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Impact of Screen Ruling on the Formation of the Printing Elements on the Flexographic Printing Plate

Authors

Tamara Tomašegović*, Sanja Mahović Poljaček, Tomislav Cigula

University of Zagreb,
Faculty of Graphic Arts,
Croatia
**E-mail: ttomaseg@grf.hr*

Abstract:

Flexography is a printing technique widely used in the packaging production. The main feature of flexography is the use of a printing plate elastically deformed during the reproduction process. The printing plate is made of an elastic material, rubber or nowadays of mainly different types of photopolymer. The elasticity of the plate enables the printing on a wide range of printing substrates, which is one of its advantages compared to other printing techniques. On the other hand, deformations of the printing plate in the printing process caused by the pressure between the printing plate and the substrate present a major limitation of flexography. Apart from the functional properties of the printing plate in the printing process, the plate making process, including photo polymerization, considerably influences the value of halftones on the printing plate, and consequently on the final product. The aim of this paper is to examine the influence of screen ruling on the formation of printing elements and the adjustment of the printing plate making process in order to achieve optimal quality of the printing plate and, therefore, the final product.

The results have shown that the use of different screen rulings is of great significance in the processes of printing plate curve adjustment. It was proven that the use of different screen ruling has a considerable influence upon relief depth and a cross-section of the printing elements (3D analysis), which again have a significant impact on the quality of the final product, but cannot be detected in 2D analysis.

Keywords:

Photopolymer, Computer to Plate (CtP), Screen Ruling, Bump up Curve, Compensation curve

1. Introduction

Flexographic printing plates are characterised by a geometrical difference between printing and non-printing areas. The original material for flexographic printing plates was rubber (*Page Crouch, 2005*). Nowadays all flexographic plates are made either of rubber or photopolymer.

With the development of material and technology in the last decade, a great improvement has been made in the use of newly formed materials and the flexographic printing plate making process. Flexographic printing plates in use nowadays are made of photosensitive monomers (mostly acrylates and methacrylates) and a number of additives, such as photo initiators and plasticizers, to obtain necessary functional properties (*Thompson, 2004; Diamond, 1991*). The reproduction of minimal dot size of 10 microns is enabled thanks to the computer-controlled workflow (****, 2012c*).

Due of the functional properties of the printing plate and characteristics of the printing ink (*Cusdin, 1999; Page Crouch, 2005*), flexography is a printing technique mostly used in packaging production.

One of the most widespread flexographic printing plate making procedures is based on the LAMS (laser ablated mask) technology (Figures 1a – 1f) (*DuPont Cyrel, 2008*). It requires a computer controlled workflow and, as can be seen from Figure 1, it is a complex multistep procedure. In the first step the laser ablation of LAMS mask has to be proceeded. Laser removes the LAMS on the areas where the printing elements will be formed. Back-exposure is needed to create a basis layer and the main exposure causes a polymerisation and definition of printing and non-printing areas of the plate. Exposure is followed by chemical and mechanical developing which remove the non-polymerised parts of the polymer. Drying and post-exposure (UV-A, UV-C) finish the photopolymerization process and improve the mechanical properties of the printing plate. Apart from those phases in the plate production procedure, digital data which will be reproduced on the plate should be adjusted digitally in order to achieve an optimal tone reproduction. That means that in a digital file the calibration curves of the system have to be corrected for obtaining high quality imprints.

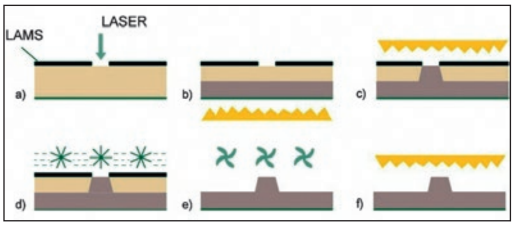


Figure 1. Production of photopolymer printing plate with LAMS; a) laser ablation; b) back-exposure; c) main exposure; d) chemical and mechanical developing; e) drying; f) post-exposure (UV-A, UV-C).

