VOLTAGE EFFECT ON DEVELOPING PROCESS AND B & W REPRODUCTION

MAJNARIC, I.; GOLUBOVIC, K.; BOLANCA, S. & MODRIC, D.

Abstract: In Electrophotography printing technique with liquid toners, large quantities of ink are deposited on photoreceptor. Voltage variations during the development phase ($\Delta V=200V$) will directly influence the thickness of ink layer on photoreceptor. Optimal reproduction is achieved when smallest image elements (screen dots) have smallest possible diameter, and respectively higher optical density. Suitable method for reproduction analysis is based on spectrophotometric measurement of halftones and on optical densitometry. By adjusting the voltage during development (II. phase) will allow largest manipulation of color ($\Delta E_{RR}=10.01$). Optimal results are achieved with voltage of -125 V. Under this conditions, average printed screen element had average diameter of $56.9 \mu m$ and a maximum reflectance of $R=33.50\%$. Variation of voltage on other two developing devices affect only slightly the color reproduction ($\Delta E_{DEV}=1.26$; $\Delta E_{SQU}=0.94$.) and have lower impact on the size of screen elements ($\Delta d_{DEV}=8.1 \mu m$; $\Delta d_{SQU}=4.1 \mu m$).

Key words: electrophotography, developing devices, ElectroInk, screen reproduction

Authors' data: PhD Majnaric, I[gor]; BS. Golubovic, K[ristijan]; PhD. Prof. Bolanca, S[tanislav]; Modric, D[amir], University of Zagreb, Faculty of Graphic Arts, Getaldiceva 2, 10000, Zagreb, Croatia, igor.majnaric@grf.hr; kristijan.golubovic@grf.hr; stanislav.bolanca@grf.hr; damir.modric@grf.hr

This Publication has to be referred as: Majnaric, I[gor]; Golubovic, K[ristijan]; Bolanca, S[tanislav] & Modric, D[amir] (2010). Voltage Effect on Developing Process and B & W Reproduction, Chapter 45 in DAAAM International Scientific Book 2010, pp. 509-524, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-901509-74-2, ISSN 1726-9687, Vienna, Austria
DOI: 10.2507/daaam.scibook.2010.45

1. Introduction

In the electrophotographic printing, in the developing phase there are at the moment three key problems. They are: the developing phase has the greatest influence on the print quality; the physical process during the toner developing has not been explained enough and the hardware parameters used in a standard manner in developing of the new printers are mathematically not enough investigated. For the needs of the printing industry the direct application of the unfixed layer of toner on the photoreceptor drum is not possible.

The aim of this work is to analyze the ink layer by indirect measuring methods (densitometry and spectrophotometry). By varying the voltage of the developing system the different color saturation is achieved which can be brought into correlation with the thickness of the toner layer. From the point of view of the reproduction quality the developing of the liquid ElectroInk is a great unknown which is explained in this work.

2. Theoretical part

From all the ways of printing, electrophotography is definitely the most complicated printing technique. The basis of this process presents the semiconductor photoreceptor which illuminates, images and prints with each printing. In order to make the final print it is necessary to perform 6 technological phases. They are: charging the photoreceptor, imaging of photoreceptor, developing of photoreceptor, toner transfer on paper, fusing the toner on paper and cleaning of photoreceptor (Fenton, 2005).

The newer constructions of printers are more complicated because of the additional phase in the printing process. It is the second transfer (the indirect printing process) which gives the print, which is more precisely and more exact (Majnaric et al., 2005).

During the developing process, the printing ink must be applied on the photoreceptor. The basic characteristic of electrophotographic ink is a stiff state which is caused by the tiny particles of expressively negative potential. Such powder ink adheres to the electrically more positive photoreceptor surfaces, forming the toner image (Kipphan, 2001).

2.1 Developing process

The final print quality is based on the quality of the work of the developing unit. Except the work on achieving the uniformity of toner application on the latent image (one-tone reproduction of text and solid areas, as well as the continuous tone reproduction of the solid areas) the investigation of the background which does not accept toner is also important.

