JPMTR-2503
DOI 10.14622/JPMTR-2503
UDC 655.344: -035.57

Original scientific paper | 200
Received: 2025-01-29
Accepted: 2025-08-06

# The effect of offset printing plate deformation on print quality

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**Abstract**

To be able to make quality prints on uncoated paper, it directly depends on the printing system, the physical properties of the substrate, the ink and ink drying method, the plate properties and the number of prints, the printing room conditions, and the properties of other main and auxiliary materials used in printing. Web offset printing system (heat-set), uncoated paper, CtP plate preparation, heat-set inks, and drying methods were considered in this paper. For prints made on uncoated papers, the loss of quality caused by the wear of the printing plate due to physical and chemical effects during the printing process was examined practically by test printings. For this purpose, 180 000 test prints were made with thermal CtP plates used in heat-set printing. Microscopic and three-dimensional/topographic images of the surface were taken before and after printing, and their areas at the level of micrometer square (μm$^2$) were measured. Dot size deformation was also visually examined and evaluated, depending on the number. For high volume print run on uncoated paper, it was determined that the plate must be replaced per 150 000 impressions or baked before printing.

**Keywords**: web-offset printing, computer to plate, offset plate deformation, print quality.

## 1. Introduction

In offset printing, consistently high quality printing results are achieved by transferring the image on the plate surface to the substrate without a loss of quality or distortion (Chinga et al. 2004). Technical quality includes the ability to physically repeat CIELAB values of color in printed products, namely the surface properties of the image, such as the precise dot reproduction of tone and color depending on the dot area values (Guan et al. 2006). There are many parameters that can affect the dimensional deviation of screen dots during printing. Some of the most important ones are: printing substrate, hardness of the rubber blanket, ink adhesion, dampening solution and the circumferential speed of the printing machine cylinder (Tahirović et al. 2009).

Physical properties of papers affect print quality in offset printing (Tuğrul 2024). One of the main parameters of the printing quality, the ink–water balance in the printing machine, depends on many factors, including plate surface grain (Răzvan-George 2016; Büyükpehlivan et al. 2021; Deshpande 2011; Kim et al. 2010).

There are two methods for web offset printing (Figure 1) known as heat-set and cold-set. In the heat-set process, the ink is fixed and dried rapidly by heating the paper surface with hot forced air (Răzvan-George, 2016; Lif, 2006).

Pure aluminum is mainly used in the production of offset printing plates. There are many graining processes available, including grinding media impact and direct mechanical paste grinding media (Pavlović et al. 2017). These plates are grained by electrochemical techniques in HCl and $HNO_3$ baths to achieve a bright, macro smooth surface with a directionally ordered microstructural roughness that generates the light scattering effect making the surface appear bright.

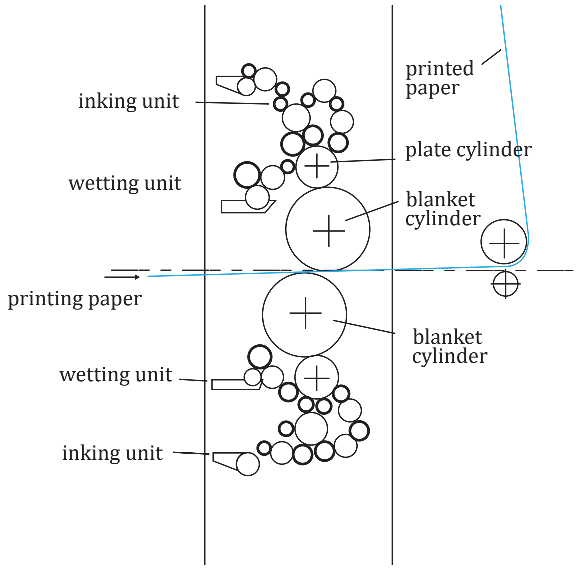



*Figure 1: Cross-section of web offset printing system*

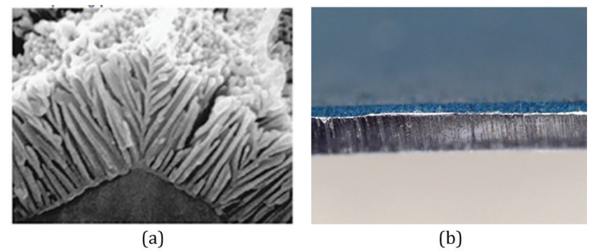



*Figure 2: Cross-section of aluminum plate grained by electrochemical technique (a) and cross-section of the offset aluminum printing plate used for test printing (b)*

