II. First, in case of negative type (Table I), three-component initiating system consisting of pyrromethene derivatives, imidazole radical generator (HABI), and co-initiator (MBT) showed the high sensitivity. Triazine (TCT) also showed the high values. Urano and his co-worker suggested a sensitization mechanism that involves a singlet electron transfer from the dye to HABI or TCT and the efficiency of the electron transfer affects the photosensitivity extremely (T. Urano, 2000). Second, the combination of pyrromethene derivatives and photoacid generator, especially NAI-105 and DPI-OTf, could afford extremely high values (Table II). Taking all results into consideration, we focused on a champion data, that is, EPP and NAI-105 and applied this initiating system to printing plate and dry film resist for printed circuit board (Figure 2).

Table I: The photosensitivity of the negative working printing plate including pyrromethene sensitizing dye and radical generator

Dye	Radical generator							
	TCT		HABI		HABI + MBT		EPA	
	488nm	514.5nm	488nm	514.5nm	488nm	514.5nm	488nm	514.5nm
HPB	16.9	24.2	25.1	97.1	5.44	15.4	?	?
EPB	13.0	9.21	134	134	44.6	40.4	?	?
EPP	24.2	18.0	267	377	91.1	57.1	?	?

unit: mJ/cm^2

upper limit: 600mJ/cm^2

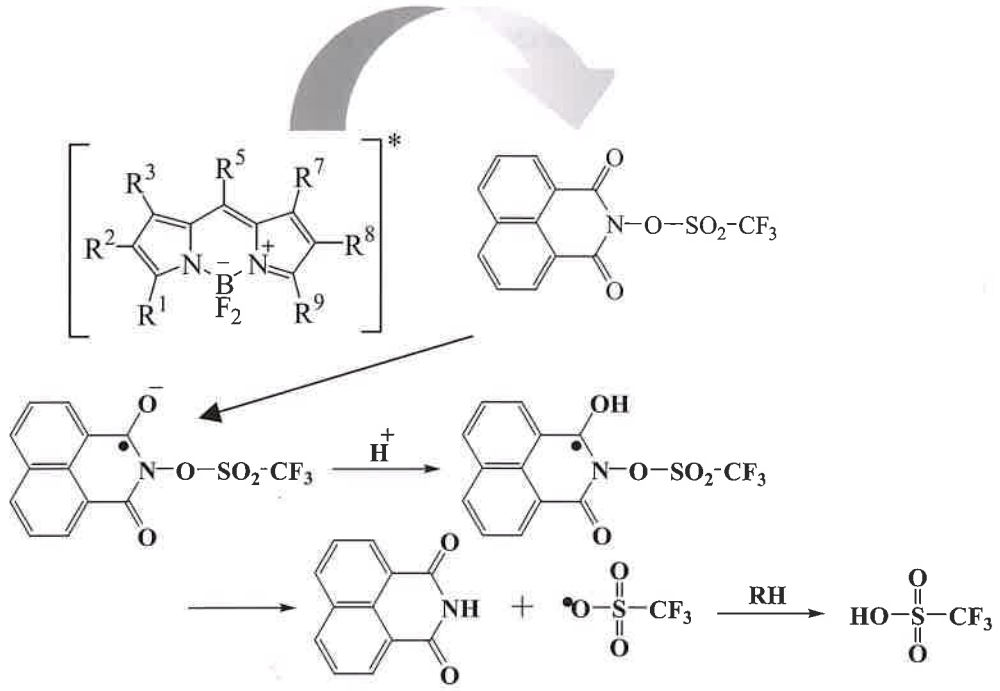
Table II: The photosensitivity of the positive working printing plate including pyrromethene sensitizing dye and photoacid generator

Dye	Photoacid generator									
	NAI-101		NAI-105		DPI-OTf		TPS-OTf		TAZ-114	
	488nm	514.5nm	488nm	514.5nm	488nm	514.5nm	488nm	514.5nm	488nm	514.5nm
HPB	30.0	44.7	0.52	1.22	19.0	15.1	?	?	?	?
EPB	58.6	61.7	1.58	1.97	37.0	34.1	?	?	?	?
EPP	95.0	61.7	0.52	0.52	37.0	48.2	?	?	?	?

unit: mJ/cm^2

upper limit: 600 mJ/cm^2

The sensitization mechanism was also considered by means of absorption and fluorescence spectra, high performance liquid chromatography, laser flash photolysis method. Scheme 1 shows the sensitization mechanism in the bimolecular reaction between the pyrromethene derivatives and naphthalimide photoacid generator.



Scheme 1: Sensitization mechanism in the bimolecular reaction between the pyrromethene derivatives and naphthalimide photoacid generator

4. Conclusion

We investigated the novel photopolymer based on chemical amplification. The combination of pyrromethene sensitizing dye and naphthalimide photoacid generator, especially EPP and NAI-105, showed high photosensitivity when irradiated by the Ar ion laser (488nm or 514.5 nm) and we applied this photopolymer to the printing plate and dry film resist.

We will discuss the more details of the novel printing plate, photoresist, and sensitization mechanism of the initiating system at the conference.

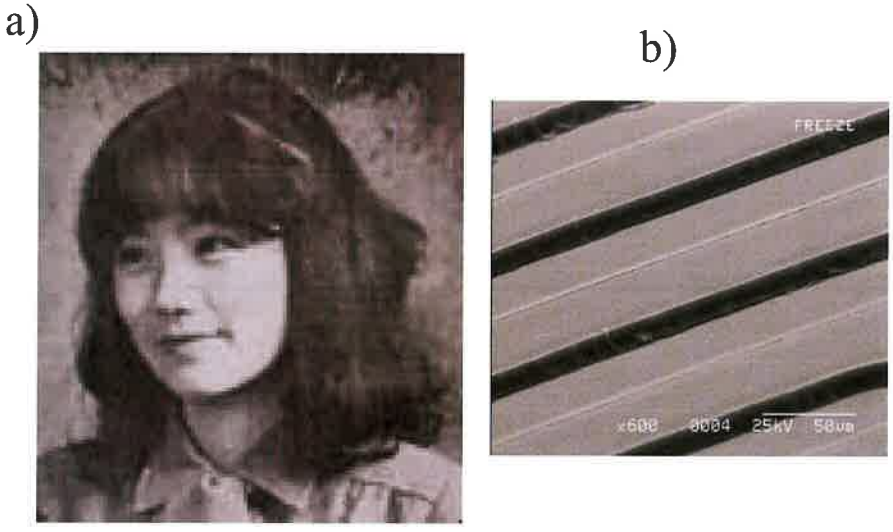


Figure 2: The application of the photopolymer including pyrromethene dye: a) printing plate (200 line) b) dry film resist

References

Wallraff G. M., Allen R. D., Hinsberg W. D., Willson C. G., Simpson L. L., Webber S. E., Sturtevant J. L., (1992), *J. Imaging Tech., 36, 5, 468*

Ito H., Willson C. G., (1982), *Polym. Eng. Sci., 23, 1012*

Ito H., Willson C. G., Frechet J. M. J., Farrall M. H., Eichler E., (1983), *Macromolecules, 16, 510*

Frěchet J. M. J., Eichler E., Ito H., Willson C. G., (1983), *Polymer, 24, 995*

Brom Jr. J. M., Langer J. L., (2002), *J. Alloys and Compounds, 338, 112*

Shah M., Thangaraj K., Soong M. L., Wolford L. T., Boyer J. H., Politer I. R., Pavlopoulos T. G., (1990), *Heteroatom Chem., 1, 389*

Allen N. S., Catalina J., Peinado C., Sastre R., Mateo J. L., Green P. N., (1987), *Eur. Polym. J., 23, 985*

Urano T., Ohno-Okumura E., Sakamoto K., Suzuki S., Yamaoka T., (2000), *J. Photopolym. Sci. Technol., 13, 673*

Bi Y., Neckers D. C., (1994), *Macromolecules, 27, 14, 3683*

6

Current topics

Environmental indicators in the newspaper industry

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Abstract

Environmental indicators promote the eco-efficient development of companies, as demonstrated in earlier study. This study builds on a previously developed model and inventory tools for industry-specific environmental indicators for the graphic arts industry.

This study is based on case studies from 14 newspaper companies with experience of the use of these industry-specific environmental indicators in actual production.

This paper presents data on industry-specific environmental indicators for the newspaper industry. The data describes the average situation and the range of values for the indicators in 14 environmentally aware newspaper companies in Sweden in 2001. The data is also grouped so as to illustrate average values for various classes:

- Newspaper companies with printing facilities.
- Newspaper companies with no printing facilities.
- Newspaper printing companies.

In addition, a preliminary comparison has been carried out using equivalent data for the commercial printing industry.

The indicators calculated for each specific company, together with average values for these indicators, have been used to identify areas for action for the various companies and to formulate action plans. The aim of this is to promote more eco-efficient activities. The study also summarizes measures already implemented at the various companies.

The use of indicators within these companies has been linked with the current and predicted future need to communicate environmental issues. Financial and social aspects have been considered to a limited extent in the study in order to put forward the concept of sustainable development in the newspaper industry in Sweden.

1. Introduction

Environmental indicators promote the eco-efficient development of companies, as demonstrated in earlier study (Enroth, 2001b). This study builds on a previously developed model and inventory tools for industry-specific environmental indicators for the graphic arts industry (Enroth, 2000; Enroth, 2001a). The model was originally developed for companies working with offset and flexographic printing. It is also applicable to digital printing and gravure printing, with some adjustment.

A sharp increase of the use of environmental indicators has been apparent since the end of the 1990s. Traditionally, many ecological indicators such as key species for biological monitoring and pollutants in the environment have been used. The use of environmental indicator systems is developing with a view

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to promoting enhanced awareness of the environmental situation, improvement of communication regarding the situation, formulation of action plans/policies and - last but not least - improvement of the environmental situation and how people operate with regard to the environment. Examples of this appear in the literature (Falconer, 2002; Malkina-Pykh, 2000; Niemeijer, 2002; Plut, 2000; Walz, 2000; Wcislo, 2002). The OECD Pressure-State-Response model (OECD, 1993), the Global Reporting Initiative model (GRI 2002) and the model of the World Business Council for Sustainable Development (WBCSB, 2000) constitute the frameworks commonly used by organisations and industries.

Around 200 newspaper companies in Sweden were affiliated to the Swedish Newspaper Publishers Association in 2002 when the study was compiled. The scope and type of activities of these companies are varied, and we have assumed that the industry-specific indicators are valid for most of the companies. With around 50 of these companies using the model in future, we were able to describe industry-specific mean values with a high level of accuracy.

2. Methods

This study is based on case studies from 14 newspaper companies with experience of the use of these industry-specific environmental indicators in actual production.

