ISSN 1330-3651 (Print), ISSN 1848-6339 (Online)
https://doi.org/10.17559/TV-20161003121341
Preliminary communication

The Impact of Top Dot Shapes of the Printing Plate on Dot Formation in Flexography

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Abstract: The top dot shape is an important element of plate dot geometry which has a significant effect on dot formation on the prints. There are several key parameters that can affect individual dot deformation: nip engagement, line ruling and dot geometry. The main question is how these parameters affect dot deformation. This paper researches the issues regarding print quality in highlights, especially dot formation on print at lighter and higher pressure which leads to inconsistency in the printing process like loss of highlight detail and unpredictable dot gain. The purpose of this research is to improve the understanding of the effect of nip engagement on dot deformation and to determine how top dot shapes affect dot formation. A test image was printed with cyan UV ink on aluminium foil on the pre-printed opaque white ink with plates of different types of top dot shapes, round and flat. The images were taken from the prints and analysed by using ImageJ software. All the important parameters of dot formation including uniformity of density, dot sharpness and dot roundness were evaluated. The results highlight the importance of the top dot shape in plate dot geometry which has a significant effect on print dot formation.

Keywords: dot formation; flexography; print quality; top dots shape

1 INTRODUCTION

Flexography is a high speed printing technology for various printing substrates mainly used in packaging industry [1]. The greatest changes in flexo printing occurred due to computer-to-plate (Ctp) making technology which has improved the reproduction quality with a wider tonal range and in more detail, particularly in the highlight area. These evolutionary changes were continuously developed with some fine tuning which can enhance the basic technology. The most important trend in the evolution of the flexoprepress is the creation of different top dot shapes on the printing plate, round and flat (Fig. 1). There are three impression levels at round top dot depending on printing pressure which can lead to significant dot deformation (dot gain) compared to one impression level at flat top dot.

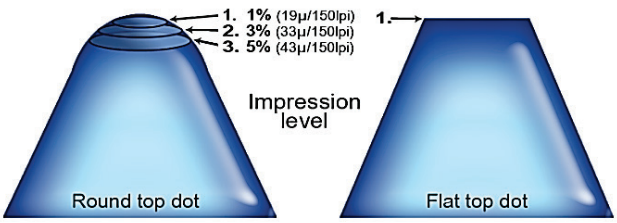

Figure 1 Two types of top dots shape

The first generation of digital CtPFlexo used round top dots. These round top dots were created when the dot surface lost its sharpness and strength due to the presence of oxygen during plate exposure process. This can result in loss of highlight detail, unpredictable dot gain, increased fluting, and decreased plate longevity. [2]

The second generation of digital CtPflexo used flat top dots. To achieve this top dot shape it is important to prevent oxygen interaction with polymer during UV exposure [3]. There are different ways to do this but the most common technologies include laminating thin film to the surface of the plate before main exposure, or exposing plate in oxygen-free environment.

The flexographic printing plate was subjected to mechanical deformation during the printing process, which primarily depends on nip engagement, plate characteristics and dot geometry. Nip engagement was defined by the nip between the plate and the impression cylinder which has to ensure uniform printing pressure.

Previous experimental research was conducted by Valdec et al. [4], and it found that the pressure between printing plate and impression cylinder has the most significant influence on mechanical dot deformation and thereby on print quality.

The pressure setting is critical in the flexographic process in order to promote good dots and prevent halo and control dot gain. The lightest pressure or "kiss impression" is ideal for printing. Kiss impression is a clean print image created while applying the lowest value of pressure possible with the plate against the paper [5]. However, if the pressure is too low, some details in the highlight area might not be transferred onto the substrate. A higher impression might produce smudged ink around the edges of the printed areas. On the other hand, if the pressure is too high, dots will be squeezed more and can be deformed [4].

This research was focused on dot distortion in the highlight area affected by pressure between printing plate and impression cylinder. The first objective was to study how the various shapes of top dots on the photopolymer plate affect dot formation including edge sharpness and dot roundness. The second objective was to research the influence of printing pressure on the uniformity of density across the dot. All parameters were analysed for both types of top dot shape. The main question is how these variables will affect the printed result.

The development in the prepress segment during the past five years has mostly concentrated on screening techniques or advantageous cell structures in the solid areas of the image carrier [6].