The main reasons for using aluminum in offset printing plates are that it is lightweight, corrosion-resistant, thermally conductive, easy to clean, and inexpensive. Aluminum has low reactivity because it forms an oxide coating that develops on its surface and adheres tightly to the metal, preventing further reactions. Aluminum is therefore resistant to air and oxygen exposure, alcohol, water, weak acids, and concentrated nitric acid.

It has been found that the controlled surface roughness of the aluminum substrate is important in understanding the durability of a printing plate throughout the printing process, where the adhesion and wear resistance of subsequently applied organic coatings are critical factors (Oktav et al. 2021). Therefore, the surface topography that creates this roughness is important for both aluminum sheet production and the printing performance of anodic and organic coatings applied to the surface.

Heat-set inks are quick-drying inks that evaporate their solvents in a high-temperature drying oven, followed by cooling to set the remaining ink. Heat-set ink comprises pigment, solvent (heat transfer oil), varnish, and a complementary wax compound. In heat-set drying, the printed web is passed through a high-temperature dryer (typically at 100–150 °C) which evaporates the solvent. The ink is then cooled to about 20–30 °C using steel cooling cylinders through which cold water is circulated. Chemical reactions and absorption processes also help fix the ink onto the paper (Hayta et al. 2022; Srividya and Thirunavukkarasu 2016).

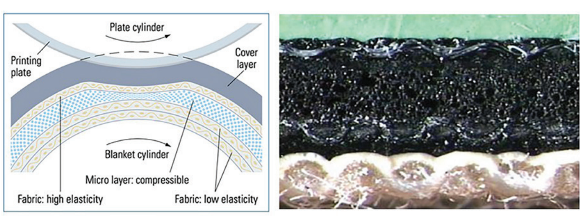
Heat-set inks typically have the advantage of fast drying, which reduces the risk of excessive ink spread and absorption on web printing machines. However, the process can cause problems on coated paper, such as blistering during heat drying if there is insufficient porosity (Özdemir, 2021; Özomay and Özdemir 2020). The printed ink film may lack the durability of a fully polymerized or heat-fixed system. Although uncoated papers have disadvantages related to ink absorption, they are more preferable in industry due to their cost-effectiveness (Särelä 2004; Gooch 2010; Ülgen et al. 2012; Skedung et al. 2010).

The main task of dampening water is wetting non-image areas on the printing plate and reducing heat and friction by emulsifying with the ink at a certain rate during printing (Liu and Shen 2008). To perform this task optimally, it must also have certain physical and chemical characteristics. Ink–water balance is important in offset printing (Nugraha et al. 2023). Insufficient dampening water in the ink–water balance causes the ink to fill the halftone dots and lose detail on the plate surface, affecting tonal reproduction. Too much water will lead to poor image quality in the printed result. The ideal ink–water balance depends on the ink distribution system, the physical conditions of the printing press, the hardness, pH, and conductivity of water, the ink's miscibility with water, the type and properties of the plate, and the levels of ink and water reservoirs (Büyükpehlivan and Oktav 2020; Varepo et al. 2017; Milošević et al. 2014).

