JPMTR 1439
DOI 10.14622/JPMTR-1439
UDC 655.1 : 763-035.4 (084)

Professional communication
Received: 2014-10-06
Accepted: 2015-02-04

Evaluation of misregister on multiple coated fine papers in sheet fed offset printing

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Abstract

Misregistration is one of the most common printing faults of wood free multiple coated fine papers in multicolor sheetfed offset printing. Misregister significantly reduces print quality and leads to complaints to the paper manufacturer. Unfortunately it is often difficult to identify the cause of a misregister problem, because apart from the potential paper impacts, several printing machine and printing ink parameters may also have an effect. It would therefore be an advantage – especially for the paper manufacturer – to be able to determine and influence the factors leading to this problem. In practice a qualitative evaluation of misregister is frequently carried out using a printer's loupe, which is a quite subjective method and has the disadvantage of a rather low resolution. Evaluation of misregistrations using a light microscope allows higher resolution but is quite time consuming.
Therefore, a new offline measuring device for fast and objective evaluation of misregistrations was developed in the R&D department of Sappi Gratkorn. First results using this device show the expected relationships between misregistration and ratio of machine/cross direction fiber orientation, influence of grain direction and filler content of the base paper. Furthermore, misregister was found to be dependent on the amount of fountain solution as well as on the smoothness of the rubber blankets.

Keywords: misregister, sheetfed offset printing, machine/cross direction ratio, fiber orientation, filler content, fountain solution

1. Introduction and background

Conventional sheetfed offset printing still is the most important printing process in the print media world, because of its high quality, the flexibility in production and the comparatively low costs. The offset print process is prone to a variety of printing faults due to the complex interactions between paper, printing ink, fountain solution, rubber blanket and other printing machine components. One of the most frequent and most complex printing faults in sheetfed offset print is misregister. Falter (1980) states that misregister can lead to a completely different and totally undesired print appearance, which underlines the significance of correct registration.

The reasons for misregister are versatile and often not easy to determine or to identify because of the inhomogeneous nature of paper, the different paper production technologies and differences in the printing process itself. Nonetheless it is clear that the main causes are to be found either in the printing machine or in the paper used. In the past significant research was carried out concerning misregistration problems, but only a few parameters allowing a reduction of the occurrence of misregister were identified. One reason for this outcome is that often only one influencing factor was considered. Furthermore, the impacts from the side of paper manufacturing and from the printing process together were rarely compared in relation to misregister. The following list shows some of the possible causes for misregistration resulting from the paper properties or from the printing process settings:

- Disadvantageous ratio of machine direction (MD) and cross direction (CD), i.e. fiber orientation or tensile stiffness orientation (Loewen and Foulger, 2002; Machattie, Paavola and Shakespeare, 2010; Odell and Pakarinen, 2001),
- Dimensional instability, high wet expansion and weakened fibrous structure of paper due to the intake of fountain solution and/or high moisture content (Aspler, 1993; Boström, 2001; Horand, 1986; Niskanen, Kuskowski and Bronkhotst, 1997; Uesaka and Qi, 1994),

- Dimensional instability resulting from the release of frozen tensions or shrinkage induced by drying and calendering (Brecht, Knittweis and Schmidt, 1971; Falter, 1980; Laurell Lyne, Fellers and Kolseth, 1996; Praast, Göttsching, 1995; Uesaka, 1991),
- Electrostatic charge of the paper (Falter, 1980),
- Cross cutter rhythm resulting in variations in thickness, smoothness, MD/CD-ratio, ink penetration, elongation or fiber orientation (Falter, 1980; Horand, 1986),
- High elastic/plastic elongation behavior of the paper (Horand, 1986; Kipphan, 2001; Weber, 1934),
- Incorrect manufacturing of the printing plate and failure during the copying and development process (Kipphan, 2001),
- Defective mounting of the printing plate; inaccurate function of grippers (Kipphan, 2001),
- Too high linear load in the printing nip (Falter, 1980; Kettinger and von Lospichl, 1975),
- High pull-off forces of paper from rubber blanket caused by high tack/viscosity inks and/or tack/viscosity increase of the inks during ink oil absorption (Bluvol et al., 2003; Gane, Matthews and Schoelkopf., 2000; Rousu et al., 2000; Resch and Bauer, 2007; Triantafillopoulos, Lee and Ave'Lallemant, 1996),
- High pull-off forces caused by very smooth paper and/or rubber blanket surfaces (Kawashima and Bousfield, 2008; Mattila and Passoja, 2006).