Two years ago a new flexo plate was developed, which is based on "pinning technology". It created the new shape of top dots on the plate called Pinning-Top-Dot (PTD). The pinning technology uses low plate surface tension to inhibit liquid flow. The ink forms a globule with a large contact angle and high pinning point. This results in a cleaner and more homogeneous ink transfer from plate to substrate. [7]

2 EXPERIMENTAL METHODOLOGY

The following section describes the effect of pressure settings on dot formation on two types of top dots on the plate so that the print quality could be compared. The research framework describing the purpose and the process of the research is displayed in Fig. 2.

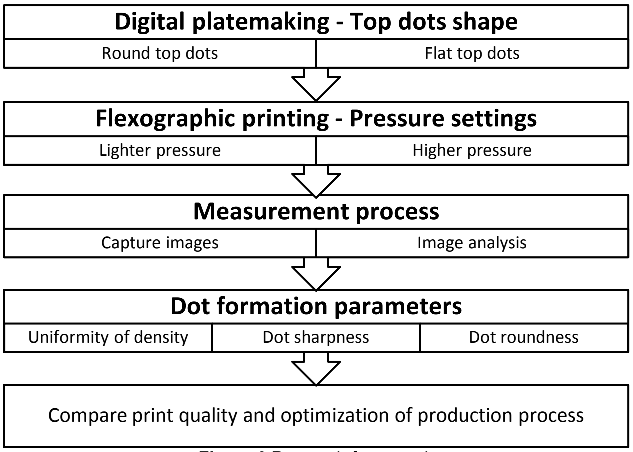

Figure 2 Research framework

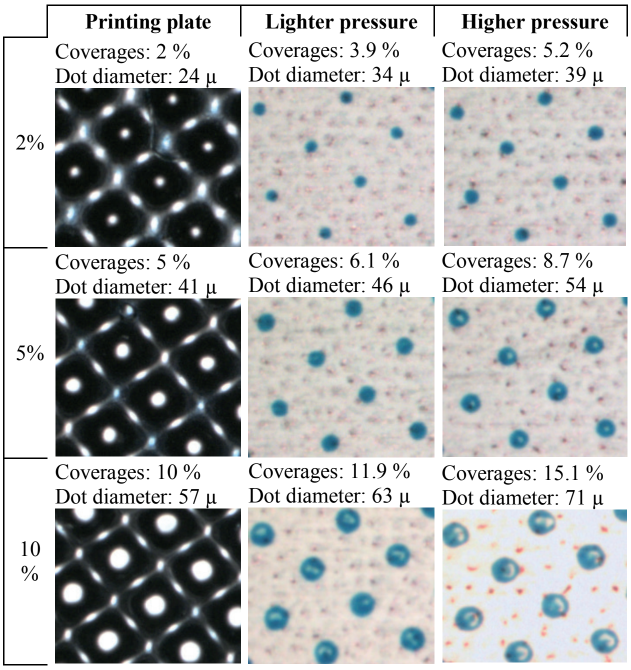

Figure 3 The comparison of the images captured on the plate and on the aluminium foil at 150 lpi round top dots solution (magnification 200×)

For the purpose of quantifying the dot formation parameters, both types of photopolymer plates and both prints were measured regarding pressure settings. The three key halftone patches of 2, 5 and 10 percent in the highlight area were selected for analysis. Patches were captured as an image using the high resolution camera X-rite vip FLEX2. The captured images for round top dots solution are shown in Fig. 3 and for flat top dots solution in Fig. 4. Firstly, the images were analysed by using PlateQualityFlexo software [8]. All the important parameters including physical dot size, dot diameter, physical dot gain and dot roundness were evaluated. All the parameters were calculated presenting the average value of all good dots on the entire captured images. Secondly, the images were analysed by using the ImageJ software for the purpose of evaluating all the important parameters of dot formation (uniformity of density, dot sharpness, edge smoothness and dot roundness).