The model developed previous and the inventory tools have been adjusted to comply with changes to legislation and the environmental performance of various means of transport, etc. over the years since their development. Throughout this study, the main aims have been to collect data and to develop a Windows-based Access database for efficient processing of data directly from the digital inventory tool in Excel used by the participating companies. In addition we wanted to illustrate the practical use of the industry-specific indicators.

The definitions of the indicators in the model have been published and discussed previously (Enroth, 2000; Enroth 2001a). The definitions of environmental impact measurements in the updated model are described in Table 1, while the definitions of measurements for the financial aspects are described in Table 2. As measurements for utility, "Total weight of products" is expressed in tonnes, while "Annual turnover" is expressed in SEK '000s (EUR 1 = SEK 9.11). The measurements "Added value" and "Number of newspapers distributed" have been used for some supplementary calculations.

The indicators are calculated with the environmental impact measurement as the numerator, and the measurement for utility used as the denominator. This means that the lower the indicator figure, the better the environmental performance. This is true for all environmental impact measurements, but not for financial aspect measurements in the model.

The updated model of industry-specific environmental indicators for the graphic arts industry is applicable mainly to companies working with offset printing. The data collected and mean and median values calculated in this study are specific to newspaper companies.

3. Results

3.1 Data on industry-specific environmental indicators for the newspaper industry

Data on the industry-specific environmental indicators for the newspaper industry is presented in Tables 3 and 4. This data describes the average situation, calculated as mean and median values, and the range of values for the indicators in 14 environmentally aware newspaper companies in Sweden in 2001.

Table I
The updated model of industry-specific environmental indicators for the graphic arts industry, including the newspaper industry.
Definition of environmental impact measurements

Environmental impact measurements	Definition	Unit
ENERGY		
Use of energy	Electricity, heating and fuel, specific energy source types.	MWh
Non-renewable energy	Energy based on sources that are not renewable within 200 years. E.g. coal, mineral oil, peat and uranium for nuclear power.	MWh
MATERIALS		
Materials, total consumption	Printing paper (printing carrier), total consumption.	Kg
Non-renewable materials	Film + metal + mineral oil in printing ink + UV ink + other plastic-based inks (e.g. toner for digital printing)	Kg
Printing paper not accepted by environmental labelling criteria	The criteria for the EU Flower, Nordic Swan or Swedish Society for Nature Conservation's Good Environmental Choice are considered.	Kg
Hazardous materials	The definition of hazardous here relates to the Swedish observation list and labelling of chemicals.	Kg
TRANSPORT		
Transport to the company	Transport of printing carrier from the place of production (paper mill). Registered in ton km and taking into account the means of transport. Calculated with regard to CO_2 from fossil fuels, using accepted emissions factors.	Kg CO_2
Distribution of the newspaper	Fuel consumption, specific type of fuel for distribution to readers within the ordinary area of distribution. Calculated with regard to CO_2 from fossil fuels, using accepted emissions factors.	Kg CO_2
Business travel	Specific means of transport, e.g. car, train, aircraft. Registered in passenger km. Calculated with regard to CO_2 from fossil fuels, using accepted emissions factors.	Kg CO_2
EMISSIONS TO AIR (excluding emissions from transport)		
CO_2 emissions	CO_2 emissions from fossil fuels from production and use of energy bought in and, possibly, produced by the company itself.	Kg
NO_X emissions	Emissions from production and use of energy and, possibly, own emissions.	Kg
SO_2 emissions	Emissions from production and use of energy and, possibly, own emissions.	Kg
VOC emissions	Emissions of volatile organic compounds (VOCs). Organic solvents/products, e.g. damping solutions and cleaning agents, at a vapour pressure of at least 0.01 kPa at 20°C are volatile.	Kg
WASTE		
Waste, total	Total amount of waste including paper waste and used metal, for example.	Kg
Landfill waste	The amount of waste sent to landfill.	Kg
Hazardous waste (excluding electronic waste)	Hazardous waste according to Swedish legislation.	Kg
Electronic waste	Total electronic waste, including both the hazardous and the non hazardous parts.	Kg

Table II: The updated model of industry-specific environmental indicators for the graphic arts industry, including the newspaper industry. Definition of financial aspect measurements

Financial aspect measurements	Definition	Unit
Cost of environmental work	All environmental protection costs, except investments according to definitions from SCB, Statistics Sweden, e.g. own labour costs, consultants, fees for environmental control and waste treatment.	EUR
Proportion of customers (readers and advertisers) who consider environmental issues to be important	Given a scale of 1-6 in a questionnaire sent to stakeholders, answers "5" and "6" are considered to mean "important" in comparison with the overall responses.	%
Proportion of customers (readers and advertisers) who consider the newspaper's monitoring of environmental issues to be satisfactory	Given a scale of 1-6 in a questionnaire sent to stakeholders, answers "5" and "6" are considered to mean "satisfactory monitoring" in comparison with the overall responses.	%

From the indicators based on the total weight of products, it can be seen that the range of values for different kinds of indicator varies widely. There is a 77 % difference between the maximum and minimum values for energy consumption, which means that this area offers many of the companies great potential for both environmental improvements and financial savings. Of the total energy consumed by the average company, around 70 % is electricity and 30 % district heating. There is only an 8 % difference between the maximum and minimum values as regards the use of materials (printing paper), thus demonstrating that the companies are consciously working to reduce their paper waste. The mean paper waste value for the entire group of companies, based on the figures in Table 3, is 12 % (paper waste in relation to the total amount of paper).

Table III: Industry-specific environmental indicators for the newspaper industry (the total weight of the products in tonnes is used as measurement for utility). This data represents the 2001 production year and shows the average situation and range of values for the indicators in 14 companies

INDICATOR, related to weight of products	Unit	Mean	Median	Min	Max
ENERGY					
Use of energy	MWh/tonne	0.729	0.662	0.319	1.41
Non-renewable energy	MWh/tonne	0.319	0.314	0	0.688
MATERIALS					
Materials (printing paper)	Kg/tonne	1139	1141	1103	1199
Non-renewable materials	Kg/tonne	12.1	10.0	3.56	30.6
Printing paper not accepted by environmental labelling criteria	Kg/tonne	6.81	0	0	94.6
Hazardous materials	Kg/tonne	0.256	0.0334	0	1.40
TRANSPORT					
Transport to the company	Kg CO_2/tonne	13.7	17.2	0.0871	29.2
Distribution of the newspaper	Kg CO_2/tonne	154	166	52.3	272
Business travel	Kg CO_2/tonne	8.86	6.90	0.0636	34.9
EMISSIONS TO AIR					
CO_2 emissions	Kg/tonne	28.1	24.7	0	67.0
NO_X emissions	Kg/tonne	0.0637	0.0625	0.0149	0.129
SO_2 emissions	Kg/tonne	0.0522	0.0468	0.0146	0.101
VOC emissions	Kg/tonne	0.336	0.184	0	1.19
WASTE					
Waste, total	Kg/tonne	163	160	110	219
Landfill waste	Kg/tonne	3.62	0	0	26.3
Hazardous waste (excluding electronic waste)	Kg/tonne	4.63	3.82	1.35	10.7
Electronic waste	Kg/tonne	0.284	0.149	0	2.06
FINANCIAL ASPECTS					
Cost of environmental work	EUR/tonne	9.9	7.4	0.81	24

As we have calculated the various transport measurements using the same unit, we can see an initial ratio between transport to the companies and the distribution of newspapers. The environmental impact of transport to the companies is around one-tenth of the environmental impact of distribution. The distribution inventory is irrelevant to the group of newspaper printing companies.

It is worth noting that it is possible to use no hazardous materials in production. Three of the fourteen companies use no hazardous materials, and four report very low values. It is also remarkable that it is possible for production to result in zero VOC emissions. In this case, three companies have no VOC emissions and one company reports a very low value.

Table IV
Industry-specific environmental indicators for the newspaper industry (the annual turnover in SEK '000s is used as measurement for utility). This data represents the 2001 production year and shows the average situation and range of values for the indicators in 14 companies. (EUR 1 = SEK 9.11 as at June 2003)

INDICATOR, related to annual turnover	Unit	Mean	Median	Min	Max
ENERGY					
Use of energy	MWh/SEK '000	0.0197	0.0171	0.00976	0.0408
Non-renewable energy	MWh/SEK '000	0.00808	0.00660	0	0.0246
MATERIALS					
Materials (printing paper)	Kg/SEK '000	37.1	22.8	15.4	96.1
Non-renewable materials	Kg/SEK '000	0.406	0.277	0.0723	1.56
Printing paper not accepted by environmental labelling criteria	Kg/SEK '000	0.394	0	0	5.47
Hazardous materials	Kg/SEK '000	0.00908	0.000692	0	0.0763
TRANSPORT					
Transport to the company	Kg CO_2/SEK '000	0.309	0.318	0.00195	1.12
Distribution of the newspaper	Kg CO_2/SEK '000	2.99	2.53	1.012	6.96
Business travel	Kg CO_2/SEK '000	0.153	0.142	0.00486	0.460
EMISSIONS TO AIR					
CO_2 emissions	Kg/SEK '000	0.691	0.467	0	1.79
NO_X emissions	Kg/SEK '000	0.00167	0.00142	0.000479	0.00362
SO_2 emissions	Kg/SEK '000	0.00139	0.00132	0.000434	0.00322
VOC emissions	Kg/SEK '000	0.00954	0.00633	0	0.0557
WASTE					
Waste, total	Kg/SEK '000	5.20	3.52	1.94	13.2
Landfill waste	Kg/SEK '000	0.0551	0	0	0.355
Hazardous waste (excluding electronic waste)	Kg/SEK '000	0.159	0.0927	0.0262	0.814
Electronic waste	Kg/SEK '000	0.00460	0.00275	0	0.0278
FINANCIAL ASPECTS					
Cost of environmental work	EUR/SEK '000	0.26	0.22	0.012	0.82

The data is also grouped so as to illustrate average values for various classes:

- Newspaper companies with printing facilities.
- Newspaper companies with no printing facilities.
- Newspaper printing companies.

Once the data has been grouped with regard to the various classes of newspaper company, it is readily apparent that newspaper printing companies have the best energy situation when indicators based on the weight of the products are taken into account. The companies in this group also have the greatest opportunity to influence their transportation of paper to their premises. The other groups have supplementary locations that have to be heated, etc.

The situation is different when indicators based on annual turnover are considered. In this case, the newspaper companies with no printing facilities seem to be more efficient in relation to their annual turnover, which is reasonable since they have the turnover from their editorial and advertising activities to balance their environmental impact.