The hardness of water is determined by the amount of dissolved calcium and magnesium salts in the water. Calcium bicarbonate and magnesium bicarbonate are responsible for temporary hardness in water, which is also known as carbonate hardness. Chloride, sulfate, nitrate, phosphate, and silicates of calcium and magnesium give permanent hardness or non-carbonate hardness. These two hardness types together are called total hardness. The ideal hardness range for offset printing is between 8–12 dH (degrees of hardness). When water with high total hardness is used in printing, the surface of the ink rollers becomes smooth and shiny over time, as it gets coated by calcium and magnesium ions from the water. This prevents the roller from accepting ink in a stable and consistent manner (Akgül 2012).

The pH of water is a measure of how acidic or basic it is. As offset printing technology developed, it has been proven that a pH value between 4.8 and 5.5 is the most favorable for printing purposes. During printing, increased acidity slows or prevents the ink from drying out. Plate dulling, which means that the image area receives less ink, causes a ghost-like image to appear in the print.

The rubber blanket consists of three or four layers of specially woven linen fabric that has been impregnated with an elastomeric adhesive mixture. Beneath the surface and under the first linen layer is a compressed (0.03–0.05 mm) layer made of cellular, processed, sponge-like polymer. During production, air or gas bubbles are blown into the hot polymer mass and compressed under pressure. Compressible blankets consist of a viscoelastic laminated composite structure comprising at least one compressible foam rubber layer, which may contain voids or microspheres, as well as various tension-resistant support fabrics and an outer, non-compressible, pressure-resistant rubber surface. Conventional blankets generally achieve pressure by causing highly elastic deformation throughout their entire thickness. The compressible surface layer deforms according to the printing form or substrate, and pressure is achieved by compressing the gases within the compressible layer (Figure 3). The printing pressure between the blanket and the printing cylinders is a critical parameter for ink transfer in the offset printing process (Milošević et al. 2014).




(a) (b)

*Figure 3: Cross section of compressible printing blanket under pressure (Kipphan 2001) (a) and cross-section of the blanket used for test printing (b)*

Small printing elements (halftone dots) ranging in size from 20 to 250 μm are reproduced during the printing process. Deformation of the halftone elements inevitably occurs during the production process, and this is directly related to the hardness and composition of the compressible rubber blanket (Majnarić et al. 2008). To transfer ink effectively, specific contact pressure is required between the plate cylinder and the blanket cylinder, and between the blanket cylinder and the impression cylinder. This contact pressure must be adjusted according to the surface structure and thickness of the paper. This is generally achieved by adjusting the position of the blanket cylinder relative to the impression cylinder, without affecting the contact pressure between the plate and the blanket. Tangential slippage refers to very slight slipping motion between the impression cylinder and the blanket cylinder. Due to the elastic deformation of the blanket, relative slippage occurs between the printing plate and the blanket, as well as between the blanket and the paper. As a result of this deformation and slippage, dot gain becomes inevitable. The friction and wear caused by tangential slippage can reduce the lifespan of the printing plate. To minimize tangential slippage, the contact pressure between the cylinders must be optimized. Lithographic offset printing uses pressure between 0.8 and 2.0 MPa to transfer ink from an image carrier to paper or other substrates effectively (Kipphan 2001). For this reason, printing pressure must be strictly controlled. Various methods exist for measuring printing pressure in the offset printing process. One method uses Prescale film, a pressure-sensitive, two-layer film that is placed in the contact area between the impression and blanket cylinders. When pressure is applied, microcapsules on the first layer rupture and the color-forming material reacts with the color developer material on the second layer. The resulting color density depends on the intensity of the applied pressure.

For papers with low surface roughness (e.g., coated paper), the compression amount should be controlled to between 0.10 and 0.15 mm. For papers with higher surface roughness (e.g., uncoated offset paper), the compression amount should be controlled to approximately 0.2 mm. The principle is to use the minimum printing pressure necessary to ensure effective ink transfer (Wu 2009). Once print quality has been approved, the nip setting is fixed for the production process. During printing, the nip gap – the minimum space between the cylinders – is adjusted, rather than targeting a specific nip pressure value. Nip pressure results from interactions between the nip and the paper, depending on the material properties of the printing form and paper, the nip gap, the initial paper thickness, and the printing speed (Yang 2020).