By the analysis of the standard observer method the prints made in electrophotographic printing have low grayness on free surfaces which is caused by the undesirable application of the toner ink. In relation to the prints made by classic offset this is a considerable difference. In relation to the developing systems based on the developing of the powder toner (cascade developing, developing with the magnetic brush, developing with the conductive magnetic brush) greater advance in the quality of the electrophotographic process is the development of the Digital Color Offset which uses the liquid toner ElectroInk. As it is known, the investigation in electrophotography is directed towards the emerging of the background areas and solid areas. The average low ratio of the toner charge per mass (Q/M) increases the size of the solid areas as well as the sizes of the background areas (Goldmann, 2004).

After the attempt to increase additionally the voltage of the background areas the more precisely formed background areas are achieved by the same ratio of Q/M , so that more complicated devices are used in the developing which contain greater number of rollers in the developer unit. It can be expensive when the number of rollers is more than 4. It can have negative influence in mechanical strain which appears during the mixing of the developing agent in the contact zone of the each applied roller (it causes the damaging of the working area) (Yamana et al., 2004).

The same effect can be achieved by lower ratio Q/M which increases the background areas. Low ration of Q/M causes the increase of the background areas and such toner mixture has got much worse application. In this case the distribution of the toner charge is limited, which leads to the automatic decrease of the average tone charge. The solid areas are decreased which leads to a bad application of toner and to minimalization of the formed background areas (Lee et al., 2003).

In order to better understand the physical process of developing it is necessary to understand the solid states of all the factors. These are: the solid areas, the background areas, construction of the developer units, toner and the way of its charging. The outer factors have also to be taken into consideration (temperature, relative humidity), which have not been tested in details.

The basis of the developing process rests on the physics of the solid states which stands on two theoretical suppositions. The first is that the developing starts with the setting up the toner charge per surface unit (s_t) which is completely neutralized after the developing of the latent image (surface charge s_s).

$$\sigma_t = \sigma_p \quad (1)$$

It means that

$$\sigma_t = \frac{M}{A} \frac{Q}{M} \quad (2)$$

$$V = \frac{\sigma_p d_s}{\epsilon_0 K_s} \quad (3)$$

where M/A is the developed toner mass per surface unit, Q/M is the ratio of the developed toner charge per mass, and V is electrostatic potential in accordance with the charge of the solid areas on the virtual printing form, dielectric distance d_s/K_s (from the earthing level)), and ϵ_0 the background area which deposited the electric energy from the electric field, which influences the future neutralization process.

$$\frac{M}{A} = \frac{V \epsilon_0}{(Q/M) (d_s/K_s)} \quad (4)$$

Big M/A has never been achieved. During the developing process greater quantity of toner, up to 9 times, has been realized, so the other factors can limit the neutralization process. Another factor is that only small particles of toner are efficient in the developing process. In synchronized movements (of photoreceptor and the rollers of the developer unit) the final quantity of toner is formed in the carrier chain per surface unit, and the carrier chain is defined as

$$\frac{M}{A} = C_t \frac{M_c}{4R^2} \frac{L}{2R} \quad (5)$$

where C_t is the toner concentration (ratio of the mass of toner and carrier), M_c is the carrier mass, $4R^2$ is the surface occupied by the carrier, L is the distance between the photoconductor and the developer rollers, while $L/2R$ is the number of the particles within the chain which fulfills the space among the developer rollers and the photoconductor. By adding the unsynchronized ratio factor of the velocities n_r/n_p into the calculation (the speed of the developer rollers divided by the speed of the photoconductor), the density of the carrier r_c is achieved.

$$\frac{M}{A} = \frac{\pi}{6} C_t L \rho_c \frac{v_r}{v_p} \quad (6)$$

By adding all the toner chains the following is achieved

$$\frac{M}{A} = \frac{\pi}{3} C_t R \rho_c \frac{v_r}{v_p} \quad (7)$$

By counting the toner in the upper layer together with the beads, it is possible to foresee the final layer. The beads will realize somewhat lesser application (insufficient quantity) which is visible. The majority of toner in contact with the latent printing form remains unused.