Table V
Industry-specific environmental indicators for the newspaper industry (the total weight of the products in tonnes is used as measurement for utility). This data represents the 2001 production year and shows the average situation for the group in its entirety and the various types of newspaper company respectively. The number of companies in each group is listed in the table

INDICATOR, related to weight of products	Unit	Mean	Median	Min	Max
Class of companies (no. of companies)		All (14)	Newspaper companies with printing facilities (7)	Newspaper companies with no printing facilities (3)	Newspaper printing companies (4)
ENERGY					
Use of energy	MWh/tonne	0.729	0.913	0.622	0.485
Non-renewable energy	MWh/tonne	0.319	0.422	0.340	0.122
MATERIALS					
Materials (printing paper)	Kg/tonne	1139	1146	1125	1138
Non-renewable materials	Kg/tonne	12.1	10.6	13.7	13.4
Printing paper not accepted by environmental labelling criteria	Kg/tonne	6.81	0	0.0232	23.8
Hazardous materials	Kg/tonne	0.256	0.302	0.0223	0.353
TRANSPORT					
Transport to the company	Kg CO_2/tonne	13.7	13.4	18.4	9.86
Distribution of the newspaper	Kg CO_2/tonne	154	190	68.8	not relevant
Business travel	Kg CO_2/tonne	8.86	10.0	11.9	0.248
EMISSIONS TO AIR					
CO_2 emissions	Kg/tonne	28.1	35.5	35.8	9.18
NO_X emissions	Kg/tonne	0.0637	0.0856	0.0512	0.0347
SO_2 emissions	Kg/tonne	0.0522	0.0735	0.0324	0.0296
VOC emissions	Kg/tonne	0.336	0.465	0.0379	0.333
WASTE					
Waste, total	Kg/tonne	163	167	155	160
Landfill waste	Kg/tonne	3.62	7.67	0.0118	0.252
Hazardous waste (excluding electronic waste)	Kg/tonne	4.63	3.89	5.68	5.15
Electronic waste	Kg/tonne	0.284	0.461	0.135	0.0187
FINANCIAL ASPECTS					
Cost of environmental work	EUR/tonne	9.9	13	4.7	7.7

Table VI: Industry-specific environmental indicators for the newspaper industry (the annual turnover in SEK '000s is used as measurement for utility). This data represents the 2001 production year and shows the average situation for the group in its entirety and the various types of newspaper company respectively. The number of companies in each group is listed in the table. (EUR 1 = SEK 9.11 as at June 2003.)

INDICATOR, related to annual turnover	Unit	Mean	Median	Min	Max
Class of companies (no. of companies)		All (14)	Newspaper companies with printing facilities (7)	Newspaper companies with no printing facilities (3)	Newspaper printing companies (4)
ENERGY					
Use of energy	MWh/SEK '000	0.0197	0.0169	0.0113	0.0310
Non-renewable energy	MWh/SEK '000	0.00808	0.00802	0.00617	0.00960
MATERIALS					
Materials (printing paper)	Kg/SEK '000	37.1	22.0	20.6	75.7
Non-renewable materials	Kg/SEK '000	0.406	0.179	0.243	0.926
Printing paper not accepted by environmental labelling criteria	Kg/SEK '000	0.394	0	0.000469	1.38
Hazardous materials	Kg/SEK '000	0.00908	0.00594	0.000449	0.0210
TRANSPORT					
Transport to the company	Kg CO_2/SEK '000	0.309	0.229	0.321	0.482
Distribution of the newspaper	Kg CO_2/SEK '000	2.99	3.74	1.22	not relevant
Business travel	Kg CO_2/SEK '000	0.153	0.171	0.205	0.0125
EMISSIONS TO AIR					
CO_2 emissions	Kg/SEK '000	0.691	0.698	0.660	0.702
NO_X emissions	Kg/SEK '000	0.00167	0.00166	0.000920	0.00225
SO_2 emissions	Kg/SEK '000	0.00139	0.00143	0.000564	0.00193
VOC emissions	Kg/SEK '000	0.00954	0.00926	0.000614	0.0167
WASTE					
Waste, total	Kg/SEK '000	5.20	3.16	2.89	10.5
Landfill waste	Kg/SEK '000	0.0551	0.110	0.000228	0.0145
Hazardous waste (excluding electronic waste)	Kg/SEK '000	0.159	0.0754	0.0970	0.352
Electronic waste	Kg/SEK '000	0.00460	0.00690	0.00264	0.00120
FINANCIAL ASPECTS					
Cost of environmental work	EUR/SEK '000	0.26	0.24	0.091	0.43

A preliminary comparison has been carried out using equivalent data for the commercial printing industry. Five commercial printing companies of varying sizes have calculated indicators for the 2001 production year. According to the indicators based on the weight of the products, the values for energy consumption (1.4 MWh/tonne) and use of materials (1250 Kg/tonne) are higher, which is likely to be due to more energy-intensive activities, such as heatset printing, finishing and comparatively small print runs. The mean value of paper waste for the small group of commercial printing companies is 20 % (paper waste in relation to the total amount of paper). It is also worth noting that the quantities of hazardous materials, VOC emissions and hazardous waste are higher than for the newspaper industry.

3.2 Environmental indicators as a basis for the identification of areas for action and action plans

One important use of the industry-specific environmental indicators is as a basis for the identification of areas for action and action plans. The indicators can then be used to both formulate and follow up environmental objectives and targets. The aims of this are to bring about continual improvement to the environmental performance of companies and to promote more eco-efficient activities.

The indicators calculated for each specific company as part of the study, together with the mean values and range of values for the indicators, have been used to identify areas for action for the various companies.

As part of the study, we have also summarized measures already implemented at the various companies. This will give companies with less experience of environmental work some inspiration for activities in a range of areas. We have formulated proposals for action plans on the basis of our knowledge of measures implemented and areas for action identified for the various companies.

The measures already implemented at the participating companies could be ordered into various areas:

- Handling of waste/sorting of material for eco-cycling.
- Use of the products choice principle, i.e. exchange of hazardous chemical products.
- Exchange of technique (photography, prepress, system for cleaning, control system, etc).
- Resource management of paper and energy (energy saving measures and purchase of declared renewable energy).
- Implementing methods and routines for environmental work (production according to the criteria of the Nordic Swan, certified environmental management system or work with parts of an environmental management system such as environmental policy, environ-mental review, environmental indicators, education and assessment of suppliers, especially suppliers of waste management and transport).

The identified areas for action for the different companies varied with earlier priorities made by the company and the present environmental experience and performance of the company. The most extensive environmental and economic savings could be done when decreasing the paper waste, use of energy and the amount of hazardous waste.

3.3 Environmental indicators as a tool for the communication of environmental issues

The use of indicators within these companies has been linked with the current and predicted future need to communicate environmental issues both internally and externally.

The internal communication is one important ingredient in the process of continual improvement of the company. The indicators give enhanced awareness about the own activity, which can be used within the company as described in 3.2. With facts about the company in form of indicators also the internal communication and motivation of the staff can be increased.

The external communication can be made easier with the use of indicators. In order to select the most adequate data from the model in a common way for external communication, we investigated the type of information requested from the companies by various stakeholders.

The type of information requested dealt with the following areas:

- Methods and routines for environmental work (environmental labelling, management systems, environmental policy, environmental objectives and targets, risk assessment, etc).
- Paper (amount of use, proportion of recycled fibres, waste treatment of used newspapers, etc).
- Forests (logging, environmental labelling, sustainable forestry).
- Allergies (concerning mainly paper, printing ink, chemical products).
- Consumption of materials (concerning mainly organic solvents, VOC).

The different stakeholders asking for environmental information were the following:

- Customers (readers, advertisers, buyers of printed material).
- Authorities (Statistics Sweden, supervisory authority, annual report)
- The public.
- Owners and financial parties.

Based on the type of information on requested by various stakeholders we recommended a selection of information from the model shown in Table 6. We considered which of the indicators that describes the most important environmental aspects of the industry and also which of the indicators being most reliable according to today's situation of the inventory process at the companies as well as the relevance of benchmarking. The target group for this information is all stakeholders. For the public we have also calculated some supplementary, more illustrative information, see Figure 1.

Table VII: A selection of information from the model of industry-specific indicators for external communication of the environmental performance of a newspaper company. The total weight of the product is recommended as measurement of utility for external communication. The example of mean values represents "Newspaper companies with printing facilities"

Environmental impact	Unit	Name of the company (Own values)	Mean value for relevant class of companies (Example)
Use of energy	MWh/tonne		0.91
Use of materials (printing paper)	Kg/tonne		1146
Hazardous materials	Kg/tonne		0.30
Transport to the company	Kg CO_2/tonne		13.4
VOC emissions	Kg/tonne		0.47
Hazardous waste (excluding electronic waste)	Kg/tonne		3.9
The proportion of renewable material in our production is xx % (example 99 %) The amount of printing paper accepted by environmental labelling criteria is yy % (example 100 %)			

As a supplement to the strict description of the environmental performance of a newspaper company we have made some calculations based on the average indicator values from the newspaper companies and complementary life cycle analysis based data on forestry, pulp and paper production to illustrate the environmental impact from a newspaper compared with other everyday occasions in our lives, see Figure 1. The comparison is based on emissions of fossil carbon dioxide to illustrate the effect upon global warming.

4. Discussion

The statistical base of the indicators with data from 14 companies and 3-7 companies in the various classes of companies does not yet make a fully satisfactory scientific base in order to put representative figures on all indicators in the model. The values for the entire group could though be used as reference values. It is worth noting that the values represent a group of environmentally aware newspaper companies.

The general indicators for the graphic arts industry take into account the environmental aspects and resource flows that are regarded as the most important or significant for offset and flexographic printing.

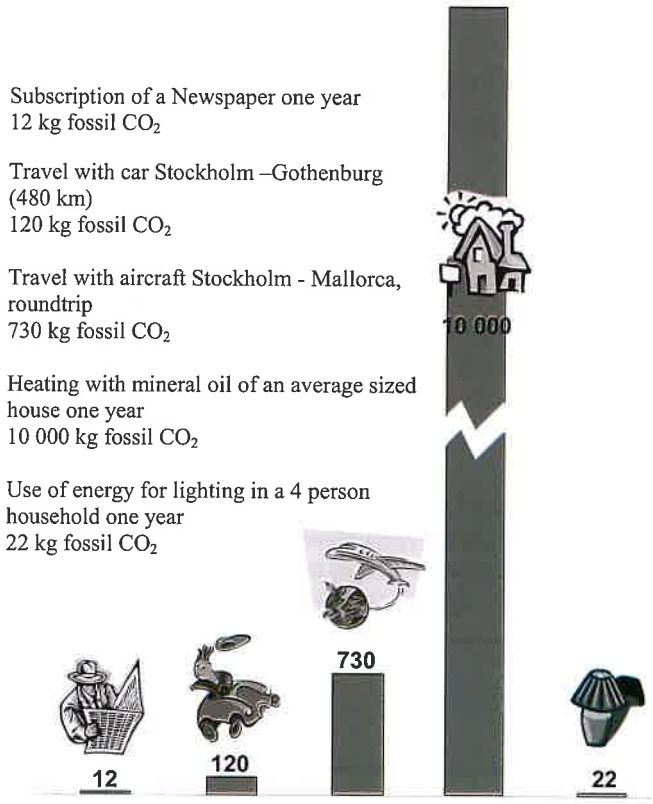

Figure 1: The environmental impact from a newspaper compared with other everyday occasions in our lives. The comparison is based on emissions of fossil carbon dioxide to illustrate the effect upon global warming. The newspaper represents a Swedish average newspaper of 110 g Grafic design: The Swedish Newspaper Publishers Association

When analysing these indicators, it is practical to use different types of measurements for utility. The product-related "Total weight of products" is useful when analysing the efficiency of resource use, for example. The financial "Annual turnover" describes differences in the market situation more effectively.