The conductivity value of dampening water is also important. Because of the dissolved carbon dioxide and mineral salts, it contains, it exhibits an ionic structure and conducts electricity, although the amount is very small. The dampening water contains useful mineral salts dissolved in water and a large number of chemical compounds that conduct electricity. In addition to the pH value of the reservoir solution, the conductivity value must be kept under control. This is because contamination caused by paper, ink, and solvent wastes during printing changes the conductivity value. In order that the dampening water gives quality printing outcomes, its conductivity must be formulated between 800 and 1500 (Ülgen et al. 2019).

During the printing process, the printing plate is exposed to mechanical and chemical forces from the machinery and chemicals used. These effects alter the plates surface, resulting in a deterioration in print quality. (Pavlović 2012).

The five most common types of offset printing plates are photopolymer-coated, diazo-coated, silver halide, electrophotographic and waterless plates. Diazo plates (suitable for 0 to 250 000 copies) provide a durable image and are particularly popular today for use with sheet-fed printing machines. Photopolymer plates (suitable for 0 to 1 000 000 copies) are more durable and therefore wear out much more slowly. Offset printing machines used for longer print runs, such as for magazines and newspapers, typically use this type (Diasinh 2025).

This study examined the web offset printing system (heat-set), uncoated paper, CtP aluminum plate properties, heat-set inks, printing dampening solution, and drying methods to guide the experimental application. The research investigated quality deterioration caused by plate wear during printing on uncoated papers due to physical and chemical effects in the printing process through practical testing.

## 2. Material and methods

It is known that web offset printing plates should be changed after a certain number of impressions. However, the important consideration is determining the critical number of impressions at which the plates must be changed before quality starts to deteriorate.

In this study, the wear of aluminum plates used in heat-set web offset printing on uncoated papers due to physical and chemical effects in the printing process was examined. For this purpose, test prints were conducted to determine quality deterioration due to plate wear. A four-color Komori System S38/1-63 cut-off heat-set web offset press with a 9 m long dryer, capable of producing more than 30 000 copies per hour, was used for the test printing. The drying temperature was set at 115 °C.

Computer-to-plate technology was used with the following plate properties: spectral sensitivity of 830 nm, exposure energy of 110–120 mJ/cm$^2$, and resolution of 200 lpi. The print room ambient conditions were maintained at 22 °C and 55% relative humidity. The plate was exposed on a Basys Print UV Setter 850 CtP machine and developed in a TDH 100 thermal processor at 25 °C with a 20 s processing speed. The properties of the selected paper and blanket are shown in Table 1 and 2, respectively.

During the printing process, Schwegmann / Schwego Soft 2 200 dampening water was used, with hardness set to 12 dH, pH value to 5.2, and conductivity value to 840 µS/cm. The CMYK inks used were from the Huber company's RDI 100 series. During the printing process, 180 000 impressions were made. Starting from the 5 000th impression, print samples were taken at the intervals of 30 000 impressions Dot structures, changes, and microscopic measurements were analyzed on the surfaces of the printed paper samples using a Leica S8APO DFC295 stereoscopic microscope with Leica LAS software. Surface profiles of new and used (180 000 impressions) printing plates from the test prints were analyzed using SensoSCAN 6 Lynx software. Three-dimensional surface images of both new and used printing plates were captured for comparison.

*Table 1: Properties of the woodfree uncoated paper used for test printing*

| Standards | Values |
|---|---|
| Basis weight (ISO 536) (g/m$^2$) | 80.0 |
| Thickness (ISO 534) (µm) | 105.0 |
| Bulk (ISO 534) (cm$^3$/g) | 1.25 |
| Brightness D65 (ISO 2470-2) (%) | 102 |
| CIE whiteness (ISO 11475:2017) | 85.4 |
| L* value D65 (D65/10°) (ISO 5631-2) | 92.8 |
| a* value D65 (D65/10°) (ISO 5631-2) | 2.9 |
| b* value D65 (D65/10°) (ISO 5631-2) | −3 |
| Opacity (ISO 2471) (%) | 91.8 |
| Roughness Bendtsen (ISO 8791-2) (ml/min) | 250.0 |