2. Tone reproduction in flexography

Tone reproduction in flexography is influenced by many factors, some being the printing plate quality, the printing ink, the printing substrate and the pressure in the reproduction process. Figure 1 witnesses to the fact that the quality of the plate depends on different processing steps. In order to obtain a high quality printing plate, every step should be defined and controlled. In a digital workflow, the quality has been significantly improved thanks to the possibility of precise settings of necessary parameters. For example, there is a possibility of correcting the tone reproduction values in a digital file which will be reproduced on the plates in order to create the required tone values on the printing substrate (****, 2012b*). In many cases the problem occurs when images with lower and shadow tones have to be reproduced. If the values have not been corrected in a digital file, lower tone values will most likely not be visible on the substrate, as it is the case with the shadows in the darker tones. The main reason for this phenomenon are the specifics of the photopolymerization process which occur in the printing plate material during the exposures. As it can be seen in

Figure 1 there are three exposures in the plate reproduction process where polymerisation occurs: back, main and post-exposure. It has already been published that, depending on a screen ruling, the printing elements at low coverage values are too small to be reproducible (*Mahović, 2012; Brajnović, 2011*). The reason for this is too small an area of the polymer surface which is exposed to the UV radiation (*Figure 1c*). Consequently, there is not enough energy which comes to the polymer to complete the photopolymerization process of the printing elements in the lower coverage values. According to that, those poorly formed elements will not have the possibility to adsorb the printing ink and transfer it on the printing substrate. In Figure 2 microscopic images of incorrectly and correctly formed printing element can be seen.

a)

b)

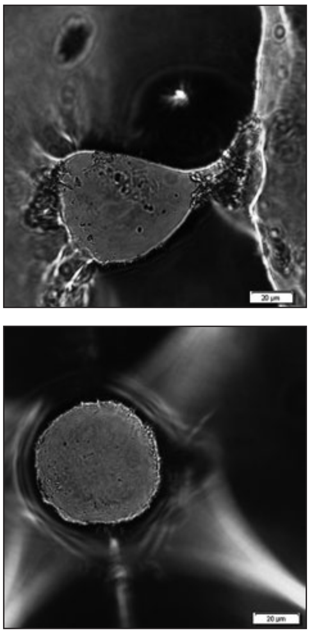


Figure 2. Microscopic images of printing element in lower coverage values; a) incorrectly formed; b) correctly formed printing element

Furthermore, undercopying occurs in the exposure process, which can cause an increased coverage value on the printing plate, resulting in a darker image on the imprint. Undercopying is caused by the angle of the UV light incidence and the diffraction of light which enables partial photopolymerization of monomer covered with LAMS, causing an increase in the printing element area, i.e. increase in tone values. Furthermore, the filling of non-printing areas on the flexographic printing plate occurs and hence the reduction of the geometrical difference between the printing and the non-printing elements. Thus, in the printing process, the pressure and the printing plate deformation could cause adhering of the printing ink on the upper surfaces of a non-printing element and would be transferred on the printing substrate, resulting as enhanced dot gain.

Considering those facts, certain corrections must be made of coverage values which will be formed on the printing plate. After the calibration of the printing plate making unit, two other correction curves have to be applied into a digital file in order to compensate the deviations of the printing plate in the plate making process, as well as the deformations in the reproduction process (*Brajnović, 2011*).

In the first step a bump-up curve has to be applied. The purpose of a bump-up curve is primarily to increase lower coverage values (0% - 10%) to a value which is reproducible on the chosen type of the printing plate. Furthermore, in the second step a compensation curve has to be applied in a digital file in order to enable the reproduction of lighter tones. It has to be adjusted according to all parameters related to the printing process: the printing plate, the printing ink, the printing substrate and the printing press. It should compensate the deformation of the printing plate in the printing process, which usually results in excessive values of dot gain. If one of the parameters is changed in the workflow, a re-evaluation of the compensation curve has to be performed. The other parameter that should also not be neglected in the plate workflow and file adjustments is screen ruling. Due to the increase of quality demands in the flexography today, higher screen rulings have been introduced and used, and newly formed screen types have been formed as well. Beside classic AM screen type (*Figure 3a*), several types of hybrid screens have been used. Hybrid screens combine classic screen with stochastic (FM) screen, which