A severe limitation regarding improvements in the registration behavior of papers is the correct quantitative measurement. Very often only a qualitative evaluation using a printing loupe or a light microscope is carried out. Results using a printing loupe are too inexact due to the low resolution of the loupe and light microscopic methods are highly time consuming. Commercial register measuring systems are available in the market (e.g. LUCHS III or AUTOLUCHS system by PITSID[1] or PressAssess system by Technology Coaching BvbA[2]), which are mainly targeted at the printing industry and are therefore not widely used within the paper industry. Also these commercial systems do not allow access to the source code of the software, which makes these systems quite inflexible.

Therefore, a register measuring device was developed in the R&D department at Sappi Gratkorn in order to allow the systematic evaluation of paper related parameters causing misregister problems. The aim is the prediction of the registration behavior of papers based on paper parameters measured in paper production. This article presents the developed register measuring device and shows some initial results from the application in the evaluation of misregister depending on some basic paper properties (e.g. grain direction, filler content) and on some printing process variables (e.g. smoothness of rubber blanket, fountain solution amount).

2. Methods

In this section the hard- and software of newly developed register measurement system is presented. Additionally an overview of the commercial printing trials and the printed paper samples is given.

2.1 Hard- and software

The offline measuring device (see Figure 1) consists of a CCD camera, a macro object lens and a lighting device. The color camera (UI-2280-SE-C by IDS[3]) has a resolution of 2 448 × 2 050 pixel and a sensor area of 8.446 × 7.066 mm. The focal distance of the object lens (MeVis-C1.6/25 by QIOPTIQ[4]) is 25 mm and needs an operating distance of at least 30 mm. The lighting device (ACIS-35/35 white, 24VDC by Volpi[5]) illuminates an area of 35 × 35 mm.

Figure 1: Hardware of register measuring device

The register measuring software and the user interface are programmed in MATLAB and allow an easy selection of the regions of interest and an automatic calculation of the amount of misregistration.

2.2 Measuring principle

Instead of print marks, measuring fields with full tone squares (3 × 3 mm) were used (see Figure 2). Each full tone square stands for the corresponding printing unit, such as the black square in the center of Figure 2, which represents the first printing unit (identifiable by the number). The distance between the centers of each field in horizontal as well as vertical direction is 4 mm.

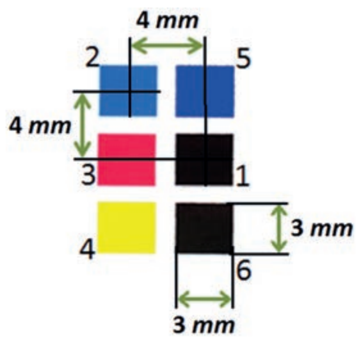

Figure 2: Measuring field with full tone squares and the horizontal and vertical distances of 4 mm to the reference square in the center

The black full tone square of the first print unit is taken as the reference because the sheet is not subjected to any significant strain before being released from the first rubber blanket.

The original distances from each of the squares to the square of the first print unit (the reference) is known from the design of the printing plate (i.e. 4 mm). These known distances are called "reference distances". After printing the measuring fields are imaged using the camera system and the so called "actual distances" are determined automatically. The differences between the "reference distances" and the "actual distances" are taken as a measure of misregistration. The procedure is repeated for each color represented by the squares in the measuring field. The principle is quite similar to the determination of misregister using standard printing marks but determination is easier as the colors are not printed on top of each other.