*Table 2: Technical characteristics of the blanket used for test printing*

| Features | |
|---|---|
| Ink compatibility | Hybrid |
| Printing surface color | Light green |
| Thickness (mm) | 1.70/1.95 |
| Average load value (N/cm$^2$) @ 0,23 mm Indentation | 250 |
| Surface roughness Ra (µm) | 0.8 |
| Feed features | Slightly positive |
| Elongation (%) | <0.9 |
| Tensile strength (N/mm) | >60 |

## 3. Results

As a result of application evaluations of the captured microscopic images of plate, it was found that dot deformations and dot losses occurred on the plate which printed 180 000 copies, compared to the unused plate (not printed) (Figure 4).

This caused image losses in print. The rate of image loss on the uncoated paper that was detected by measuring with a Leica S8APO DFC295 stereoscopic microscope increased as the number of prints increased. It was found that this loss was caused by the mechanical stress of the ink and humidification rollers in contact with the plate at the

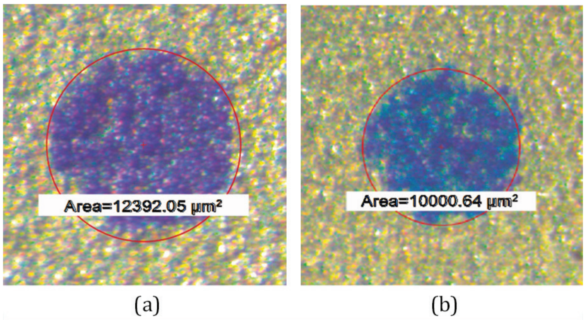



*Figure 4: Microscopic photo of a printed dot on unused plate (a) and used plate showing the deformation after 180 000 copies (b)*

nip point and the deteriorating effect of the temperature caused by friction on the emulsion. In addition to diameter reduction at the screening point, there are also emulsion spills at the grain–emulsion boundary (Figure 5).

To prevent this deterioration, it is necessary to use the hard emulsified plate and kiln drying of the plate. The pressure of the rollers contacting the plate should be checked at the nip point. Over pressure should be optimized by measuring with a NIP Inspector tool. Depending on the number of prints, the shrinking and deformation of the dots is shown with graphics in Figure 6. It is seen that the grain structure, outside the image area is also disrupted by the aforementioned deteriorating effects; roughness of the plate decreases by the abrasion caused by printing (Figure 6).

As a result of measurements made on cyan print samples, it is seen both during the visual checks and point diameter measurements that the dot structure was printed very smoothly in the first 5 000, 30 000 and 60 000 prints, and that it is within acceptable limits (Figure 7).

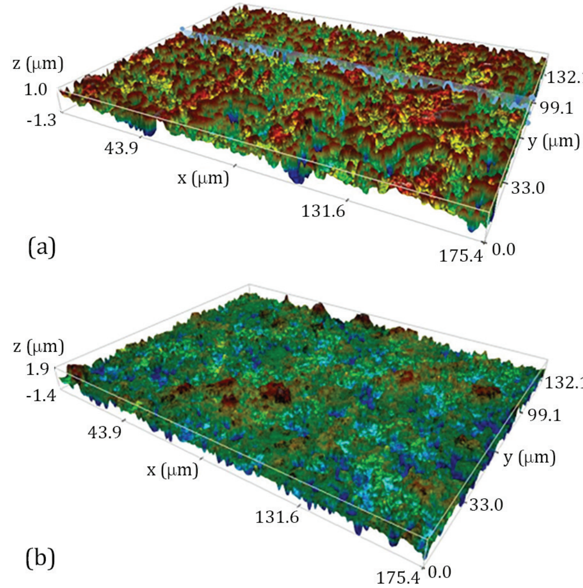



*Figure 5: Microscopic photo of a printed dot on unused plate (a) and used plate showing the deformation after 180 000 copies (b)*