By monitoring the final print, the development of the solid areas is much more complicated than the developing of the solid tones. However the analysis is limited because of two reasons: because of the non-standardized electric field as well as the different ratios of the background area and the surface of the solid tones. Electric fields which define the solid areas are studied in order to explain the nature of that problem. One solution of the problem is the application of the semiconductors (photoreceptor surface). The strength of the electric field depends on the thickness of the semiconductor by which the thickness of the solid areas is varied, i.e. of the background areas.

The change of the strength of the vertical electric field depends directly on the thickness of photoreceptors. The quick surface change of the electric field enables the leading of the electric field on the value of zero, on the majority of the solid areas as well as on the solid tones. If the space between the solid area and the developing device increases (more than 150µm) and the diameter and the potential of beads remain the same, both surface electric fields are changed.

As the toner develops and the surface of the solid areas neutralizes, the electric field of the future solid area moves towards the interior of the solid tone. In the following development process it continues to move in the direction of solid areas centre, increasing the boundary zone (surface). The evaluation of the ratio of the developed solid areas and the solid tones can be made by ignoring the above mentioned problems. In this case the counter electrode is added to the construction which forms the uniform field above the boundary field.

$$E_{\text{air}} = \frac{V}{d_s/K_s + L/K_E} \quad (8)$$

In this case V is the electrostatic potential of the latent image, L is the distance between the photoreceptor and the counter electrode, K_E is the dielectric constant for the toner mixture (toner particles and particles of the developing agent). If the dielectric constant of the toner mixture increases for 100%, the electric field will decrease in the boundary zone to a half. It means that the electric field of the future solid area becomes double strong as the electric field of the solid tones. The relation between the toner mass per surface unit is defined by the ratio 2:1 for the developer units which are build on the basis of the insulator materials. (Schein, 1992).

The developing process with the controlled background areas represents a very important investigation area. It can keep the developing system without the influence of the outer interferences, where the background areas around the solid tones have the same oscillations. There are other aspects in the developing technology which are discussed very rare. They are: the through flow mechanism of toner particles in two component developing system, problems during the work, supplementation of the toner etc.

2.2 Construction of the developing unit for liquid toner

Although electrophotography with the powder tone is usual, we have recently been witnesses of the electrophotographic machines which use inks in liquid state. Such inks contain easy volatile petroleum oil (liquid carrier) within which the pigment particles (about 1 μm) are dispersed, with a smaller addition of liquid for increasing the electric conductivity (Landa, B. 1994).

Because of possible dripping, such inks demand very complicated developing device. This means that except the voltage regulation on the photoreceptor surface, the liquid for cleaning the background areas is also applied. During the developing process the ink quantity on photoreceptor has to be continuously decreased, because of which three devices are used: developer drum (DEV), reverse roller (RR) and the squeegee roller (SQU) (Majnaric et. al 2010).

The voltage on DEV (developer drum) is about -400 V (Figure 1). The ink in the area between the developer drum and the printing form has the tendency of directing towards the positive charge. This means that the ink from the background (-800V) is transferred to the positive developer drum, while the ink from the solid areas (-100V) stays on the printing form. (Drennan B. 1997).

Fig. 1. The developing process of the liquid electro photographic toner
a) DEV drum, b) RR roller c) SQU roller

The developed ink on the surface of DEV is completely brushed away with the steel blade and sediments in the catching pot with five chambers from which it returns to the container (four ones for the process inks and the fifth additional blade for final cleaning of the developer drum). The applied liquid toner on solid areas is not effective and it often leaks through. In order to prevent such occurrence two rollers are built in the printing machine (figure 1b: the roller for applying the mineral oil and the reverse (RE) roller for reversing the used oil in the separator (-100V).

After the RR roller returns the mineral oil in the separator, the applied layer of oil is mechanically squeezed with the SQU roller, it additionally acts with its constant charge of -1350V, fixing the oil to photoreceptor. The applied oil layer with the height of 13 μm decreases to the height of 6 μm (figure 1c).