Business travel and electronic waste are so far uncertain indicators in the model, for a variety of reasons. Newspaper distribution figures should also be handled with care. This indicator is very important from environmental point of view but should be used mainly for internal communication and actions.

We would like to spread the model among newspaper companies in Sweden and Europe. For the 2002 production year 20 Swedish newspaper companies are calculating the indicators and we hope for even more companies the 2003 production year.

5. Conclusions

In this study we have mapped and measured the environmental performance in 14 Swedish newspaper companies in a general way using a model for industry-specific indicators. We have further developed the inventory tools needed for collection, evaluation, calculation and storage of the data. Together with participating companies we have also been able to illustrate the practical use of the indicators in actual production.

A key to practical use of industry-specific indicators is data availability both representing the own company different production years and representing an adequate group of companies to benchmark against, according to the number of companies and the type of activities.

The study presents detailed data from a relative large group of newspaper companies in Sweden if the entire group is considered. This means that data can be used as reference values for example when developing criteria for environmental labelling and spreading the model in Sweden and in Europe.

The areas of use of the indicators for a company as well as the newspaper industry, can be summarised in enhanced awareness of the situation, possibilities to reach continual improvement of environmental performance and financial savings, improved internal and external communication of environmental issues. Altogether this will help companies in their efforts to strive for a sustainable production and to develop even more environmentally adapted newspapers and information products.

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Literature references

Enroth, M., A. Widing (2000), *Environmental indicators in the graphic arts industry, Advances in Printing Science and Technology, Vol. 26, Bristow, A. (ed.) Pira International 2000, pp. 337-356.*

Enroth, M. (2001a), *Promoting sustainability using business specific indicators, Conference Proceedings of the 2001 Eco-Management and Auditing Conference, June 2001, Nijmegen School of Management, The Netherlands, ERP Environment, UK, pp. 60-67.*

Enroth, M. (2001b), *Tools for Eco-efficiency in the Printing Industry, Licentiate Thesis, Royal Institute of Technology (KTH), Stockholm, TRITA-NA-0142.*

Falconer, K. (2002), *Pesticide environmental indicators and environmental policy, Journal of Environmental Management, 65/3, pp 285-300.*

GRI, Global Reporting Initiative (2002), *Sustainability reporting guidelines, www.globalreporting.org.*

Malkina-Pykh, (2000), *From data and theory to environmental models and indices formation, Ecological Modelling, 130/1-3, pp 67-77.*

Niemeijer, D. (2002), *Developing indicators for environmental policy: Data-driven and theory-driven approaches examined by example, Environmental Science and Policy, 5/2, pp91-103.*

OECD/GD(93)179 (1993), *OECD Core Set of Indicators for Environmental Performance Reviews, Environment Monographs No 83, Paris.*

Plut, D. (2000), *Environmental challenges of Europe: The state of environment and environmental trends in the EU (EU15) and the Accession Countries (AC10), GeoJournal, 52/2, pp 149-155.*

Waltz, R. (2000), *Development of environmental indicator systems: Experiences from Germany, Environmental Mangement, 25/6, pp 613-623.*

WBCSB, World Business Council for Sustainable Development (2000), *Measuring eco-efficiency, A guide to reporting company performance, www.wbcsb.org.*

Wcislo, E., T. Dutkiewicz, J. Konczalik (2002), *Indicator-based assessment of environmental hazards and health effects in the industrial cities of upper Silesia, Poland, Environmental Health Perspectives, 110/11, pp 1133-1140.*

The role of intellectual property in scientific research Example: Patents in graphic arts technology

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Abstract

The role of Intellectual prorerty in scientific research with the emphasis on patents is presented on several examples from graphic technology.

A patent is an exclusive right granted for an invention - product or apeocess that provides a new way of doing something, or offers a new technical solution to a problem. Inventors therefore gain recognition and material reward for their creativity. An invention must be of practical use, show an element of novelty, and involve inventive step, which is not known in the prior art inits technical field. Finally, its subject matter must be accepted as "patentable" under law.

All patent owners are obliged,in return for patent protection, to disclose information on their invention in order to enrich technical knowledge in the world and promote further creativity and innovation in others. Patents provide valuable information and inspiration for researchers and inventors as well as protection for the owner. The patent application contains the title of the invention, the description of the background, indication of its technical field, detail description of the invention and claims, which determine the extent of protection granted by the patent. Such descriptions are usually accompanied by visual materials - drawings, plans, or diagrams to better describe the invention.

A patent can be granted by a national patent office or by a regional office. The WIPO-administered Patent Cooperation Treaty (PCT) provides with the filing of a single international patent application protection in as many signatory states as needed.

The newly developed Algorithm - H (patent pending) was used to process patent documents in full text to determine the latest technologies, materials and processes on several examples fromgraphic technologies.

1. Scientific research

The use of informatics in scientific research assures order and clarity over all the publications including patent documents. The researcher has the Right and Duty to be informed!
In years of scientific research the following stages of research project management have been developed. They represent sequence of tasks needed to assure successful project results.

Scientific research stages

1. Technology resources available (equipment, ...),
2. Environment for the research (financial, organizational conditions in institute, firm, ...),
3. Research workers (relevant education, motivation, quantity, reliability, ...),
4. Primary sources of information (up-to-date books, papers, patents, journals, internet sources, ...),
5. Chronology of research (the latest information so far, history of patent applications, ...).

In my paper I have decided to examine the role of Intellectual property with the emphasis on patents in scientific research.

2. Intellectual property

Intellectual property surrounds us in nearly everything we do, at home, at school, at work, as well as at rest and at play. No matter what we do, we are surrounded by the results of human creativities and inventions. It includes patents, Trademarks, Industrial Designs, Geographical Indications, Copyrights and Related Rights (WIPO, 2003).

A trademark is a distinctive sign which identifies certain goods or services produced or provided by a specific person or enterprise. Its origin dates back to ancient times, when craftsmen reproduced their signatures or "marks" on their artistic or utilitarian products. Over the years these marks evolved into today's system of trademark registration and protection. The system helps consumers identify and purchase a product or service because its nature and quality, indicated by its unique trademark, meets their needs.

An Industrial Design is the ornamental or aesthetic aspect of an article. The design may consist of three-dimensional features, such as the shape or surface of an article, or of two-dimensional features, such as patterns, lines or colors.

Industrial designs are applied to a wide variety of industrial and handcraft products: from technical and medical instruments to watches, jewellery, and other luxury items; from housewares and electrical appliances to vehicles and architectural structures; from textile designs to leisure goods.

To be protected under most national laws, an industrial design must appeal to the eye. This means that an industrial design is primarily of an aesthetic nature, and does not protect any technical features of the article to which it is applied.

A patent is an exclusive right granted for an invention - product or a process that provides a new way of doing something, or offers a new technical solution to a problem. Inventors therefore gain recognition and material reward for their creativity.

An invention must be of practical use, it must show an element of novelty and must involve inventive step, which is not known in the prior art in its technical field. Finally, its subject matter must be accepted as "patentable" under law.

All patent owners are obliged, in return for patent protection, to disclose information on their invention in order to enrich technical knowledge in the world and promote further creativity and innovation in others. Patents provide valuable information and inspiration for researchers and inventors as well as protection for the owner.

3. International patent classification - IPC

The International Patent Classification, which is most often referred to as the IPC, has now existed for 25 years and is the only truly worldwide classification system for technical information. The IPC is a hierarchical classification system comprising sections, classes, subclasses and groups (main groups and subgroups). The seventh edition of the IPC, which is in force from January 1, 2000, consists of 8 sections, 120 classes, 628 subclasses and approximately 69,000 groups.

Every subdivision of the IPC is indicated by a symbol and has a title. The IPC divides all technological fields into eight sections designated by one of the capital letters A through H, as seen in Table I. Each section is subdivided into classes their symbols consist of the section symbol followed by a two-digit number.

Table I: IPC classification

Section	Description
A	HUMAN NECESSITIES
B	PERFORMING OPERATIONS; TRANSPORTING
C	CHEMISTRY; METALLURGY
D	TEXTILES; PAPER
E	FIXED CONSTRUCTIONS
F	MECHANICAL ENGINEERING; LIGHTING; HEATING; WEAPONS; BLASTING
G	PHYSICS
H	ELECTRICITY

The IPC is based on an international multi-lateral treaty, administered by WIPO - World Intellectual Property Organisation. This treaty is called the Strasbourg Agreement Concerning the International Patent Classification. However, the industrial property offices of more than 100 States, four regional offices and the International Bureau of WIPO under the Patent Cooperation Treaty - PCT actually use the IPC.

The IPC is indispensable for the retrieval of patent documents in the search for "prior art." Such retrieval is needed by patent-issuing authorities, potential inventors, research and development units, and others concerned with the application or development of technology.

Graphic technology is according to IPC classification classified in several sections: B - performing operations, C - chemistry, D - textiles, paper, G - physics and H - electricity.

4. Patent information

Primary sources of information including journals, books, technical reports, conference proceedings, trade publications and patents are representing the extensive expansion of information.

Patents provide protection for the invention in return for early publication of research results. Therefore they represent the most advanced novelty. Published patents generaly precede journals, books and other publications by months and in some cases years and are early sources of new information.

Patent applications started as national applications can subsequently be extended to other countries via European or PCT applications, recognizing national patent application priority date. Dates are important for two reasons: establishing priority if someone else tries to patent the same invention or starting the commercialisation of the invention as patents lifetime is 20 years.

Patent information are available in several databases, some specialize in granted patents and patent application from all over the world in full text and local patent offices. Most databases are available over the internet and provide search tools and patent documents granted and applications in full text including pictures. The number of patents is increasing very rapidly. In Figure 1 we can see the increase in patent documents for year 2003. In six months Thomson Delphion Patent Data Base added 1 million new documents.