As determined on the used plate, dot deformations began to appear in prints after 90 000 copies. Especially when the 180 000th sample was examined, it was determined that the dot structures were extremely deteriorated and that most of the dots at 3%

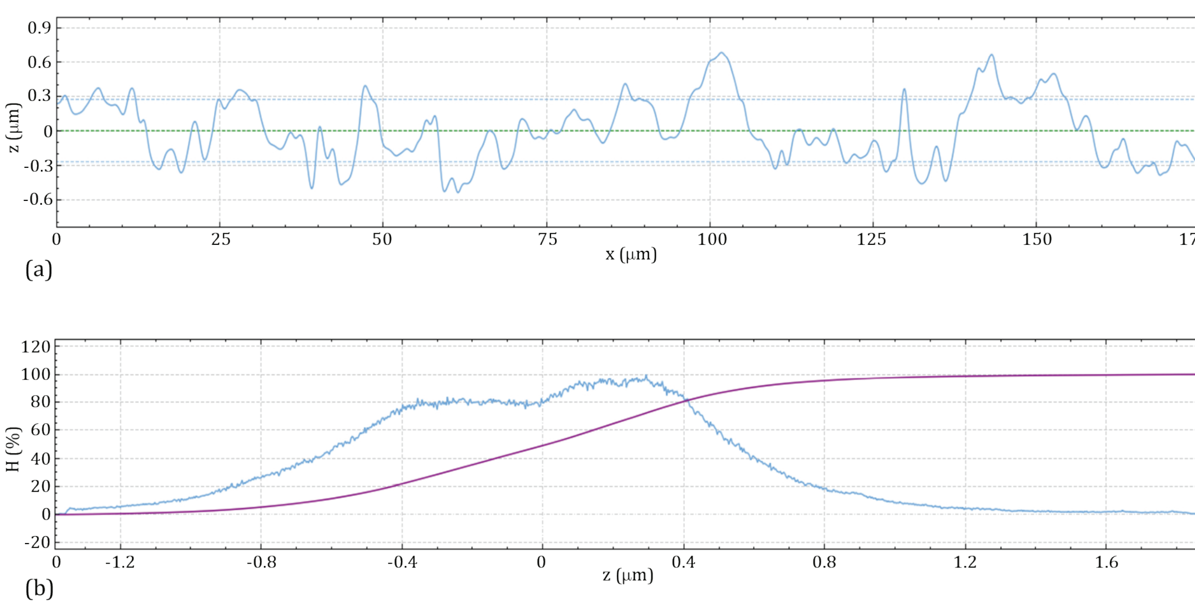
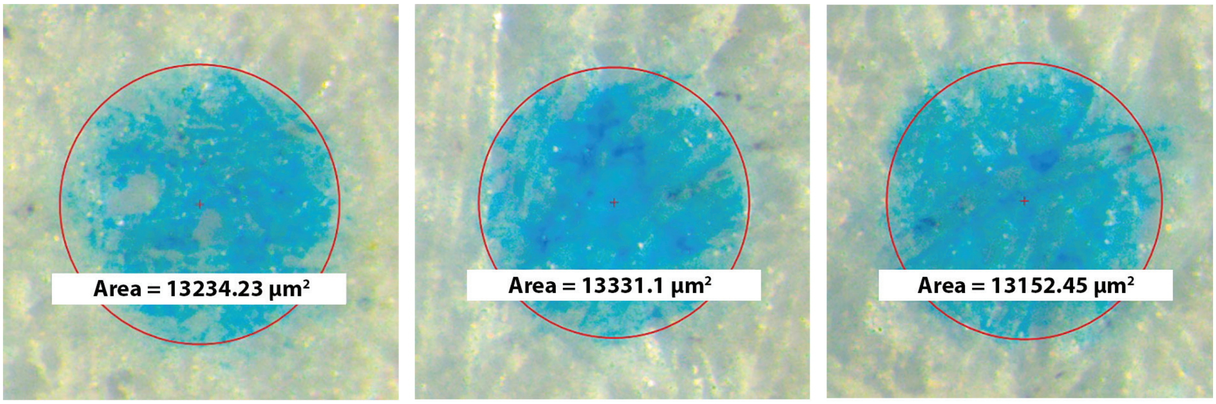