The toner adherence on the photoreceptor is possible to be indirectly observed. For this the measuring printing methods are used which analyze the finally formed print on paper. In multi-color printing, the reproduction of the tinniest screen elements has a decisive importance. For their analysis the lightest tones are used (10 – 30% screen value) which form the screen dots which are regular and mutually separated. For monitoring the toner layer the densitometric methods are used (inking density, screen value, screen dot size, reflectance) while for the inking quality of the solid tones the spectrophotometric methods are used (tonal value $\text{CIEL}^*a^*b^*$, chromatic value C, hue angle H and the inking difference ΔE). (Majnarić et al. 2009)

3. Experiment

For the needs of this work the special printing form was made which contained the following printing elements: black wedges in the ratio from 10 – 100% screen value and the standard ISO achromatic illustration for visual control. For creating the experimental samples the developing system of the electrophotographic printing machine HP Indigo TurboStream was used and 135 g/m^2 glossy fine art paper was used as the printing substrate.

At the beginning of the experimental printing the calibration was performed after which all the relevant parameters (scorotrone charges, laser strength, and transfer charges) were bypassed by which their permanent value was kept. The experiment continued in printing during which the charge of individual developer units was changed while the others were bypassed (they were constant). The regulation was also performed in the following voltage range: developer drum $\Delta V_{\text{DEV}}=300\text{V}$, reverse roller $\Delta V_{\text{R.R.}}=250\text{V}$, and the squeegee roller $\Delta V_{\text{SQ}}=200\text{V}$. The obtained prints were analyzed by densitometers and spectrophotometers. For the analysis three prints were used (the print from the beginning of the run, one in the middle of the run and one at the end of the run). By calculating the arithmetic mean the final results are presented in two-dimensional (Δd , ΔR) and three-dimensional form (CIE Lab, ΔE). (Fleming, P. D. et. al 2003.).

Fig. 2. Schematic presentation of the experiment

4. Results and discussion

For the analysis of greater screen areas the spectrophotometric methods are usually used. The precise results are obtained in 3D graphic presentation which describes the changes that appeared in inking, saturation and brightness. The influence of the voltage change of the developer units on the inking of a print is presented as CIE LAB ΔE (figure 3).

The increase of the negative voltage of DEV drum results in the increase of the black color. The appeared differences in inking are the following ones: $\Delta E_{200-280}=0,10$; $\Delta E_{200-350}=0,59$; $\Delta E_{200-430}=1,12$; $\Delta E_{200-500}=1,26$. It is characteristic that the increase of inking is the biggest one between -280V and -430V. The difference in inking formed in that way is $\Delta E=1,26$ (visually a small difference) which appeared in brightness. The increase of the negative voltage on RR roller causes the decrease of black inking. The dependence of the inking density on voltage can be described by linear function. The formed differences in inking are visually great: $\Delta E_{0-50}=2,23$; $\Delta E_{0-125}=5,46$; $\Delta E_{0-200}=8,47$; $\Delta E_{0-250}=10,01$. Further voltage increase completely eliminates the ink layer and causes the loss of the image information.

The voltage regulation on SQU roller ($\Delta V=200V$) does not create visually visible change in inking. Although by the spectrophotometric measurements it was noticed that the increase of the negative voltage caused the decrease of the black inking ($\Delta E_{1250-1300}=0,44$; $\Delta E_{1250-1350}=0,52$; $\Delta E_{1250-1400}=0,94$; $\Delta E_{1250-1450}=0,86$). As SQU roller is the last developing unit (after which greater layer of ink is not allowed to stay) the application of the voltage of -1400V is recommended which gives somewhat brighter print without the satellite stains on the non printing areas.

Fig. 3. CIE L*a*b* and ΔE_{2000} values of black 20% screen surface, which appeared by the charge variation on DEV drum, RR roller and SQU roller

For more precise analysis of the printed image, the method of image analysis is applied, which is based on the densitometric measurements of the surface the size of which is 2,5 x 2,5 mm. In this case it is possible to determine the exact number and the shape of the screen elements (dots) as well as their deviations in diameters. In figures 4, 5 and 6, the increased segments of the reproduced bright screen values (10–30% screen value) are presented together with the belonging diagram of diameter deviation caused by the voltage variations on the developing equipment.