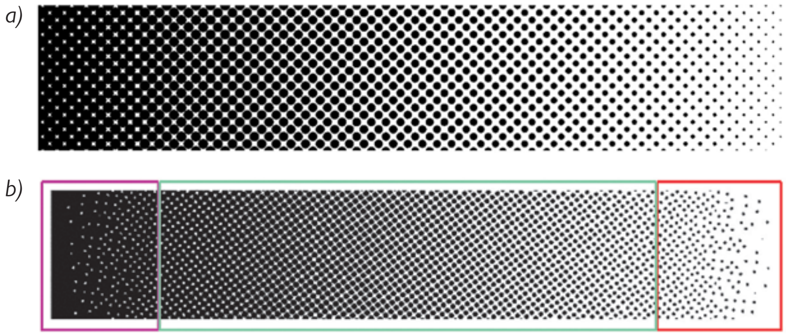


Figure 3. Examples of screen type in flexography – a) AM screen, b) hybrid screen

is usually applied only in lower and higher coverage values (*Figure 3b*). The use of hybrid screen the dot gain in higher coverage has helped reduce the value and the reproducibility of lower coverage values has been improved (*Esko-Graphics, 2004*).

3. Experimental

3.1. Materials and methods

Flexographic printing plates used for this research were Asahi AFP-HF with LAMS mask (****, 2012a*). Samples of the printing plate were imaged in Esko CDI Spark 5080 unit, UV exposed in BASF – Nyloflex unit and chemically proceeded in a commercial solution. The plate making process was conducted according to the procedure obtained by the printing plate manufacturer. A digital control wedge with coverage values from 1% to 100% was generated in order to monitor the formation of the printing elements on the printing plate in a whole tone scale (a step of 5%). For a detailed control of the lower coverage values, a wedge step of 1% was set in the area from 1% to 10%. The control wedge on the printing plate was produced in two screen rulings, 76 lpi and 121 lpi. For each screen ruling, three samples of the printing plate were made – with the calibration curve (without a bump up curve), with a bump up curve, and with an application of compensation curve. Classic AM screen type was used.

Coverage values on the samples were measured by the VipFlex, a device for the analysis of tone reproduction on film, imprint and flexographic printing plate. In addition, visual analysis of the printing elements of different coverage values was made by observing images captured by the Olympus Metallurgical Microscope BX51.

For a detailed view of the printing elements on the printing plate samples, the AniCAM 3D scanning microscope was used. This measuring unit enables the capture of a set of images obtained on a different height of the lens focus, which again enables the capture of the sample topography (*Figure 4*).

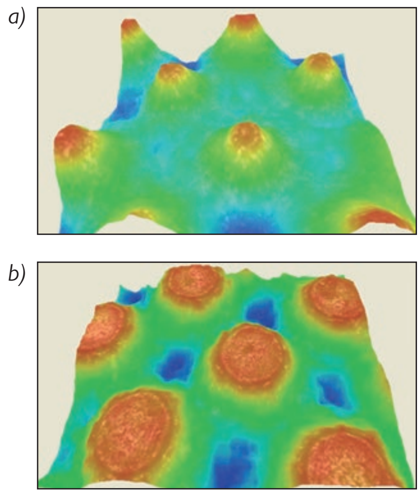


Figure 4. 3D view of flexographic printing plate at a) 5% and b) 50% nominal coverage value, 76 lpi

3.2. Results and discussion

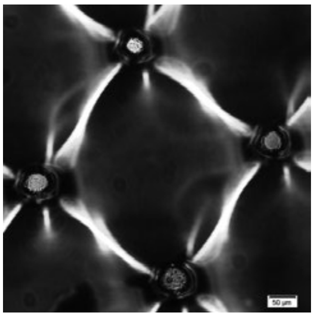
Microscopic images of the samples were captured in order to analyze the formation of printing elements on the printing plates. In the first step the images were captured on the samples without the application of the bump-up curve, and afterwards the images were captured on samples with the bump-up curve. Figure 5 shows the printing elements of a 3% coverage value without the application of the bump-up curve for the 76 lpi and the 121 lpi screen rulings.

It is obvious that the printing elements at a 3% coverage value have not been formed correctly on both plate samples without the application of the bump-up curve (proceeded with the screen of 76 lpi and 121 lpi). The printing elements on the 76 lpi screen ruling are of different sizes (from 30 μm to 50 μm) as a result of insufficient light energy required to initiate the photopolymerization process and form the elements correctly (*Figure 5a*). On the other hand, printing elements of the 121 lpi screen ruling are only partially formed, their structure or their size cannot be seen (*Figure 5b*). The reason for this is identical as at the 76 lpi screen ruling, i.e. the energy that reached out the polymer is too low and the elements could not be formed. This is the main reason why the application of the bump-up curve is necessary and it was applied in the next processing step.