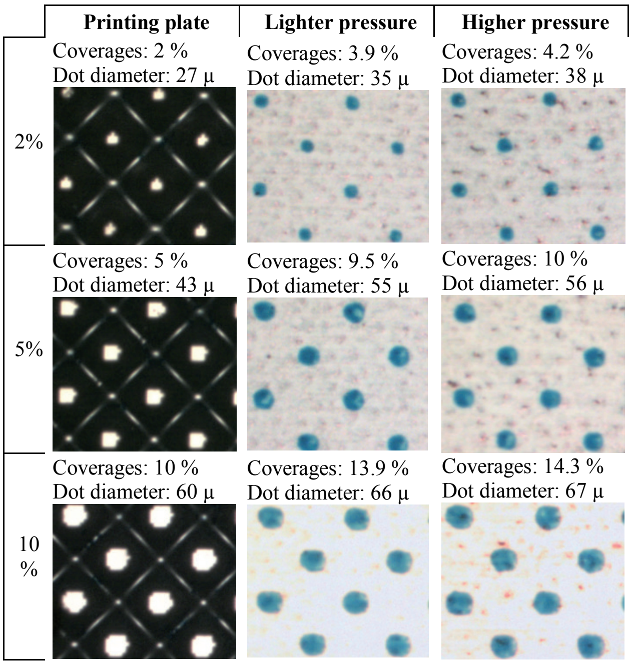

Figure 4 The comparison of the images captured on the plate and on the aluminium foil at 150 lpi flat top dots solution (magnification 200×)

2.1 Photopolymer Plate Evaluation

The flexographic printing plates used for this research were Flint nyloflex ACE Digital plate (hardness acc. to DIN 53505, Shore A is 62) and Kodak Flexcel NX Digital Plate (hardness acc. to DIN 53505, Shore A is 73). There is little difference in the hardness of the polymer and it was insignificant for this research.

Fig. 5 shows the standard top dot shapes of two types of flexo digital plate making. The lower part of each image represents the dot on printing plate, and the upper part represents the surface of impression cylinder. The traditional digital LAMS dot is on the left side and the advanced digital flexo dot with flattened tip is on the right side.

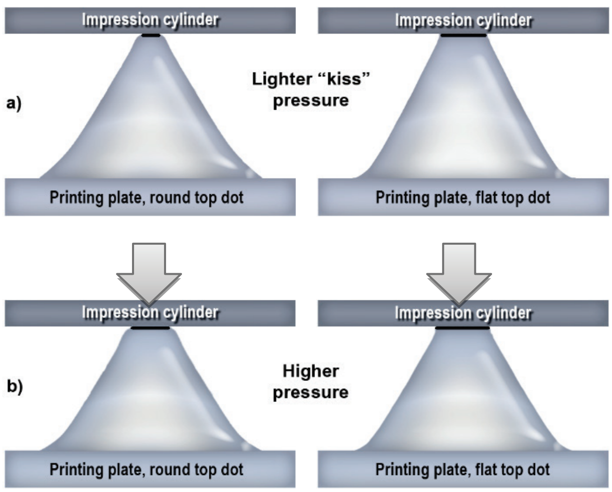

Figure 5 Scheme of deformation mechanism for both types of top dot

The force of pressure at round top dots was maximum in the centre of the dot and it was further transmitted to the edge of the dot. This resulted in rise of the dot shoulder and the side shoulders of the dot became a part of the printing surface after the pressure was applied [9]. It was the primary mechanism of round top dots deformation. The second mechanism was that of ink spreading after being squeezed by the pressure applied. Both mechanisms of deformation have significantly greater impact on dot formation and hence on the physical dot gain.

When the pressure was applied on the flat top dots the force of pressure was exerted and uniformly distributed across the printing surface. The surface expanded slightly after compression and it was the primary mechanism of flat top dots deformation.

2.2 Evaluation of Test Prints

During the printing process a substrate passes between plate cylinder and impression cylinder. The space between them must be optimal to give the proper printing pressure [10]. The printing pressure settings can change from lighter to higher but in this experimental research it was defined by two pre-set values. The research considers the deformation of the tip of the dot under two levels of impression setting. The lightest pressure, or "kiss impression", between the plate and impression cylinder is ideal for good quality printing. The gap value or the nip engagement used was 3 thousand of an inch or 75 microns (0.0762 mm). It was the first level of printing (Fig. 5, stage a) with the lowest pressure value possible. The second level of pressure is a higher pressure and the gap value used was 6 thousand of an inch or 150 microns (0.1524 mm) (Fig. 5, stage b).