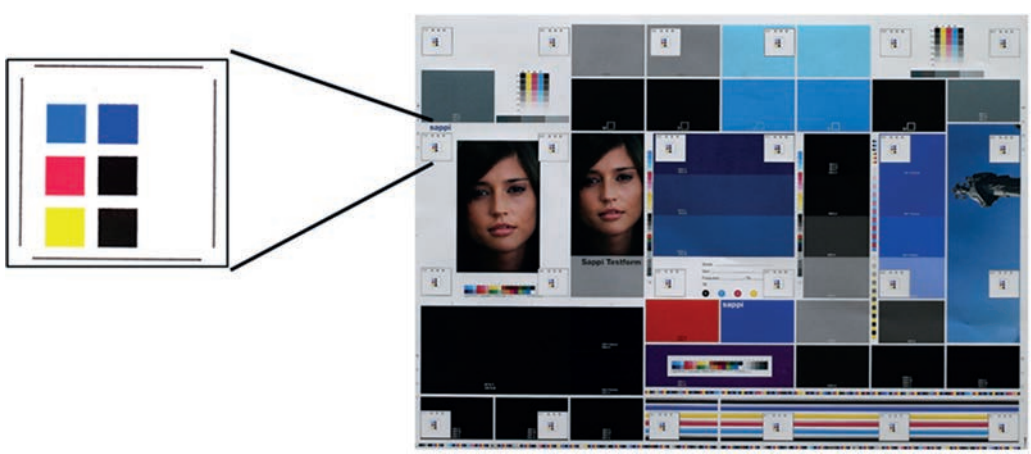

Figure 3: 63 × 88 cm standard print test form with the 24 integrated measuring fields

In the evaluation of misregister, the system measures two distances [µm] for each printed color for each of the 24 measuring fields representing misregister in the print direction and in the cross direction (i.e. 240 single values per printed sheet, see Figure 3). In order to facilitate the interpretation of the results, the following procedure is applied to arrive at a single value per sheet: The maximum and minimum values in printing and cross direction for each color in the 24 measuring fields on a sheet is determined by the software. The absolute difference of this maximum and minimum value in printing and cross direction for each color is calculated. Then the mean absolute difference for all colors in printing and cross direction is determined. Applying the Pythagorean theorem the so called "misregister value [µm]" for the whole sheet is computed from these two absolute mean values.

2.3 Print trials

In order to evaluate the developed measurement system a series of print trials were carried out where parameters known or expected to have a clear effect on misregister were varied. The print trials were targeted at two areas: The first area concerned paper related parameters and some important paper properties were varied. In the second area, the influence of two important printing process related parameters was evaluated.

In all trials, glossy or silk wood-free coated papers with a grammage of 115 or 135 g/m² were used (see Table 1). The print speed for all trials was 8 000 sheets per hour. The used printing inks were manufactured by Flint Group.[6] During the trials, five consecutive paper samples were taken. These five sheets were evaluated in a climate room (23 °C, 50 % relative humidity) after one day storage, using the procedure described in 2.2. The mean value and the standard deviation of the five "misregister values" were calculated.

2.3.1 Paper quality related trials

The influence of grain direction (long grain or short grain), MD/CD ratio of tensile strength (MD/CD-tensile ratio) and filler content of the base paper on misregistration was investigated. Also rolls taken from the center (CR) and the edge (ER) of the web coming from the paper machine were evaluated. The sheet size of the paper in these trials was 63 × 88 cm and the trials were carried out on a Heidelberg Speedmaster XL 105-8-P (see Table 1). The rubber blankets used during the paper quality related trials were manufactured by Birkan[7] (DotMaster RS, smoothness 1.3 µm).

2.3.2 Print process related trials

Investigations concerning the effect of the smoothness of the rubber blanket (RB) and the amount of fountain solution (FS) on misregistration were carried out. The used rubber blankets were manufactured by Birkan (DotMaster RS, smoothness 1.3 µm) and Flint Group (dayGraphica 3000, smoothness 0.5 µm). During the investigation concerning fountain solution, merely the rubber blankets from Flint Group were used. The sheet size of the paper samples was 50 × 70 cm and the trials were run on a Heidelberg Speedmaster XL 105-5+L (see Table 1).