The results of the measured coverage values depending on the nominal coverage values are shown in Figures 6 to 8. In all Figures points (squares or triangles) present the values measured and the lines present the trend lines of the measured values.

Figures 6a and 6b illustrate the comparison of the measured coverage values on the printing plate for the 76 lpi screen ruling when the calibration curve (blue squares) and when the bump-up curve (red triangles) is applied. The calibration curve is applied to the printing plate after calibrating the LAMS ablation unit. With the calibration curve no corrections considering the printing plate reproduction properties and printing process were made. It is evident that after applying the bump-up curve, all coverage values on the printing plate are enhanced. The main purpose of the bump-up curve is to enhance the lower coverage values (0% - 10% or more, depending on the type of the printing plate) because in low coverage values, energy which is reaching monomer base through small void surfaces in the LAMS layer is not sufficient to cause the polymerization of the printing elements. In order to achieve a fluent tone transition, all coverage values on the printing plate must be subjected to the bump-up curve. It could also be seen in Figure 6b that the differences between measured and nominal coverage values are nearly invisible from 50% nominal value with the exception of two points, on 70% and 95% nominal values, which could be the consequence of the plate making process or a measurement error.

a)



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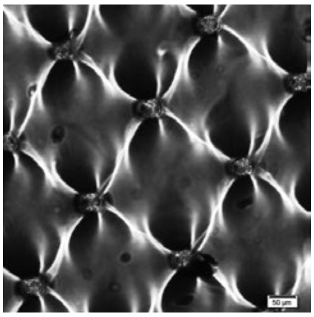


Figure 5. Microscopic images of flexographic printing plate sample on 3% nominal coverage value at 200× magnification after application of the calibration curve (without the bump-up) for a) the 76 lpi and b) the 121 lpi screen ruling

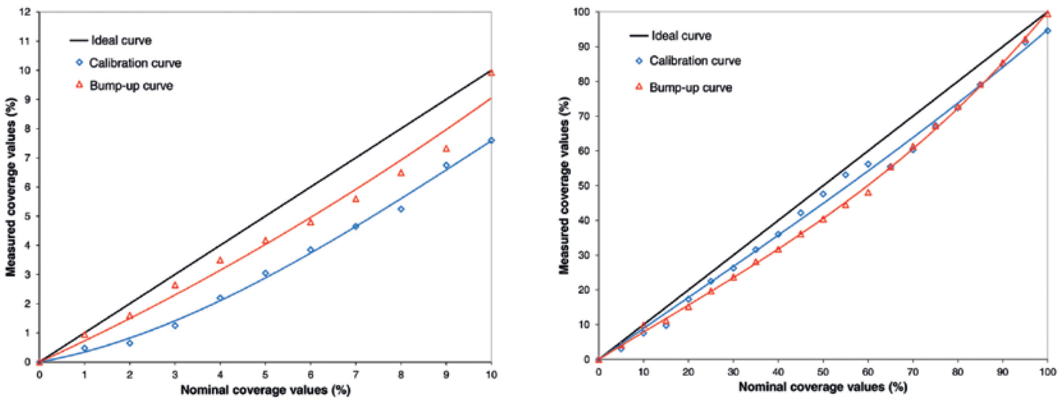
The results measured on the plate with the 121 lpi screen ruling and by means of the bump-up curve differ from the bump-up curve for the 76 lpi screen ruling. In Figures 7a and 7b one can see that the bump-up curve mostly affects coverage values from nominal 1% to 60%. Since the 121 lpi screen ruling uses smaller printing elements than the 76 lpi, applying the similar bump-up curve could result with an excessive dot gain. Consequently, bearing in mind the undercopying, the results of higher nominal coverage values (90%

to 100%) could lead to the polymerisation of the whole surface area and to the decrease of the reproducibility of darker motives.

Figure 8 shows the results of the difference between the enhancement of coverage values from 1% to 10% for the 76 lpi and the 121 lpi screen ruling. It is visible that the difference between the bump-up and the calibration curve is higher for the 121 lpi screen ruling. The 121 lpi screen ruling has smaller printing elements, and therefore the larger correction is needed in order to form reproducible printing elements on the printing plate.