According to the patent legislation an invention must first be patented, before it is presented anywhere else. That is the reason why a patent documents precede other non-patent documents for about 2 years. That is the time needed by patent offices to perform the patentibiliy search, to determine the invention is really new, never patented before.

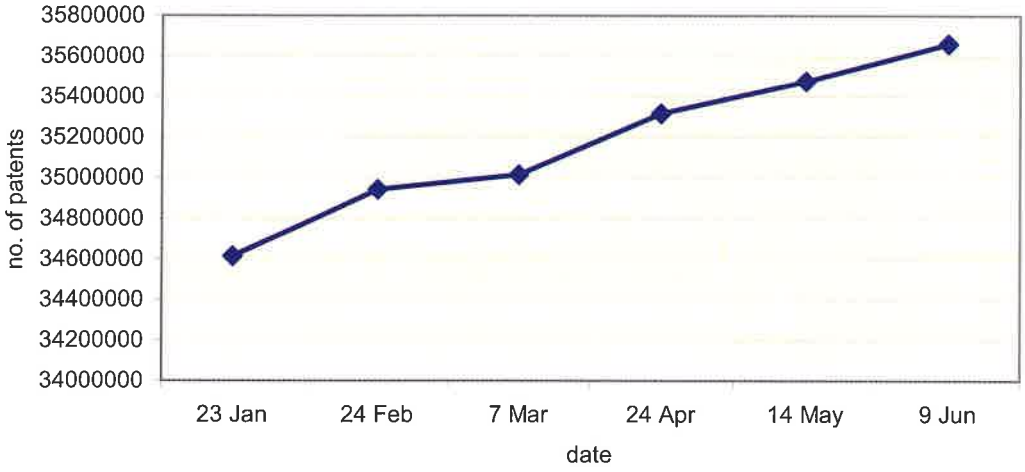

Figure 1: The increasing number of patent documents for 2003.
Source: Thomson Delphion (Thomson Delphion 2003)

For researchers and developers, the patent documents provide an important source of information:

- What is already under the patent protection in case they want to patent a novel invention and
- what others are doing and how far their research has gone.

Patent documents are composed of two parts: the bibliographical part and the technical part.

The Bibliographical part includes information about:

- Country of patent application
- Inventor
- Assignee
- Date of patent application
- Date of published patent
- IPC classification
- Other classifications
- Patent agent, attorney or firm
- Designated countries
- Patent family
- Abstract

The Technical part includes information about:

- Background of the invention
- Detailed description of the invention
- Patent claims
- Summary
- References

A patent can be granted by a national patent office or by a regional office. The WIPO - administered Patent Cooperation Treaty - PCT provides with the filling of a single international patent application protection in as many signatory states as needed - designated countries. Patent applications in several countries are connected to high financial expenses, so the designated countries have to be chosen very carefully. Those patents represent a patent family.

From the bibliographical part we get the information who are the most important inventors and companies, where they have patented their invention, when they have applied for the patent, how long will the patent last and the information regarding patent classification.

From the technical part of the patent document we get to know the background of the invention, detailed description of the invention and in patent claims, what exactly is protected with the patent. All this information is very valuable for the researcher. In the backround of the invention we see what has already been patented but later abandoned or improved or what the newest inventions are or one can get some new insight to old problems. If the background text is very short, it is the case of new field of research.

Detailed description of the inventon explains the invention practically so it can be repeated, it includes the infornation about the materials used, technology, methods and the use of the invention as well as visual materials - drawings, plans, or diagrams to better describe the invention. The researcher can so get some new insights and in some cases see if the inventor has missed obvious important new solutions.

Patent claims describe exactly what is protected. If the inventor has missed something and it is not claimed in the patent, that part of invention is free to use and explore. Patented inventions are upgraded all the time and therefore also patent applications, old granted patents get abandoned and new applied for, to assure continuous patented protection from the competition. For the researcher that means constant search in patent databases for novelties.

5. Example from graphic technology

Computer-to plate technology was used as the example. Patent Data Base - Thomson Delphion, search was performed on June 12, 2003, the base included 36 828 068 patent documents, US granted patents and applications, EP granted patents and applications, WIPO PCT Publications and Abstracts from Japan. The documents in data base were searched first just the front page and abstracts and then full-text patent documents were searched, using different search phrases. In Table II we can see the results of the search - the number of patent documents.

Table II: The results of patent data base search

Search phrase	Front page and abstract	Full text
(print)	538 447	958 643
(press)	248 183	805 550
(paper)	366 531	893 438
(graphic technology)	128	586
(computer to plate)	83	568
(computer-to-plate)	126	1010
(CTP)	618	6963
(CtP)	126	1010

The results indicate the full text search to be more relevant than just front page search. In our case we can see that the phrase (computer-to-plate) is the best. CTP phrase gives more results, but they also include documents from other fields of science like biology, electronics, chemistry and pharmacy.

For detail analysis I have chosen the patent documents for the last 20 years that were the result of (computer-to-plate) full text search.

In Figure 2 we can see the increasing number of patent documents over the last 20 years.

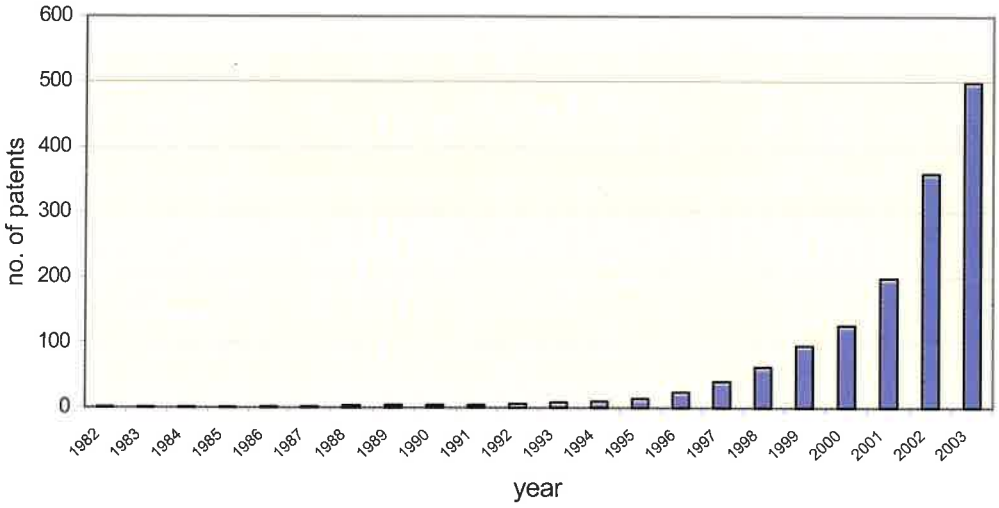

Figure 2: Increasing number of patent documents over the last 20 years

The number of patents is increasing since 1995 very sharply, and in the year 2003 up to 12th of June, 140 new patent documents were added to the date base.

In Figure 3 we can see the patent applications arranged by the countries of patent applications.

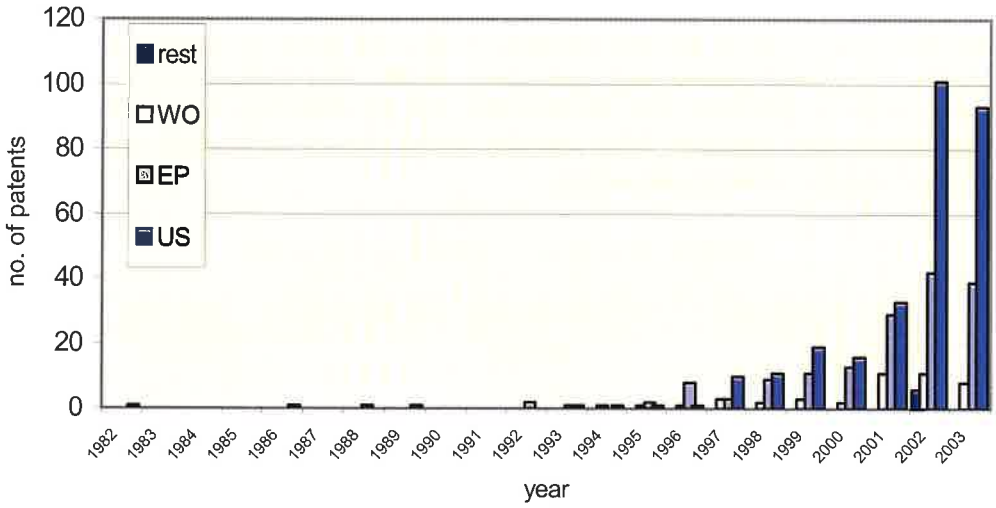

Figure 3: Increasing number of patent documents by the country of application per year

The biggest increase is in US patents, followed by EU patents, meaning that the US and Europe are the biggest markets for CTP techology. As for the rest of the world there is less interest for CTP, the only exeption is Japan. But with the increasing number of patents in the last year that is going to change.

The percentage of the market is presented in Figure 4, where we can observe that with more than half of patents US is the leader, followed by Europe with more than 30 %. There are only 10 % PCT - WO patents, the rest with 1 % of patents is mostly represented by patents from Japan.

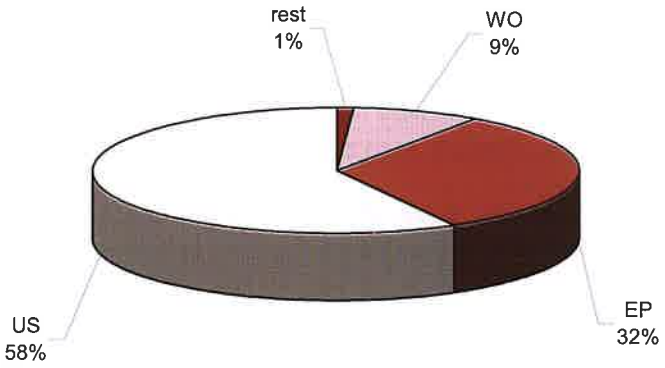

Figure 4: The percentage of patents by countries

IPC classification gives us the information what exactly is protected by patents. In our case half of the patents is in section B - Performing opeations, transporting, and 40% in section G - Physisc, the remaining 10 % of patens are classified in sections H - Electricity and C - Chemistry as we can see in Figure 5.