Table 1: List of printed paper samples and print process adjustments

Printed Paper, grammage [g/m²] and sheet size [cm]	**Grain direction**	**Varied parameter**	**Printing machine; Heidelberg Speedmaster**
Paper quality related trials			
Silk 135; 63 × 88	Long grain	MD/CD-ratio = 2.0	XL 105-8-P
Silk 135; 63 × 88	Long grain	MD/CD-ratio = 2.4	XL 105-8-P
Silk 135; 63 × 88	Long grain	MD/CD-ratio = 2.8	XL 105-8-P
Silk 135; 63 × 88	Short grain	Center Roll	XL 105-8-P
Silk 135; 63 × 88	Long grain	Center Roll	XL 105-8-P
Silk 135; 63 × 88	Short grain	Edge Roll	XL 105-8-P
Silk 135; 63 × 88	Long grain	Edge Roll	XL 105-8-P
Gloss 135; 63 × 88	Long grain	Filler content = 16.0 %	XL 105-8-P
Gloss 135; 63 × 88	Long grain	Filler content = 21.9 %	XL 105-8-P
Gloss 135; 63 × 88	Long grain	Filler content = 32.6 %	XL 105-8-P
Print process related trials			
Gloss 135; 50 × 70	Long grain	RB 0.5 and 1.3 µm	XL 105-5+L
Silk 115; 50 × 70	Long grain	RB 0.5 and 1.3 µm	XL 105-5+L
Gloss 135; 50 × 70	Short grain	FS standard and increased amount	XL 105-5+L
Silk 135; 50 × 70	Long grain	FS standard and increased amount	XL 105-5+L
Gloss 135; 50 × 70	Long grain	FS standard and increased amount	XL 105-5+L
Silk 135; 50 × 70	Long grain	FS standard and increased amount	XL 105-5+L
Gloss 135; 50 × 70	Long grain	FS standard and increased amount	XL 105-5+L
Silk 135; 50 × 70	Long grain	FS standard and increased amount	XL 105-5+L

3. Results and discussion

3.1 MD/CD-tensile ratio and grain direction

Figure 4 shows the effect of a change in MD/CD-tensile ratio on the misregister value. Three paper samples with distinctly different MD/CD-tensile ratio of 2.0, 2.4 and 2.8 were manufactured. The samples were printed in long grain. As expected the sample with the highest MD/CD-tensile ratio clearly showed an increase in misregistration compared to the samples with the lower MD/CD-tensile ratios.

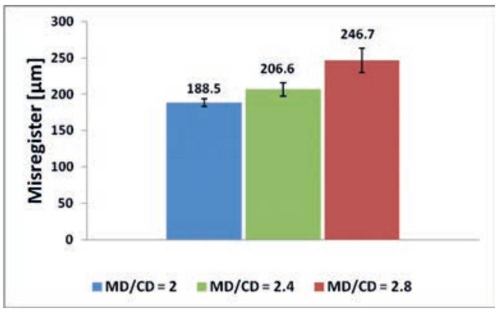

Figure 4: Influence of MD/CD-tensile ratio on misregister; the error bars indicate the standard deviation of the misregister measurements

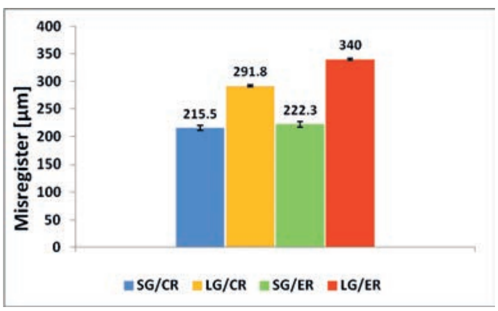

Figure 5: Impact of grain direction and paper sheets from the center or edge of the roll on misregister (SG/CR means short grain center roll, LG/CR long grain center roll, SG/ER short grain edge roll and LG/ER means long grain edge roll); the error bars indicate the standard deviation of the misregister measurements

The influence of grain direction and of the position where the sheets were taken from the paper machine web (center and edge rolls) on misregister are presented in Figure 5. Two long grain (LG) and two short grain (SG) paper samples, taken either from the center (center roll, CR) and edge (edge roll, ER) of the paper web from the same mother reel were compared. While the grain direction had the expected significant effect (misregister increased by 35 % for the center roll and by 53 % for the edge roll for long grain compared to short grain samples), the effect of the position in the paper machine web (edge roll compared to center roll) on misregister was insignificant for the short grain samples and showed a 16 % increase for the long grain samples.

3.2 Filler content

Three paper samples with varying filler contents were produced on the same paper machine and with the same coat weight and surface qualities. All paper samples were printed in long grain. A clear linear correlation between filler content and misregister can be observed in Figure 6. According to Fairchild (1992) and Li, Collis and Pelton (2002), paper sheets with higher filler content show lower stability (for instance tensile strength or breaking length) which means higher elongation at same load. And this seems to cause higher misregistration.