*Figure 6: Representation of grain structure of unused plate (a) and deterioration of used printing plates after 180 000 copies (b)*




(a) (b) (c)

*Figure 7: Dot structures formed in the first 5 000 (a), 30 000 (b) and 60 000 (c) impressions obtained on uncoated paper*

-5% screening tone value were destroyed (Figure 8 - 9) and that significant dot deformation was observed.

The image quality resulting from high volume prints was at a much higher level at the beginning of the first print and compared to prints up to 60 000 copies. Due to deterioration of the emulsion and grain structure, there are also distortions in ink transport and color intensity depending on water ink imbalance (Figure 10).

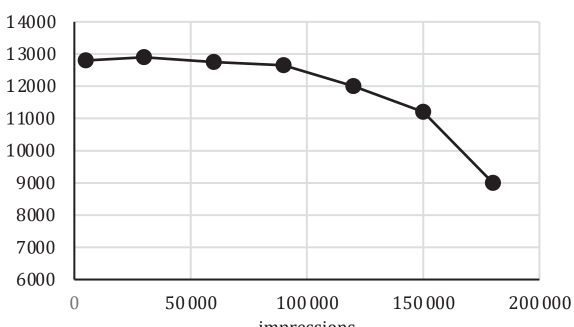
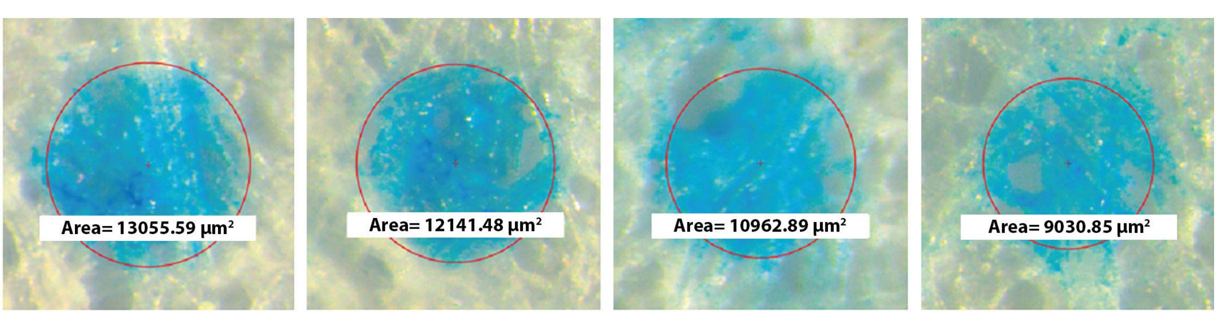



*Figure 8: Change of dot area due to increase in the number of impressions*

## 4. Discussion and recommendations

In this study, quality deterioration of aluminum plates, one of the factors affecting print quality on uncoated paper, was examined in relation to the number of impressions. For this purpose, test printing was carried out on woodfree uncoated paper. Based on the test prints and measurements, the following results and recommendations are presented. In a comparative examination of dot structures on unused plates versus high-impression plates, very high-level dot deformation was observed in both visual evaluation and technical measurements, causing loss of color and tone in printing. Micro-particles that break off from the paper surface during high-volume printing on uncoated paper have a corrosive effect on the plate surface. The pressure applied by rollers in contact with the plate surface, the content of the dampening solution, its pH value and hardness, and the characteristics of printing ink are the main factors that affect the plate during the printing process and change quality parameters. Even if these parameters are set optimally at the beginning of printing, they can change negatively during the process. For this reason, print operators should monitor these parameters




(a) (b) (c) (d)

*Figure 9:* Dot structures formed in 90 000 (a), 120 000 (b), 150 000 (c), and 180 000 (d) impressions obtained on uncoated paper.