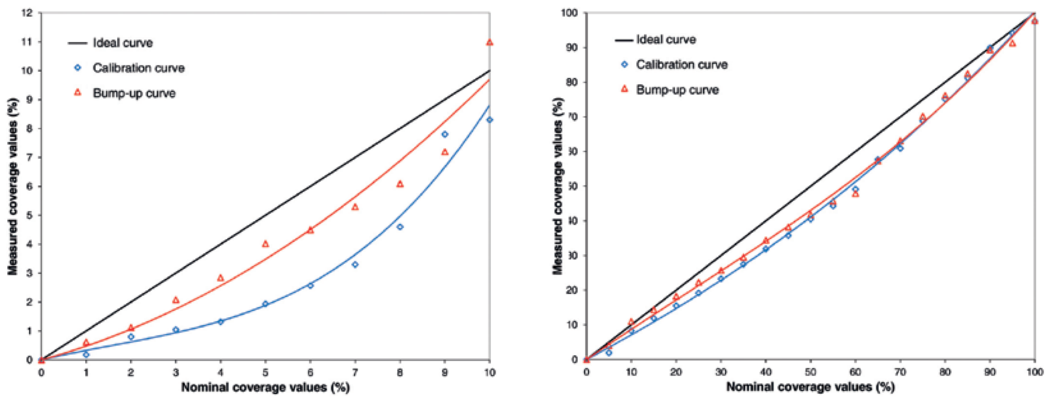
The result presented in Figure 8 has been confirmed with microscopic images presented in Figures 9 and 10 which show the size and area of the printing elements for both screen rulings. Images have been captured at 500× magnification.

Figures 9 and 10 show the printing element before and after the application of the bump-up curve. Figures 9b and 10b show the enhancement of the captured printing element in the same proportion to Figures 9a and 10a. Figure 9a presents an image of the printing element on 5% coverage value for the 76 lpi screen ruling that covers the area of 2795 μm². Upon the application of the bump-up curve, the area has been increased to 5690 μm². Surface area of 5% coverage value for the 121 lpi screen ruling covers the area of 318 μm² and upon the application of the bump-up curve, the area has been increased by five times (1613μm²). These images have confirmed the results of the coverage values measurement, which showed a higher value increase at the 121 lpi screen ruling.



a) b)

Figure 6. Comparison of the results of the calibration and the bump-up curve for the 76 lpi screen ruling a) coverage values from 1% - 10%; b) coverage values from 1% - 100%



a) b)

Figure 7. Comparison of the results of the calibration and the bump-up curve for the 121 lpi screen ruling a) nominal coverage values from 1% - 10%; b) nominal coverage values from 1% - 100%

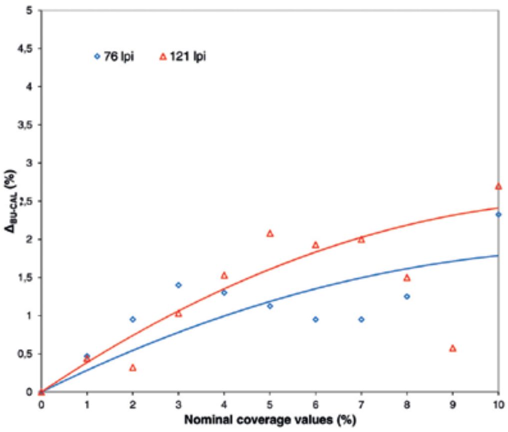
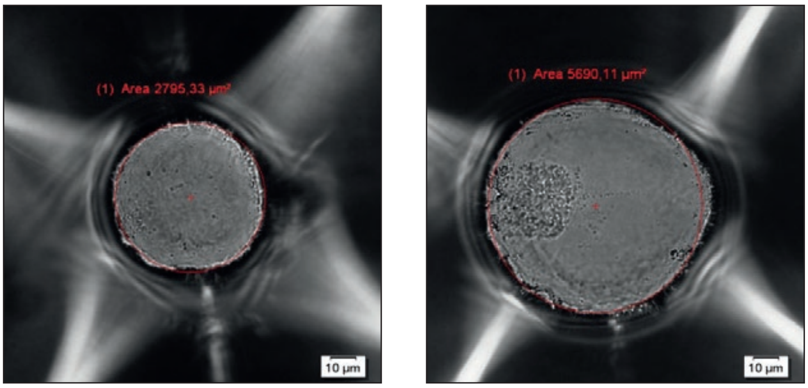
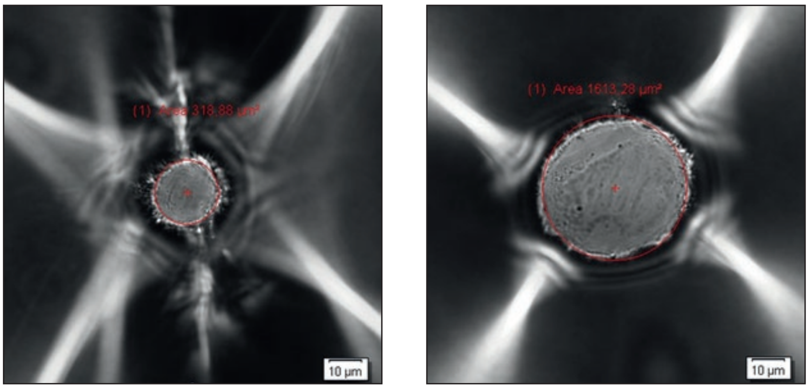