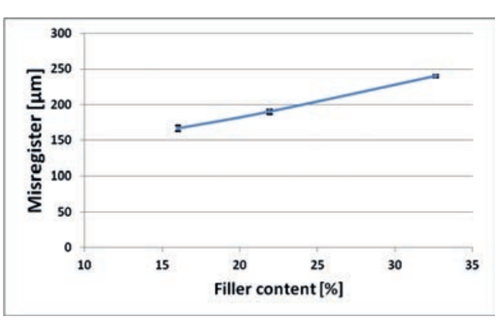

Figure 6: Impact of filler content on misregistration; the error bars indicate the standard deviation of the misregister measurements

3.3 Smoothness of the rubber blanket

Two rubber blankets with different smoothness levels of 0.5 µm (dayGraphica 3000 manufactured by FlintGroup) and 1.3 µm (DotMaster RS manufactured by Birkan) were used during the print trial. The rubber blankets had the same properties regarding thickness, micro hardness, elongation and compressibility. Both paper samples were printed in long grain. Figure 7 shows an increase of misregistration at approximately 20 % for the smoother blanket compared to the rougher blanket. It seems that smoother rubber blanket surfaces create higher pull-off forces which cause higher misregister.

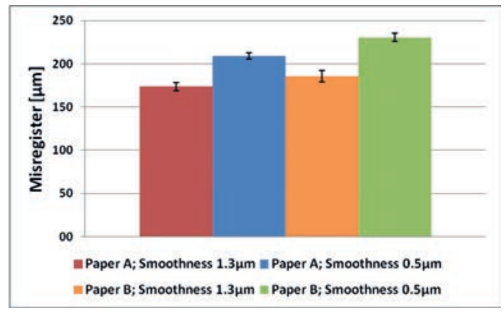

Figure 7: Impact of a smoother rubber blanket on misregistration; the error bars indicate the standard deviation of the misregister measurements

3.4 Amount of fountain solution

Six different glossy and silk WFC paper samples were printed in this trial first using the standard amount of fountain solution and then a 20 % increased feed rate. It was unfortunately not possible to determine the increase in the amount of fountain solution that actually came in contact with the paper. Except the first sample, all papers were printed in long grain. On average, misregister increased by 8.5 % for the higher amount of fountain solution, but the increase also depended on the type of paper sample with some samples not showing a significant increase. This rather low influence of the increased amount of fountain solution could also be explained by the decreased tack of the ink. Figure 8 shows that a higher amount of fountain solution increases the level of misregistration.

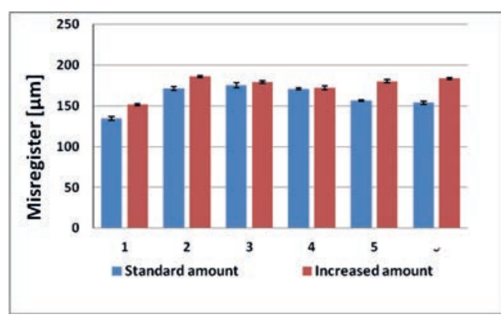

Figure 8: Impact of different amounts of fountain solution on misregistration; the error bars indicate the standard deviation of the misregister measurements

4. Conclusion

The developed measurement system proved to be a valuable tool in the systematic investigation of misregister problems. The results of the paper related trials shows the expected influence of the grain direction with lower misregistration for short grain paper sheets. A modification of the MD/CD-tensile ratio from 2 to 2.8 caused 30 % more misregistration. A difference between center and edge roll paper sheets, particularly in the case of long grain was observed. Misregistration was high when long grain sheets were cut from an edge roll. The reason is the well-known fact, that the edges of a paper web show lower tensile strength and higher elongation in CD-direction. Filler content in base paper and misregister show a clear linear correlation.

In the print related trials the use of smoother blankets clearly resulted in higher misregister values. More force seems to be needed to separate the paper sheet from the blanket when the blanket is smoother (Kawashima and Bousfield, 2008). The increase in the amount of fountain solution on misregistration was lower than expected, presumably to a decreased tack of the ink caused by higher emulsification (Fröberg et al., 2000; and Xiang and Bousfield, 1999).

Acknowledgements

The author thanks Sappi Fine Paper Europe for financial support and Anton Albert for carrying out the printing trials.

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Notes

[1] http://www.pitsidleipzig.com
[2] http://www.tcbvba.be
[3] http://www.ids-imaging.de
[4] http://www.qioptiq.de
[5] http://www.volpi.ch
[6] http://www.flintgrp.com/
[7] http://www.birkan.de/