Two plates, each with different types of top dot shape, were tested experimentally. The nip pressure before printing was adjusted on the initial value and then readjusted onto a higher pressure. The goal was to achieve that the same quantity of ink is transferred to the printing substrate. A UV curing ink was used on an aluminium foil to eliminate absorbtion of ink into the printing substrate. The research examined two different types of top dot shapes at two defined engagements.The cyan ink was printed on-line on the pre-printed opaque white ink.

The printing conditions were set by percentage coverages, line ruling, top dots types and engagement which varied. Three key percentage coverages were chosen in the highlight area of the experimental research (2, 5 and 10 %). This is the primary area of interest considering that a greater control in highlight dot size is intrinsic to high print quality.

3 RESULTS AND DISCUSSION

The following section describes the results obtained by measurements of both printing plate and test prints at two pressure settings. All the parameters to analyse dot quality at different top dots shapes including dot diameter, dot area, physical dot gain, dot sharpness and dot roundness were evaluated.

The value displayed for each parameter was calculated as the average value for all dots on the entire captured images by using PlateQualityFlexo software. This measuring method eliminates the optical dot area and it was used for measuring all parameters on the plates and prints.The physical dot gain was calculated as the difference between plate and print dot area. The results are shown in Tab. 1 and Tab. 2.

The measuring of dot diameter was used to compare the physical growth of the dot on the substrate relative to the dot on the plate.

Table 1 The average values of measurements for the photopolymer plate and two type prints at round top dots

Round Top Dots	Plate Flint ACE 1.14		Lighter pressure $D_{S\ (cyan)}$=1.54			Higher pressure $D_{S\ (cyan)}$=1.64		
Nominal Dot area (%)	Dot diameter (μm)	Dot area (%)	Dot diameter (μm)	Dot area (%)	Phys DG (%)	Dot diameter (μm)	Dot area (%)	Phys DG (%)
2	24	2	34	3.9	1.9	39	5.2	3.2
5	41	5	46	6.1	1.1	54	8.7	3.7
10	57	10	63	11.9	1.9	71	15.1	5.1

Table 2 The average values of measurements for the photopolymer plate and two type prints at at flat top dots

Flat Top Dots	Plate Flexcel NX 1.14		Lighter pressure $D_{S\ (cyan)}$=1.54			Higher pressure $D_{S\ (cyan)}$=1.64		
Nominal Dot area (%)	Dot diameter (μm)	Dot area (%)	Dot diameter (μm)	Dot area (%)	Phys DG (%)	Dot diameter (μm)	Dot area (%)	Phys DG (%)
2	27	2	35	3.9	1.9	38	4.2	2.2
5	43	5	55	9.5	4.5	56	10	5
10	60	10	66	1.,9	3.9	67	14.3	4.3

The result showed that nip engagement has a greater effect on RTD than on FTD shapes. The cause for this is the rounded tip of individual dots where the ink strongly spreads on the substrate under printing pressure. This rounded structure enables the ink to move down the dot shoulder. The individual dot is squeezed under the pressure and the ink spreads from the centre of the dot toward the edge of the dot.

The increased engagement to a higher setting showed that the dot deformation appears in both cases, but again the flat top dot structures have a much lower dot diameter increase.

As expected, the result shows that as the surface coverage decreases the force of pressure per unit area also increases, resulting in a larger relative dot gain. It turned out that the coverage was the least significant parameter, where there was very little variation in dot gain compared to nominal coverages. The variation in dot gain was greater in the interaction with pressure and different for each top dots shape. These types of top dots shape directly relate to ink transfer and print quality.

Table 3 The changes of dot diameter and physical dot gain increasing printing pressure on both types of top dots shape

	Round Top dots		Flat Top Dots	
Nominal Dot area	ΔD_d (μm)	$\Delta PhysDG$ (%)	ΔD_d (μm)	$\Delta PhysDG$ (%)
2%	5	1.3	3	0.3
5%	8	2.6	1	0.5
10%	8	3.2	1	0.4

ΔD_d – changes of dot diameter
$\Delta PhysDG$ – changes of physical dot gain

Tab. 3 shows that the printing pressure has a great effect on the print quality depending on top dots shape. Significantly greater changes are evident at round top dots. The changes of dot diameter were 5–8 microns at round top dots and 1–3 at flat top dots respectively. The changes of mechanical dot gain are insignificant and value at 0.5 % at flat top dots while at round top dots they are significantly higher, ranging from 1.3–3.2 %. Accordingly, it is evident that the round top dot is much more sensitive to the change of pressure than the flat top dot.