Figure 8. Results of coverage values in lighter tones after application of the bump-up curve for the 76 lpi and the 121 lpi screen ruling



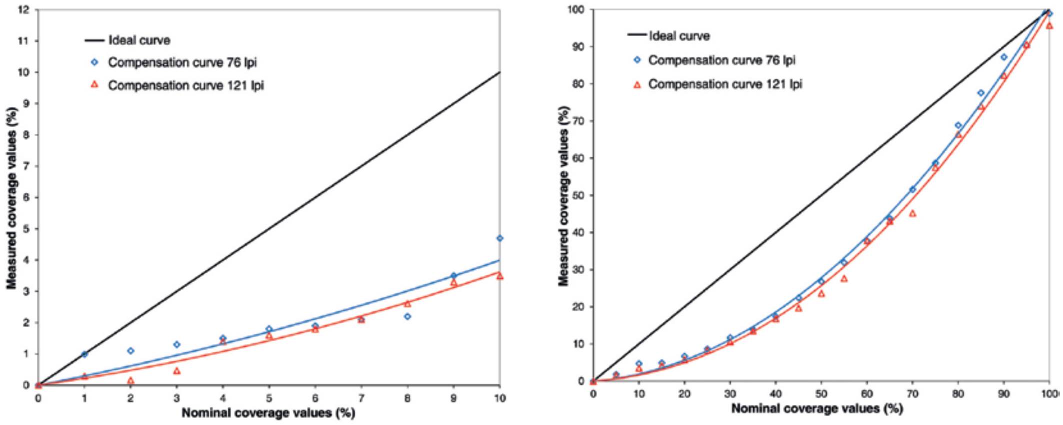
a) *b)*

Figure 9. Images of flexographic printing plate sample at 5% coverage value for the 76 lpi screen ruling a) after application of the calibration curve; b) after application of the bump-up curve



a) *b)*

Figure 10. Images of the printing plate sample at 5% coverage value for the 121 lpi screen ruling after corrections with a) application of the calibration curve; b) application of the bump-up curve



a) *b)*

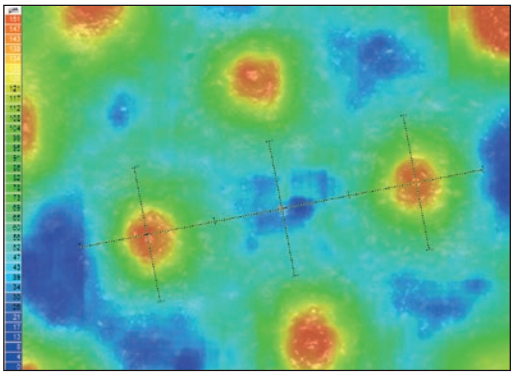
Figure 11. Comparison of the results of the compensation curves for the 76 lpi and the 121 lpi screen ruling a) nominal coverage values from 1% - 10%; b) nominal coverage values from 1% - 100%

After the application of the bump-up curve which enables the formation of printing elements on the printing plate, a further correction is required. After proofing, it is necessary to apply the compensation curve to the printing plate in order to adjust the reproduction of coverage values to the printing system which includes the printing substrate, the printing ink and the printing press. Differences in printing systems can cause a general increase of coverage values on the imprints, i.e. enhanced dot gain. Uncoated printing substrate and more viscous printing ink cause higher dot gain then, for example, the PE printing substrate or printing ink of lower viscosity (*Tabbernor, 2007*).