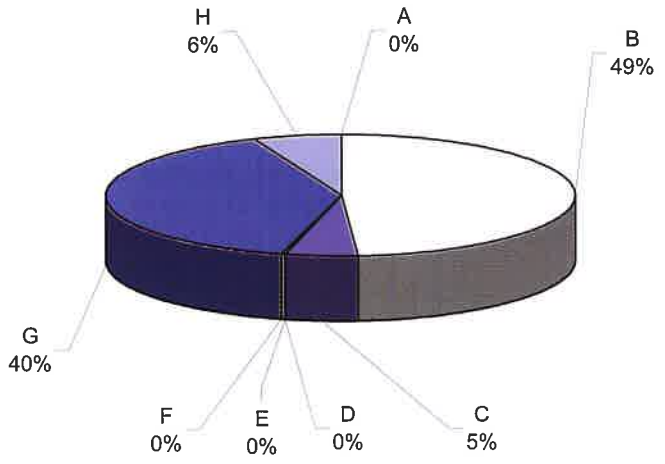

Figure 5: Patent documents by IPC classification

Detailed look at the sections reveals more exactly what is patented.

In Section B:
- B32B - layered products,
- B41C - processes for the manufacture or reproduction of printing surfaces,
- B41F - printing machines or presses,
- B41J - typewriters selective printing mechanisms; Correction of typographical errors,
- B41N - printing plates or foils, materials for surfaces used in printing machines, inking, damping, or the like; Preparing surfacres for use or conserving them.

In Section G:
- G03F - photomechanical production of textured or patterned surfaces, e.g. for printing, for processing of semiconductor devices,
- G03C - photosensitive materials for photographic purposes; Photographic purposes; auxiliary proceses in photography.

In Section C C25D - Processes for the electrolytic or electrophoretic production of coatings; Electroforming.

The look at the sections reveales, what actually is protected by the patents, in our case manufacturing procceses for CTP printing plates, materials used and the use of CTP plates in printing process.

For latest information on novelties the newly developed Algorithm - H (patent pending) was used, which identifies the most relevant documents in a chosen filed or research.

In out selected case regarding novelties in CTP technology the algorithm has identified the following patent documents to be the most relevant.

US20030113666A1:

Lithographic printing plate precursor;
A lithographic printing plate precursor with a support and a hydrophilic layer capable of hydrophobicizing by heat, the hydrophilic layer with a particulate hydrophobicizing precursor, a photo-heat converting agent, a hydrophilic polymer having a silane coupling group, and a metal complex catalyst. (Endo 2003)

US20030113653A1:

Imaging member containing carbon black and methods of imaging and printing; A negative-working printing plate or on-press cylinder, comprising of latex polymer-carbon black composite particles, prepared with a hydrophilic imaging layer comprised of a heat-sensitive hydrophilic polymer having ionic moieties and the latex polymer-carbon black composite particles as a photothermal conversion material. The latex polymer-carbon black composite particles can be formulated in water or water-miscible solvents without agglomeration with other components such as charged polymers. (Zheng 2003)

US6576401:

On-press developable thermosensitive lithographic plates utilizing an onium or borate salt initiator; Thermosensitive lithographic plate which is imagable with an infrared laser and on press developable with ink and/or fountain solution. (Teng 2003)

US6576397:

Heat-sensitive lithographic printing plate precursor;
Lithographic printing plate precursor for CTP system enabling handling in bright room. (Kita 3002)

US20030104314A1:

Thermal switchable composition and imaging member containing complex oxonol IR dye and methods of imaging and printing; Negative-working printing plate or on-press cylinder, prepared with a hydrophilic imaging layer comprised of a heat-sensitive hydrophilic charged polymer (ionomer) and an infrared radiation sensitive negatively-charged oxonol dye that has a λ_{max} of greater than 700 nm. (Zheng 2003)

US20030101887A1:

Device and corresponding method for rapid image data transfer in printing presses; A device for fast image data transfer in printing press having at least one RIP, including a data manager to which image data is supplied, storage unit and one imaging unit. (Wiedemann 2003)

US6569601:

Radiation treatable printing plate;
CTP printing plate material coated with one or more layers of a polymer composition. (Bennett 2003)

US20030107772A1:

Printing color management system, and printing color management method;
The printing color management system and method capable of creating a printed image closely similar in color to a target printed matter. (Shimazaki, 2003)

US6526886:

Computer-to-plate by ink jet;
A method for preparing a lithographic printing plate by means of ink jet where ink jet fluid contains oleophilizing compound - 1,3-dicarbonyl group. (Loccufier 2003)

US6520088:

Re-usable printing form with a printing surface and method for forming images on the printing surface; A printing form that can be used many times with a printing surface with a metallic titanium layer. For imaging, the printing form is selectively coated hydrophilically in point-by-point manner by supplying controlled energy. After the printing, the image on the printing form can be erased by heat. (Vosseler 2003)

EP1218184:

Prediction and prevention of offset printing press problems;
A prepress and press system including the means and methods for predicting press related problems and preventing them digitally. (Barak 2002)

6. Conclusions

Intellectual property has become an international category on basis of economy, technology and science. The legal protection is granted for the invention in return for disclosure of novelty. Patent documents are among primary sources of information for researcher disclosing the details of the invention, background of the invention and in patent claims exactly what is protected by patent.

Patent legislation demands that invention must be new, industrially applicable, have the inventive step and has never been seen before, therefore patents precede other publications for at least a year or more. A careful analysis of patent documents in full -text can reveal the latest information from the research field.

Just the patent itself is not enough unless it is supported with profound technological know-how and exact product behind it.

Literature

Barak 2002, *Prediction and prevention of offset printing press problems, European patent EP1218184*

Bennett 2003, *Radiation treatable printing plate, United Stares patent, US6569601*

Endo 2003, *Lithographic printing plate precursor, United States patent, US20030113666A1*

IPC classification 2003, *International Patent Classification , http://www.wipo.int/classifications/*

Kita 3002, *Heat-sensitive lithographic printing plate precursor, United States patent, US6576397*

Loccufier 2003, *Computer-to-plate by ink jet, United Stares patent, US6526886*

Shimazaki, 2003, *Printing color management system, and printing color management method, United States patent, US20030107772A1*

Teng 2003, *On-press developable thermosensitive lithographic plates utilizing an onium or borate salt initiator, United States patent, US6576401*

Thomson Delphion 2003, *Thomson Delphion Patent database; http://www.delphion.com/home*

Vosseler 2003, *Re-usable printing form with a printing surface and method for forming images on the printing surface, United States patent, US6520088*

Wiedemann 2003, *Device and corresponding method for rapid image data transfer in printing presses, United States patent, US20030101887A1*

WIPO 2003, *Intellectual property, World Intellectual Property Organization, http://www.wipo.org*

Zheng 2003, *Imaging member containing carbon black and methods of imaging and printing, United States patent, US20030113653A1*

Zheng 2003, *Thermal switchable composition and imaging member containing complex oxonol IR dye and methods of imaging and printing, United Stares patent, US20030104314A1*

The end user aspects in print product development

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Abstract

The structure and the properties of paper are determined by the materials and the process that have been used in the paper manufacturing. The consumer's perception of the print product is dependent both on the paper and the print properties. So far the visual properties of the print products have been studied, but also other senses, like touch and sound, have an effect on the general impression. The choice of the products is made according to the liking of end-user. Liking and preference of user depend on one hand on the properties of the printed product, e.g. contents, functionality, usability, pleasantness, image, on the other hand on the values and attitudes of the user. In our work we are mapping the end-user preferences with usability testing.

Touch and feel properties of printed products have been found to affect the overall impression of quality by the consumers. In reading products this is an important part of the image of the magazine. In our work we are expanding the scope of the perception towards the tactile properties, where we have developed a test method. The method for testing touch and feel properties has been adapted from the textile industry and then revised to be more suitable for paper products.

According to the EN ISO 9241-11 standard, the usability of a product is defined as the effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in a particular environment. In our usability studies we have focused on user experience on reading and writing in laboratory (so-called short-term tests) and on reading habits in families (so-called long-term tests).

1. Introduction

The choice of the print product is based on the end user's liking and impression of the product. The handling and appearance are of central importance in printed communication, even though they are features seldom realized by the consumer himself. It is essential that the appearance and the content of the product convey the same message.

According to Cano (2001) touch is more important in printed products than in any other media. Paper plays an important role in magazines, especially for women, who will become "friendly" with the magazine if the feel of the pages pleases them (Karske 2001). Light, thick, smooth and having a non-reflective surface are the properties of paper that positively affect the impression of quality. In addition, the physical structure of the magazine and the ease of leafing through it affect the quality assessment. (Forsell 2003) Jernström (Jernström 2000) recommends in her thesis that research should continue towards customers' requirements and expectations. These should be collected, documented, analyzed and, in the end, combined with the paper technical properties. One step towards the goal is to clarify which tactile and handling properties are significant and what is their relevance to the perceived overall quality.

The aim of this study was to develop a testing method for evaluating the touch and feel properties of paper, and to link them to the physical properties. Also, the relevance of touch and feel properties in sensing the pleasantness of paper is discussed.

2. Method development for testing touch and feel properties of paper

The method development for testing touch and feel properties of paper is based on using a trained testing panel. There are several references to the training of the panelists that we have adapted (ASTM E 1499-97, ISO 8586-1, Civille & Dus, 1989). The panel, consisting of 20 people, tested the touch and feel properties of three different laboratory-calendered samples under standard conditions (23 ±1 °C, 50 ±2 % RH) with their eyes closed. Table I lists the calendering conditions used for sample preparation.

Table I: The calendering conditions

Paper	Linear load (kN/m)	Temperature (°C)	Moisturizing during calendering
TMP	100	80	No
TMP	uncalendered reference		
Fine paper	160	80	No
Fine paper	160	180	Yes
MWC	160	180	No
MWC	uncalendered reference		

The method for describing the touch and feel properties was conducted in two steps: the first step was to choose the descriptors for touch and feel properties and the second step was to evaluate the intensity of the properties (Figure 1). First, the panelists described the surface, the structural and handling properties and the sound of the paper with as many adjectives as possible. The panelists selected the descriptors together. Then the panel tested the samples again and evaluated the intensity of each descriptor using a 7-step scale. The pleasantness of the samples was also evaluated. The touch and feel properties and the laboratory measurements of physical properties were linked with multivariate data analysis. The methods used were principal component analysis and partial least square method.

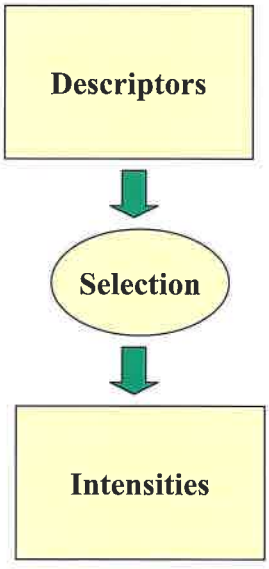


Figure 1: The steps of method development for evaluating touch and feel properties

Principal component analysis (PCA) is a multivariate projection method designed for visualization of similarities and differences between samples (Eriksson et al., 1999). First, a K-dimensional space is set up (K = number of variables). Each variable represents one co-ordinate axis. Each observation of the X-matrix is plotted in the K-dimensional variable space. The result is a cloud of many points distributed in space.