Dot formation is a term that refers to the quality of halftone dots, such as dot sharpness or softness, edge smoothness, and uniformity of the density across dots, as influenced by different characteristic of printing process [11].

3.1 Uniformity of Density

The analysis of the dot formation was made using the visual evaluation based on pseudo 3D topographic view of the ink density and also on the two dimensional dot profile generated by ImageJ analysis software. In order to illustrate how pressure affects dot formation, the dot structure values of the same tone were compared, which is presented in Fig. 6 and Fig. 7. The images of dots at light pressure are on the left side while those at high pressure are on the right side.

The dots images were taken and analysed through a 3D rendering program (tool: Interactive 3D Surface Plot) that transforms density into proportional height [12] to see just how thick the ink film is. For the same tone percentage, the flat top dot has a thinner and more uniform ink film than the round top dot.

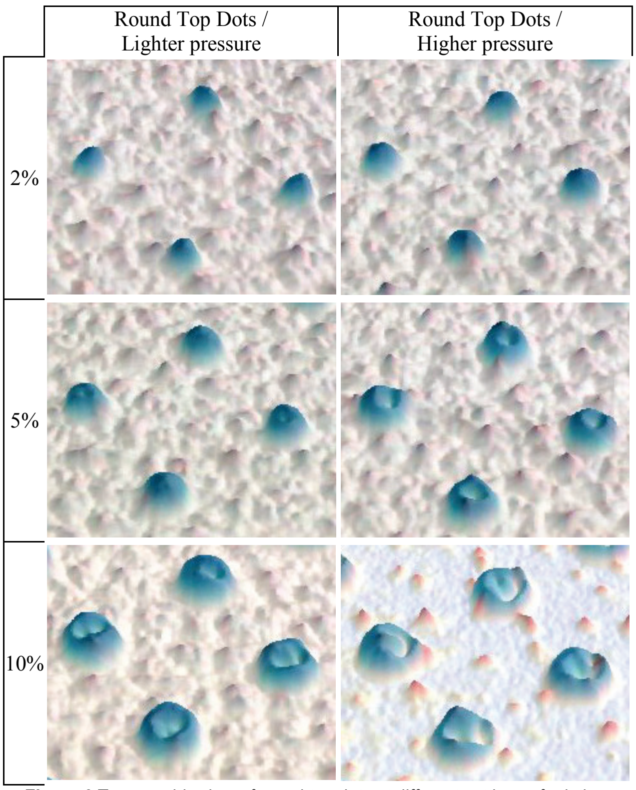

Figure 6 Topographic view of round top dots at different settings of printing pressure

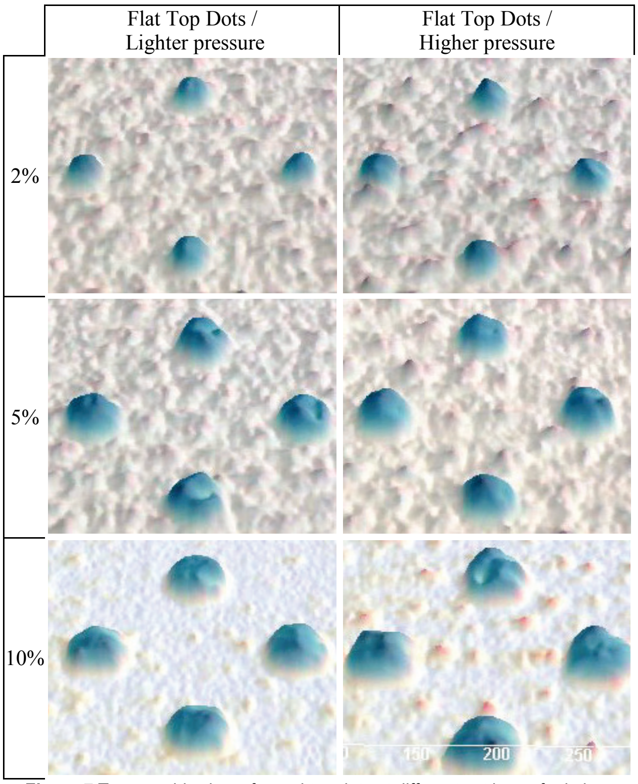

Figure 7 Topographic view of round top dots at different settings of printing pressure

The projection of density clearly shows the level of uniformity of density over the entire dot surface. The images show absolute density which is directly related to the ink film thickness and characteristics of the printing substrate.