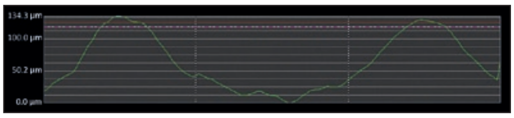
As it is evident from the Figures 11a and 11b, the compensation curve decreases coverage values on the printing plate in order to reduce dot gain, but without the influence on the lower coverage values in order to remain them reproducible. Since the 121 lpi screen ruling has a higher dot gain due to more printing elements on the same area than the 76 lpi screen ruling, a larger decrease of coverage values is required for the 121 lpi screen ruling, which can be seen in the Figure 11. The highest correction of coverage values is made in lower and middle tones (from 1% to 50% nominal values) to ensure a reproduction with the highest range of coverage values, as the highest dot gain in printing process is expected in the midtone area (*Kipphan, 2001*).

In order to see the formation of the printing elements on the printing plate, an image analysis was made by means of the Troika's AniCAM 3D scanning microscope. Figures 12 to 15 present topography and a profile of the printing plate at lower and higher coverage values.

Figure 12a displays an analysis of the recorded area of the printing plate, where red presents peaks and dark blue presents valleys of the plate, with total difference on the recorded area of 150 µm. Figure 12b presents the cross section of selected area and a profile of the printing elements. By this cross-section one can get the insight of the printing element shape and see that total difference from peek (the printing element) to valley (the nonprinting area) is over 130 µm. It is visible that the printing element's surface is not flat which can result with different amount of ink adhering on the surface. The printing elements in Figure 2b differ in height as well, approximately 6 µm. Those differences could cause a variation in the pressure between the anilox roller and the printing plate in the reproduction process and the differences in dot size on the imprint. This behaviour could be explained by the influence of oxygen on the reduction of the polymerisation process between ablation of the LAMS layer and UV irradiation. On the other hand, mechanical and chemical processing of the printing plate after main exposure could also damage the surface of the printing elements and result in a variation of the printing and nonprinting surface topography.

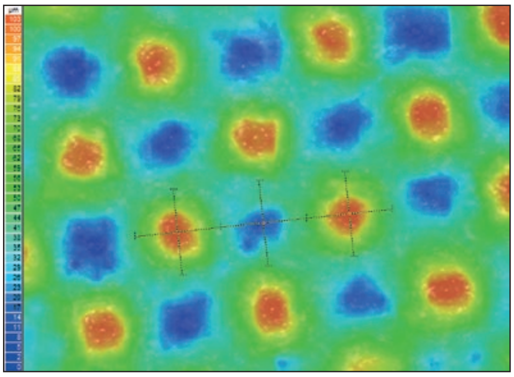


a)



b)

Figure 12: Images of the printing plate sample at 5% nominal coverage value at the screen ruling of 76 lpi a) surface topography; b) cross-section of selected area



a)

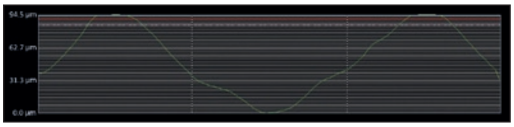


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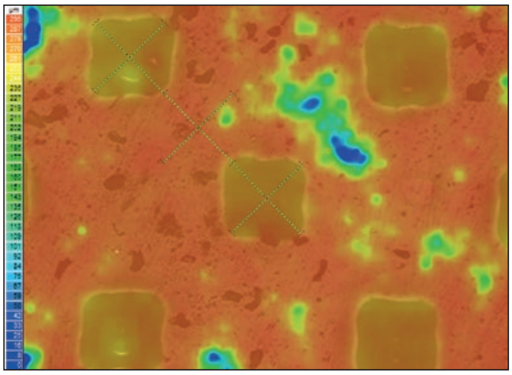
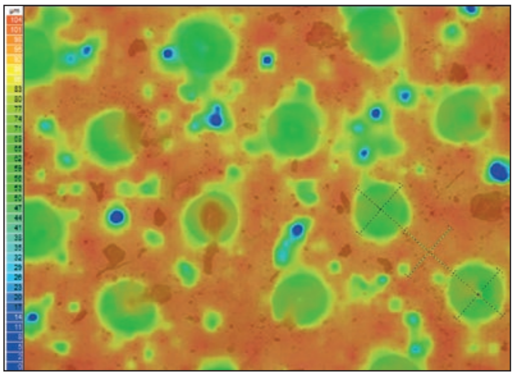
Figure 13: Images of printing plate sample at 5% nominal coverage value at the screen ruling of 121 lpi a) surface topography; b) cross-section of selected area



a)

b)