The first principal component, PC1, is a line in the K-dimensional space that describes the largest variance in the data set. Usually, one principal component is insufficient to model adequately the variation in a data set, and a second principal component, PC2, is therefore calculated. PC2 is orthogonal to PC1 and reflects the second largest source of variation in the data.

Two principal components define a plane. By projecting all observations onto a plane, it is possible to visualize the structure of the data set. A *score plot* shows a projection of the observations onto a plane with PC1 as the x-axis and PC2 as the y-axis. The scores are called *t1* and *t2*. The *score plot* obtained is a map of how the samples are related to each other. Samples near each other have similar properties, whereas samples far from each other are more dissimilar. The corresponding *loading plot* gives information about which variables are responsible for the patterns or grouping seen in the *score plot*: for example, which physical properties or touch and feel descriptors are important for the classification of the samples. The loading vectors are called *p1* and *p2*. Variables contributing similar information are grouped together, that is, they are positively correlated. When variables are negatively correlated, they fall on opposite sides of the plot origin, and in diagonally opposed quadrants. Moreover, the further away from the plot origin a variable lies, the stronger the impact that particular variable has.

The data obtained here was evaluated using SIMCA-P version 8.0 software (Umetrics AB, Umeå, Sweden, 1999) for multivariate data analysis.

Partial least square, PLS is a method for relating data matrixes, X and Y, to each other using a linear multivariate model. PLS fits two "PCA-like" models at the same time, one for X and one for Y, and then ascertains that these are coherent. Each observation is represented by one point in the X-space and one in the Y-space (Eriksson et al., 1999).

In the PLS model the observations are projected onto two projection co-ordinates "the scores" t1 and u1. X-data is projected into score vector t1 whereas Y-data is projected into score vector u1. The score plot contains the information about the observations and their similarities / dissimilarities with respect to the given problem and model. The slope is one, when there is good correlation between the X- and the Y-data. The position of observation in a given direction in a score plot is influenced by variables lying in the same direction in the *loading plot (weight plot)*. In the PLS model weight vectors show how the original X- or Y- variables are linearly combined to form the score vectors t and u. Weight vector w is related to X- variables and weight vector c to Y- variables. The weights w*c gives information about how the variables are combined to form the quantitative relation between X and Y. These weights are essential for the understanding of which X- variables, for example, are important or which X- variables provide the same information, the interpretation of the score plot. In our data set physical laboratory measurements represent X- variables. They were used to predict touch and feel properties of the paper. Touch and feel properties in question represent the Y- variables.

3. Results and discussion

3.1 The method for evaluating the touch and feel properties of paper

Table II shows the descriptors of touch and feel properties and sound. The descriptors are divided into four categories: surface properties, structural properties, handling properties and sound. The sample handling is different for each category: the surface properties are tested by sliding fingers over the paper surface; the structure properties are tested by taking the sample in the hand and evaluating the rigidity; handling properties and sound are evaluated by turning the pages of the samples.

Tables III and IV show the results of the touch and feel testing. The panelists evaluated the properties with a 7-step scale. The deviation between the panelists was rather high. For example, the relative standard deviation in stickiness for sample MWC uncalendered is 59 %, but in durability it is only 15 %.

Table II: The descriptors of touch and feel properties and sound

Surface	Structure	Handling	Sound
Graininess	Rigidity	Posture	Sound intensity
Smooth - Rough	Flexible - Rigid	Loose - Posture	Silent - Noisy
Tackiness		Durability	Pitch of sound
Slippery - Tacky		Fragile - Durable	Low - High
Stickiness		Browsing	
Unsticky - Sticky		Difficult browsing - easy browsing	

From this data it is obvious that the explaining of the descriptors is an essential part of the method and it should be done using the mother tongue of the panelists. More effort should be put into explaining the descriptors that have the largest relative standard deviations; in this data set they are tackiness, stickiness, browsing and the pitch of sound.

The panelists also evaluated two replicate samples: MWC uncalendered paper and fine paper that had been calendered without moistening. The deviation between the replicates was at a reasonable level (approx. 10 % for each property). This indicated that the individual panelist was quite repeatable in his evaluation. However, the deviation between the panelists was quite large, which indicated that they needed more training.

Table III: The results of surface and structure properties in touch and feel testing

	Graininess		Tackiness		Stickiness		Rigidity	
	Ave	stdev	Ave	stdev	Ave	Stdev	Ave	stdev
MWC uncalendered	2.5	0.9	2.2	0.8	2.2	1.1	4.4	1.1
TMP calendered	4.8	1.2	4.0	1.5	2.1	1.0	1.6	0.7
Fine paper, without moist.	3.3	0.7	4.1	1.6	3.4	1.6	5.4	1.0
MWC uncalendered (rep.)	2.8	1.4	2.1	1.2	2.5	1.5	4.8	1.0
MWC calendered	1.5	0.6	3.1	1.9	4.7	1.3	4.5	1.1
Fine paper, with moist.	3.1	1.1	2.7	1.1	2.6	1.2	4.6	1.4
TMP uncalendered	6.5	0.7	5.0	1.5	1.6	0.7	2.0	0.6
Fine paper, without moist. (rep.)	3.8	1.0	3.4	1.3	3.3	1.3	5.4	1.0

Table IV: The results of handling and sound properties in touch and feel testing

	Browsing		Durability		Posture		Sound intensity		Pitch of sound	
	Ave	stdev	Ave	stdev	Ave	stdev	Ave	stdev	Ave	stdev
MWC uncalendered	3.1	1.7	5.4	0.9	5.5	1.3	4.0	1.1	3.5	1.1
TMP calendered	3.4	1.9	2.2	0.9	1.5	0.8	4.4	1.1	4.0	1.5
Fine paper, without moist.	3.4	1.9	5.8	0.9	5.9	0.9	3.5	1.1	2.8	1.3
MWC uncalendered (rep.)	3.1	1.7	5.5	0.8	5.2	1.0	4.7	1.2	4.1	1.4
MWC calendered	4.6	2.0	6.0	0.9	5.5	1.1	2.7	0.9	2.5	1.1
Fine paper, with moist.	2.8	1.4	4.7	0.9	5.0	0.9	4.6	1.2	4.1	1.3
TMP uncalendered	2.7	1.5	2.1	1.0	2.1	0.8	5.4	1.4	4.5	1.3
Fine paper, without moist. (rep.)	3.1	1.2	5.5	0.8	5.5	1.1	3.3	1.1	2.5	1.1

The differences between the samples with respect to the touch and feel properties can be visualized in Figures 2a and 2b. In Figure 2a, the PPS-roughness was 2.45 μm - 3.25 μm for all samples. In Figure 2b, the Bendtsen-hardness was between 35 % and 45 %. Figures 2a and 2b show, firstly, that the touch and feel properties of different papers are very different. Secondly, the touch and feel properties depend on several physical properties of paper. For example, Figure 2a shows that the graininess of the sample depends also on other properties than the physical roughness.

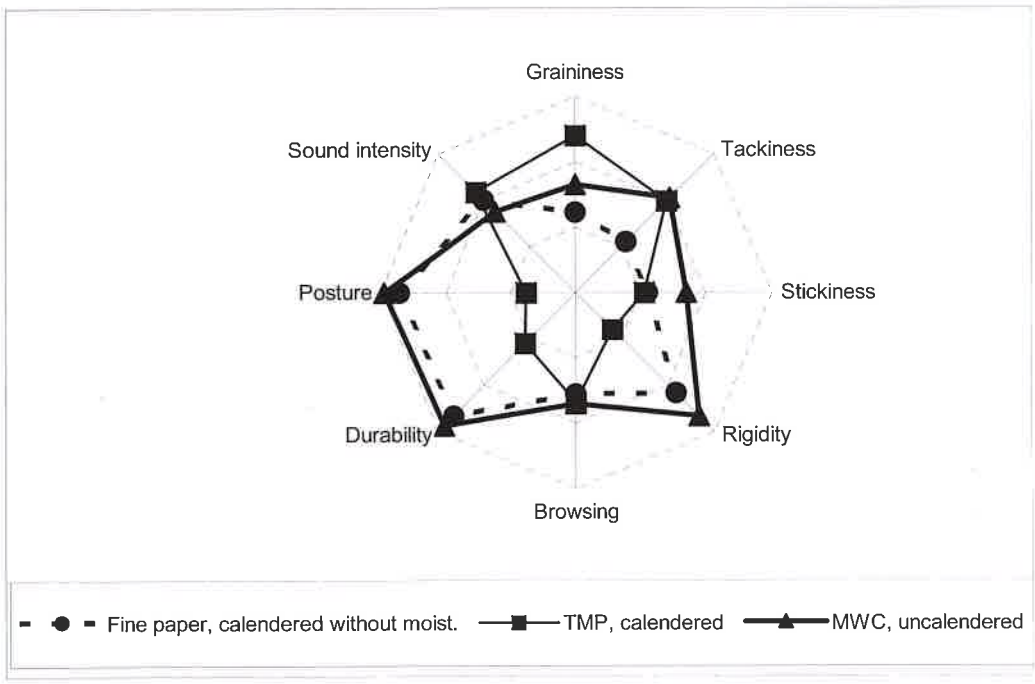


Figure 2a: Radar image of touch and feel properties of samples, PPS roughness 2,45 μm - 3,25 μm