3.2 Dot Sharpness

The evaluation of dot sharpness actually represents the evaluation of edge sharpness or edge smoothness. It is the edge of dot which starts from solid tones to the unprinted area of substrate.

The ImageJ analysis software (tool: Plot Profile) was used to generate the two-dimensional dot profile. Firstly, the line is drawn on the image over a single dot that indicates the area to be analyzed, and then its dot profile is generated. The same distance (85 microns) at 45 degrees along the line ruling was taken for all measurements.

The curve of the two-dimensional dot profile shows the relation between the gray value and distance along the entire measuring length.

The two-dimensional profile of the dot was applied on both types of plates, in order to connect the dot sharpness on the print with the dot sharpness on the plate, which is presented in the Figs. 8, 9 and 10.

The graph shows transition from the darkest to the lightest level in the round top dots system of approx. 10 micrones, whereas such a distance in the flat top dots system is 5 microns, which is directly connected to the edge sharpness of the dot and entirely affects dot sharpness and dot size on the print.

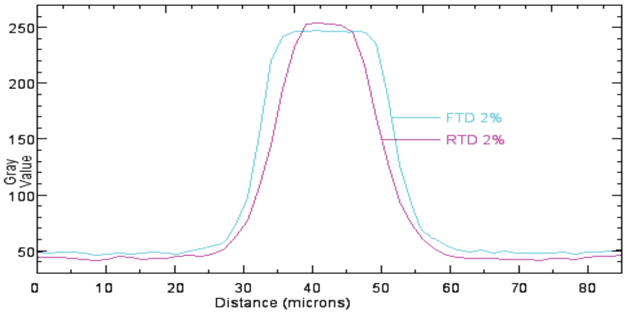

Figure 8 Two-dimensional dot profile at 2 % tonal value on both plates

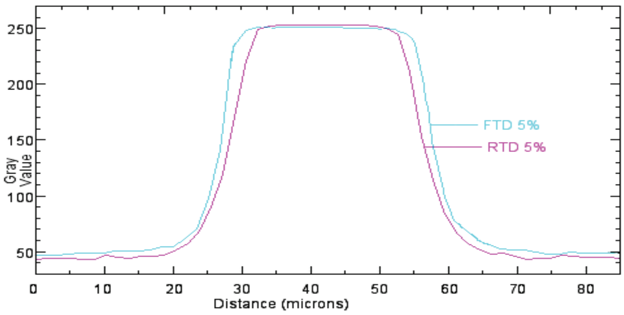

Figure 9 Two-dimensional dot profile at 5 % tonal value on both plates

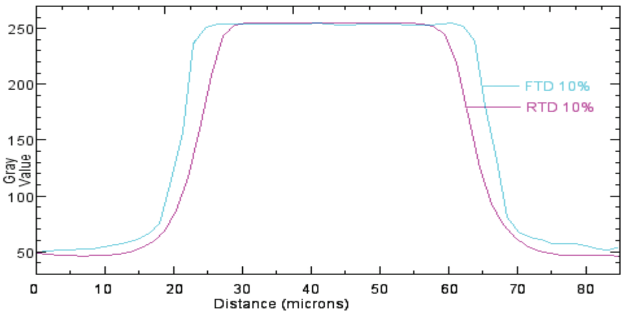

Figure 10 Two-dimensional dot profile at 10 % tonal value on both plates

The illustration of a two-dimensional profile of printed dot for both top dot shapes for all investigated tonal values is shown in Figs. 11, 12 and 13.