Figure 14: Images of printing plate sample at 95% nominal coverage value at the screen ruling of 76 lpi a) surface topography; b) cross-section of selected area



a)

b)

Figure 15: Images of printing plate sample at 95% coverage value at the screen ruling of 121 lpi a) surface topography; b) cross-section of selected area

Figure 13a demonstrates the topography of the analysed image of the 5% coverage values with higher screen ruling. When compared to Figure 12a, the difference between the lowest and the highest point is smaller, 103 µm. In addition, the topography throughout the whole observed area, the depth of non-printing areas and the height of the printing elements is more equal than on the sample with lower screen ruling (*Figure 12a*). The cross section of the selected printing element (*Figure 13b*) shows that the printing elements have a flat surface and that there is no difference in the height of the printing elements. The difference between the printing and the non-printing elements is much smaller (less than 95 µm). This is probably the consequence of UV light's angle of incidence and the distance between two printing elements, as polymerisation is probably initiated at the crossing of the light rays coming from opposite angles of the two neighbouring elements. This might imply some problems in the printing process, i.e. variation in amount of the ink transferred to the printing substrate.

Figures 14 and 15 present topography and cross-section of 95% coverage value at the screen rulings of 76 lpi and 121 lpi. One can see that the surface of the printing plate is more inconsistent on a sample at the screen ruling of 121 lpi. This is probably the consequence of mechanical processing after main exposure. Minor defects can be seen on the sample at the screen rulings of 76 lpi too (blue area), but they are not so frequent. At the same time, it is evident that the printing elements have flat surface, but the difference in height between the printing and the non-printing areas (approximately 40 µm) occurs. The difference in peek to valley height is almost 300 µm at the screen ruling of 76 lpi, while only a bit more than 100 µm at the screen ruling of 121 lpi. Small differences between printing and non-printing areas and the variation of the height of non-printing areas are the consequence of the light beam incidence and undercopying, which could cause ink adsorption on the non-printing areas during the reproduction process, thus reducing the imprint quality.

4. Conclusion

This research was made with the aim of evaluating the impact of screen ruling on the formation of printing elements on flexographic printing plates. In order to achieve that goal, test control fields were made on the printing plate samples in two different screen rulings, 76 lpi and 121 lpi. In addition, samples of the printing plate were made by applying different correction precalculations: the calibration curve, the bump-up curve and the compensation curve.

The results have shown that the use of different screen rulings is of great significance in the curve adjustment of the printing plate. It was proven that there is a difference in coverage value between the control fields made with different screen rulings of the same nominal value. The correction with the bump-up curve shows more influence on coverage values of higher screen ruling in the lower nominal values. The correction with the compensation curve decreases coverage value mainly in the middle tones, as it was expected, in order to adjust the tone reproduction to the printing system. Furthermore, the relief, i.e. the difference between the printing and the non-printing areas is smaller in the control fields with higher screen ruling. It can be stated that higher screen rulings can increase the imprint quality, but at the same time the correction curves which were used for lower screen ruling are not applicable. Furthermore, the printing process factors, the pressure between the printing plate and the anilox roller and the printing plate and the printing substrate has to be precisely defined so as to eliminate ink transfer from the non-printing areas, as the relief on the higher screen ruling is lower.

This all leads to conclude that screen ruling is an important factor which has to be taken into consideration in the digital file correction procedure. This research emphasized the fact that the evaluation of printing elements through measurement of surface coverage (2D analysis) could not give a full insight into the characteristics of the printing plate. It was proven that the use of different screen rulings has a profound influence upon relief depth and a cross-section of the printing elements (3D analysis), which again have a significant impact on the quality of the final product, but cannot be detected in 2D analysis.

Bearing in mind that the printing plate is a decisive factor which directly defines the imprint quality, the characterization and correct adjustment of its production procedure should be of high priority in standardisation of the flexographic reproduction chain.

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