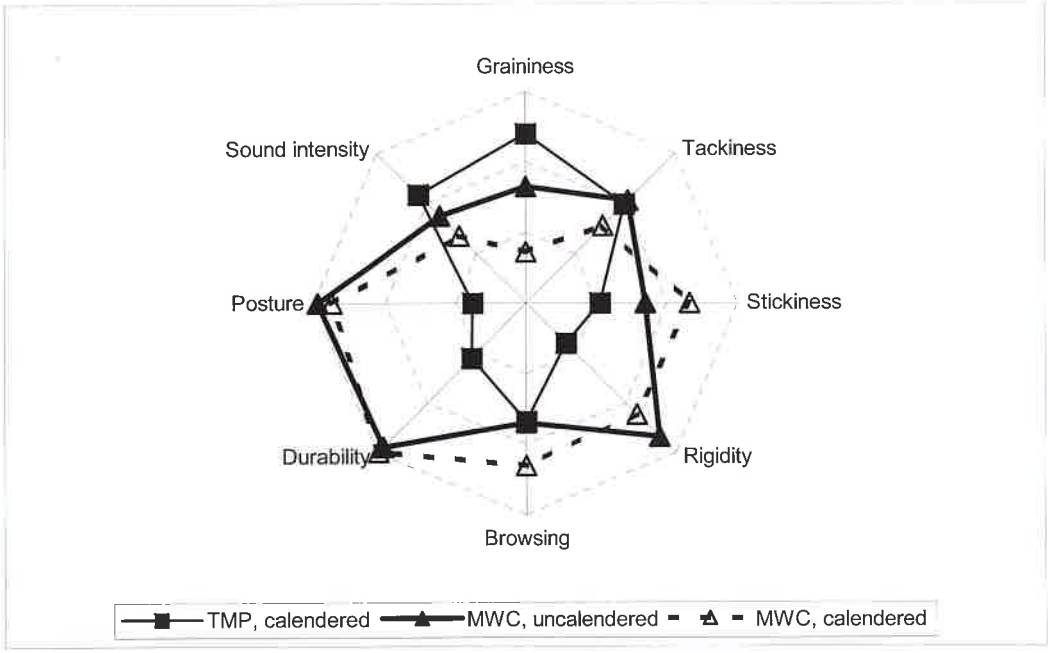
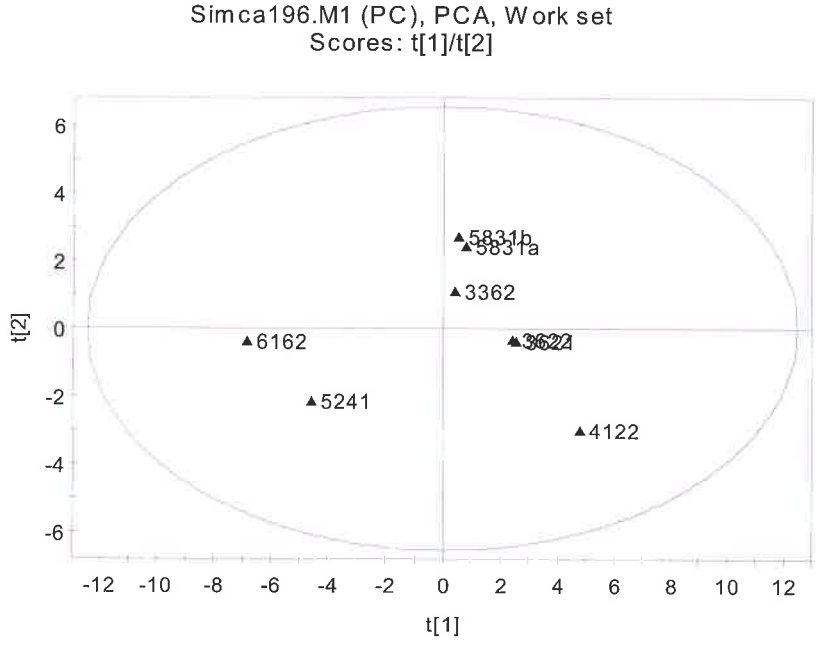


Figure 2b: Radar image of touch and feel properties of samples, Bendtsen hardness 35 % - 45 %

3.2 Linking the touch and feel properties with physical properties of paper

The linking of the touch and feel properties with the laboratory measurements was performed with multivariate data analysis. The methods used were principal component analysis (PCA) and partial least square method (PLS). PCA-analysis visualizes similarities and differences between samples. If the samples are near to each other in the score plot, they have similar properties, whereas samples further from each other are less similar. Figure 3a is the score plot of the samples. It shows that they were quite different. However, samples 5831a and 5831b, which were replicate samples of uncalendered MWC-paper, and 3621 and 3622, which were replicate samples of calendered fine paper with no moistening during calendering, were quite similar, indicating that the test method was repeatable.

Figure 3b is a loading plot of the samples. It illustrates which properties of the samples explain the differences. Variables contributing similar information are grouped together. When variables are negatively correlated, they fall on opposite sides of the plot origin, and in diagonally opposed quadrants. Moreover, the further away from the plot origin a variable lies, the stronger the impact that particular variable has. According to Figure 3a the calendered MWC sample (4122) differed from other samples. According to Figure 3b this is explained by differences in browsing, stickiness and gloss. Also, calendered and uncalendered TMP papers (5241 and 6162) form a group (Figure 3a) that differs from other samples. According to Figure 3b the differences are due to tackiness, graininess, moisture and bulk. An interesting detail is that pleasantness is on the opposite side of the origin. This implies that there was a negative correlation and that the TMP papers were evaluated as being unpleasant.



3362	Fine paper, calendered with moist.	5241	TMP, calendered
3621	Fine paper, calendered without moist.	5831a	MWC, uncalendered
3622	Fine paper, calendered without moist.	5831b	MWC, uncalendered
4122	MWC, calendered	6162	TMP, uncalendered

Figure 3a: PCA score plot of tested samples based on touch and feel and physical properties

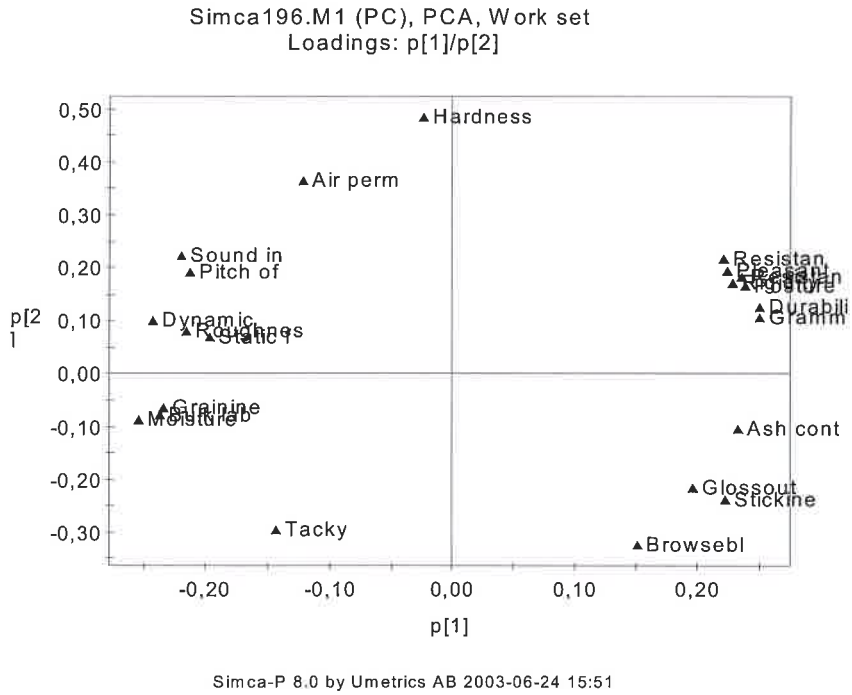


Figure 3b: PCA loading plot of touch and feel properties and physical properties

PLS-analysis was used for modeling the touch and feel properties with physical properties. The aim was to clarify which physical properties could be used as predictors. The touch and feel properties could be quite well modeled with the physical properties of paper. Surface and structure properties in particular were modeled with relatively high reliability. When analyzing the results it should be remembered that the tested samples were very different. This might affect the results and the conclusions are therefore not self-evident. In Table V the most significant physical properties that can be used to predict each touch and feel property are listed.

Table V: The most significant predictors of each touch and feel property

Descriptor	**Most significant physical properties**
Graininess	Static friction, Roughness
Tackiness	Air permeance (negative effect) Hardness (negative effect)
Stickiness	Gloss, Dynamic friction
Rigidity	Resistance to bending Grammage
Browsing	Hardness (negative effect) Static friction (negative effect)
Durability	Moisture (negative effect) Grammage
Posture	Resistance to bending, Grammage
Sound intensity	Dynamic friction, Ash content (negative effect)
Pitch of sound	Dynamic friction, Ash content (negative effect)

From Table V it can be seen that the most significant predictors are very reasonable. Surface property testing involves sliding the fingers over the surface of the sample. It is quite natural that roughness and friction associated with the sample have an effect on the feel. Air permeance and hardness have a negative effect on tackiness. This means that if air permeability or hardness values are smaller, for

example, due to calendering or coating, the tackiness is higher. This result is quite surprising, but an explanation for this behavior could be due to the individual panelists pressing the sample with different amounts of force. If a sample is pressed very firmly, the tackiness will overlap with stickiness. It is reasonable for a coated paper to have a higher stickiness than an uncoated paper. The most significant predictors for rigidity and posture are resistance to bending and grammage. It would be expected, therefore, that there would probably be overlapping between these two descriptors. It is remarkable that the sound descriptors have the same predictors, which implies that they are overlapping descriptors. As the ash content of a sample increases the sound intensity decreases. This meant that coated papers were more silent than uncoated papers.

PLS-analysis was also used in modeling pleasantness with touch and feel properties. Durability, posture and non-graininess were the most significant predictors. Surprisingly, browsing was the least significant predictor. According to the results, a pleasant paper or magazine can be leafed through many times; it is rigid enough and its surface is smooth.

3.3 Future plans

The data presented in this paper are very promising. The touch and feel properties provide additional information relating to the overall quality of the paper. So far we have studied very different unprinted papers. We will continue examining similar samples, for example samples within one paper grade, and the effect of upgrading or downgrading on the pleasantness of touching the paper. The effect of printing will also be taken into account.

4. Conclusions

The data presented in this paper are based on relatively small numbers of samples. However, the results indicate that the touch and feel testing complements the physical property measurements of the paper and gives valuable additional information relating to paper properties. The handling properties are of central importance, because the physical measurements cannot solely explain them.

The target of analyzing the touch and feel properties is to link them with the pleasantness of touching the paper. This area will be the main focus in the future.

Literature

Civille, G. V. and Dus, C. A., *(1989) Development of terminology to describe the handfeel properties of paper and fabrics, 'INDA-TEC 1989: The International Nonwoven Fabrics Conference' 30 May-2 June 1989, Philadelphia, PA, USA, pp 141-158.*

Eriksson, L., Johansson, E., Kettaneh-Wold, N. and Wold, S., (1999) *Introduction to Multi- and Megavariate Data Analysis using Projection Methods (PCA & PLS), Umetrics, Sweden , pp.43-68.*

Forsell, M. (2003), *Product quality - consumers' perception of quality in printed products, Pro gradu, The University of Helsinki, EE-series 125. 88 p*

Jernström, E. (2000) *Assessing the technical competitiveness of printing papers, Doctoral Thesis, Lappeenranta University of Technology, Acta Universitatis Lappeenrantaensis 95, 156 p.*

Karske, M. A., (2001) *A whole new way of marketing magazines, The Griffin, No 3, pp. 29-30.*

Riihiaho S., (2000), *Experiences With Usability Evaluation Methods, Licentiate's Thesis, available online at http://www.soberit.hut.fi/~sri/Riihiaho_thesis.pdf, reference on 2003-06-23*

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