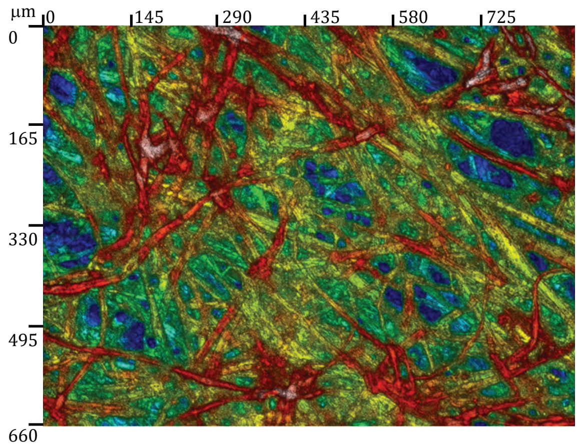



*Figure 10: The dot on the printed paper with the plate deteriorated after 180 000 impressions due to microstructural deformation*

during the printing process using TDS (Total Dissolved Solids) meters, spectrophotometers, and pH meters. The technical properties of offset printing blankets directly impact print quality. This is because halftone dots, which can be as small as a few microns in diameter, are transferred from the blanket to the substrate. Various types of printing blankets are used in offset printing, and printing operators must be familiar with their properties. The composition and surface properties of the substrate (e.g., paper or cardboard) determine the type of printing blanket used. Compressible blankets with a thickness of 1.65 to 1.95 mm and Shore A hardness values of 60° to 85° are typically used. During the printing process, under the same pressure conditions, these blankets provide a significantly larger contact area at the nip point with both the printing plate and the substrate than traditional blankets do, resulting in minimal deformation. However, higher hardness levels contribute to the deformation of smaller halftone dots. Additionally, due to the absence of tangential forces under nip pressure, compressible blankets slip less than traditional blankets. In this study, it was determined that the surfaces of the plates used in test prints on uncoated papers began to deteriorate at a microscopic level after 90,000 impressions. However, this deterioration became visible after 150 000 impressions and was reflected in the image quality (Figure 8).

Due to economic constraints, it is not possible to replace the printing paper, so new plates must be prepared and replaced as plate deformation occurs during high-volume printing jobs. Alternatively, before the start of printing, baking treatment should be applied to plates to increase their durability by hardening the emulsion. Significant variables such as pH, conductivity, water hardness, and temperature of the dampening solution, which affect plate deterioration, should be established at the beginning of printing, adjusted optimally, and checked frequently during the printing process. Ideally, the water hardness of the dampening solution should be 8–12 dH and the pH value should be between 4.8 and 5.5. Dampening solution temperature is typically maintained between 10 and 15 °C. At the same time, printing operators should know that condensate can collect on pipes and in dampening solution reservoirs at low temperatures, which can lead to water droplet formation. Dampening solution additives are complex material systems in which various components are included to support adequate emulsification and wetting (surface tension). The pH adjustment and stabilization (buffer systems) are significant for protection against corrosion and prevention of cooling effects and slime formation (biocides).

## Conclusion

The aim of this study was to determine how plate wear affects dot transfer on uncoated paper under controlled heat-set web offset test printing conditions. This study shows that dot deterioration begins on uncoated paper after a certain number of print runs by comparing the microscopic structures of both plates and paper. The critical number of impressions where plates must be changed was determined to be 90 000 impressions for microscopic deterioration and 150 000 impressions for visible deterioration affecting print quality. Baking the printing plate could be a solution to increases its resistance to printing inks and processing chemicals, thereby enhancing its printing capacity.

As a result, it is not economically feasible to change the printing paper at the customer's request when printing high volumes on uncoated papers. For high-volume print jobs, plates should be changed periodically to ensure consistent image quality from the beginning to the end of printing. The number of replacement plates should be determined according to when dot deterioration begins. A sufficient number of plates should be prepared under identical conditions.

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