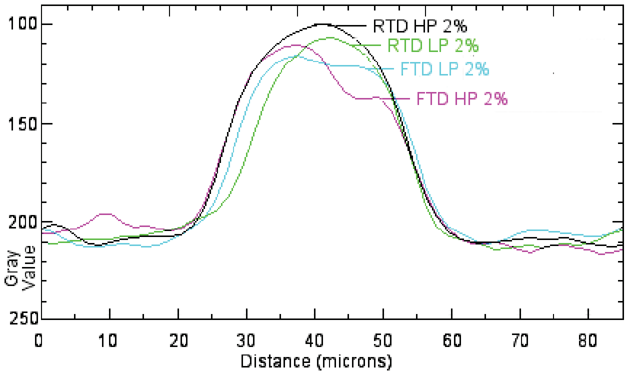

Figure 11 Two-dimensional dot profile for 2% tonal value on print at both pressure settings

Standard digital Ctp technology for flexography created a round top dots photopolymer plate that, under pressure, squeezed and transferred ink to the substrate. The result was reproduction of halftone dots that often appeared to be surrounded by a sharp-edged "halo", especially at higher pressure which was shown in chart of two-dimensional dot profile (Figs. 11, 12 and 13.).The ink density was not similar across the halftone dot.The same effect occured in the halftone dots of 5 and 10 percentages which have dark edges and light centres.

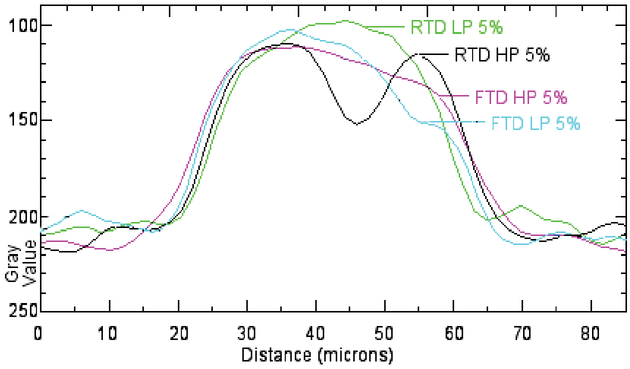

Figure 12 Two-dimensional dot profile for 5 % tonal value on print at both pressure settings

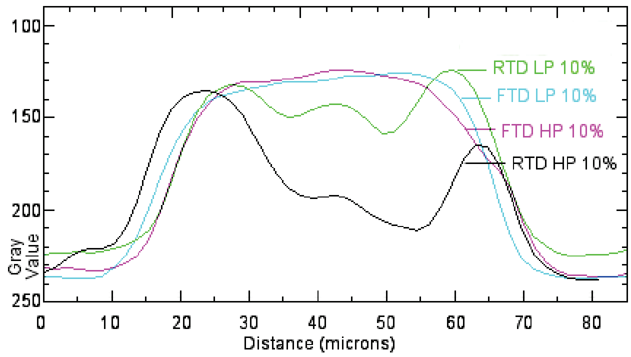

Figure 13 Two-dimensional dot profile for 10 % tonal value on print at both pressure settings

Due to the pressure the ink was squeezed to the edge, which is visible in significant difference of gray levels along the complete dot surface. The difference in gray levels is considerably lower in the flat top dots system, where there are no substantial differences due to increased printing pressure which is visible in the graph.

Both systems show a characteristic shift from the area of the lower colour density to the dot edge due to higher pressure and larger surface coverage, which is the result of the dot deformity according to the direction of the movement of the printing substrate in the press. Such an effect is stronger in the RTD systems.

Smaller tops distributed around dots are characteristic of pre-printed white ink which does not cover the entire printing surface. Due to incomplete coverage of the printing surface, the print shows certain blank spaces. It is presumed that these blank spaces cause partial increase of colour density, which are presented as separate pinning tops in topographic lay-out.

Halftone dots in both top dots shapes have very sharp and well defined edges.This is evident from the charts which show very steep starting lines at the beginning of the dot. The edge sharpness print capabilities of Flexo, Offset and Gravure are probably similar if sufficient attention is paid to the preparation of the printing plates and the setting of the machine given a similar substrate used [13]. The topic is certainly worth of more detailed research.

The edge sharpness is very important in printing of line elements, particularly bar codes, which has effect on speed of its readings.

3.3 Dot Roundness

The dot roundness was defined by the ratio of the circumference of a circle with the same average radius and the perimeter length of the dot [14]. The ideal round shape has a dot roundness value equal to 1. Any screen element that has the value roundness greater than 0.90 belongs to the round screen element. Dot roundness was obtained by image analyzis using PlateQualityFlexo software.

Table 4 Average value of dot roundness for three chosen tonal values

	Round Top dots			Flat Top Dots		
Nominal Dot area	Plate	Lighter pressure	Higher pressure	Plate	Lighter pressure	Higher Pressure
2 %	0.923	0.858	0.857	0.827	0.847	0.830
5 %	0.900	0.850	0.845	0.824	0.849	0.833
10 %	0.894	0.840	0.836	0.837	0.852	0.840

Each measured screen element at round top dots plate had a dot roundness greater than 0.90. When printed with different printing pressure, the dots showed similar roundness. Dot roundness at prints was lower than at plate. However, when the printing pressure increases the dot roundness slightly decreases. The same principle occurs at the flat top dots system, but the dot roundness at the plate was significantly lower than at the round top dots plate (Tab. 4). It was lower due to the SQUAREspot Thermal Imaging Technology which was used for plate imaging at CTP system [15].

4 CONCLUSION

The goal of the research presented in this paper was to study how different top dots of the polymer plate affect dot geometry, individually or through interaction with the most important flexo-print parameters.

Two top dots shapes, which were round and flat, were researched with two pressure settings. The pressure was evaluated relative to light "kiss" printing (LP) for different top dots shapes. Round top dots showed high sensitivity to change underpressure, while flat top dots were more stable to variations in pressure settings.

The results showed that as the pressure was increased the ink film thickness was reduced on the printing substrate. It was the main reason why the density at round top dots was not uniform all over the dot surface. This reduced ink film thickness in the centre of the dot surface resulting in accumulation of ink at the dot edge and accordingly there was increased tonal reproduction.

The dot formation in the RTD system is significantly lower compared to the FTD system. The dots are less compact, especially under higher pressure during printing. The inhomogeneity of the dot is more stressed in case of a higher surface coverage, which means that the colour density is not equal in each part of its surface. Accordingly, the colour density becomes lower on the dot edge.

During printing several impression levels may appear, depending on the pressure on the dot, which results in larger or smaller dot diameter, i.e. the interaction between the top dot and the side shoulders is significantly stressed.

The dot sharpness on the print is directly connected to the dot sharpness on the plate.

The result showed that engagement has a greater effect on mechanical dot deformation on the plate. Based on the quality analysis of topographic shots it was concluded that the rounded top of the dot shows a great sensitivity to the pressure changes upon printing, which results in inconsistent prints. On the other hand, the flat top of the dot provides consistent print in accordance with the increase of pressure.

It was determined that the flat top dots have a better defined edge and subsequently a better defined printing surface. Therefore, it can be concluded that the FTD system may be used in printing processes which require higher pressures, without making any substantial negative impacts on the reproducation quality. When applying the round top dots, it is impossible to reliably determine the impression level. Therefore, the interaction between the upper printing surface and the dot shoulder is rather high.

The analysis of the dot roundness through three production phases has shown that the differences in the dot roundness are too small and do not substantially affect the reproduction quality. The conclusion is based on the fact that relatively small dot roundness on the plate in the RTD system does not result in negative reproduction characteristics. The differences in the dot roundness would be more significant it the ink of a higher viscosity and non-absorbent printing substrates were used.

The research results are valid only for printing conditions defined in the experiment.These conditions included printing with UV ink on aluminium foil on the pre-printed opaque white ink. For other types of substrates (coated or uncoated paper, PP foil and other) new research is required since the interaction between ink and substrate, or between multiple layers of ink, is different.

The results of this research give new scientific knowledge necessary for a simpler and easier implementation of the abovementioned technologies in the production process. These results also enable a reliable, repeatable and consistent reproduction. The gained knowledge, values of qualitative reproduction parameters as well as guidelines on usage are all based on a complete comparative analysis of top dots reproduction created by implementation of different top dot element shapes on photopolymer plates.

Abbreviations

RTD – Round Top Dots
FTD – Flat Top Dots
PTD – Pinning Top Dots
LP – Light (Kiss) Pressure
HP – Higher Pressure
Phys DG – Physical Dot Gain
CtP – Computer to plate

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