By the increase of the screen value the sizes of the printed screen elements increase too. Varying the 5 experimental voltages the printing elements in the lightest tested area (10 % screen value) give the following diameters of the screen dots: $d_{200V}=49,41\mu\text{m}$, $d_{280V}=54,69\mu\text{m}$, $d_{350V}=52,54\mu\text{m}$, $d_{430V}=56,23\mu\text{m}$, $d_{500V}=53,01\mu\text{m}$. The smallest reproduced screen element is obtained by the application of the lowest voltage (-200V) while the greatest one is obtained by the voltage of -430V. In this case the maximal achieved aberration is $\Delta d=6,82\mu\text{m}$. In the area of 20% screen value, the following diameters of the screen dots were achieved by varying the voltage: $d_{200V}=72,56\mu\text{m}$, $d_{280V}=76,68\mu\text{m}$, $d_{350V}=73,42\mu\text{m}$, $d_{430V}=80,66\mu\text{m}$, $d_{500V}=80,41\mu\text{m}$.

The smallest printing element was formed under the voltage of -200V, while the greatest one was formed under the voltage of -430 V. It means that by adjusting the voltage of the DEV drum the change of the screen dots diameter of $\Delta d=8,1\mu\text{m}$ can be achieved. In the darkest analyzed area (30% screen value) the voltage variations realized the following diameter changes of the screen elements: $d_{-200\text{V}}=96,52\mu\text{m}$, $d_{-280\text{V}}=98,86\mu\text{m}$, $d_{-350\text{V}}=95,38\mu\text{m}$, $d_{-430\text{V}}=102,35\mu\text{m}$, $d_{-500\text{V}}=102,21\mu\text{m}$. The smallest printing element appeared by using the voltage of -350V, while the greatest screen element was produced by the voltage of -430 V. In this case the maximal aberration of $\Delta d= 6,97\mu\text{m}$ was achieved.

Fig. 4. Presentations of (10x increase) the black screen elements caused by the voltage change on DEV drum $\Delta V=300\text{V}$, together with the presentation of the average diameters of the screen dots

It is visible that the voltages of the DEV drum which are greater than -430V have simply no application, because the sizes of the screen elements do not increase any more. At minimal voltage (-200V) the minimal diameter of the printed elements is noticeable, but unfortunately a certain loss of the printed screen dots appear (lesser number of the printed dots). For all the tested areas the optimal voltage is about -350V, which enables the diameter small enough, but it also satisfies the number for the reproduction of the screen elements.

Fig. 5. Presentations (10x increase) of the black screen dots, which appear by the voltage change of RR rollers $\Delta V=250V$, together with the presentation of the average changes of the screen dots.

Densitometric analysis showed that the increase of the negative voltage of the RR roller led to linear increase of the diameter of the black printed screen elements.

In the area of 10% screen value with the variation of 5 experimental voltages the following diameters of the printed elements were obtained: $d_{0V}=53,73\mu\text{m}$, $d_{50V}=51,08\mu\text{m}$, $d_{125V}=56,9\mu\text{m}$, $d_{200V}=64,95\mu\text{m}$, $d_{250V}=69,78\mu\text{m}$. The smallest screen element was obtained with the voltage of -50V while the greatest one was obtained with the voltage of -250V. In this case the maximal deviation was achieved which was $\Delta d_{0-250}=18,7\mu\text{m}$.

The earlier defined voltages have in the area of 20% screen value the following changes of printed elements: $d_{0V}=75,66\mu\text{m}$, $d_{50V}=84,5\mu\text{m}$, $d_{125V}=94,62\mu\text{m}$, $d_{200V}=101,77\mu\text{m}$, $d_{250V}=105,46\mu\text{m}$. The greatest printed element is obtained with the voltage of -250V, and the smallest one with the voltage of 0V. Great regulation of printed elements was achieved in that case $\Delta d_{0-250V}=29,8\mu\text{m}$.

The darkest measuring areas (30% screen value) are characteristic after the greatest screen elements. The deviations of the voltage of 250V give the following diameters: $d_{0V}=95,61\mu\text{m}$, $d_{50V}=105,15\mu\text{m}$, $d_{125V}=115,94\mu\text{m}$, $d_{200V}=122,75\mu\text{m}$, $d_{250V}=125,29\mu\text{m}$. In this case the maximal deviation of $\Delta d_{0-250V}=29,68\mu\text{m}$ was achieved.

SQU roller does not considerably influence the diameter of the screen elements. The smallest screen elements were obtained at the voltage of -1300V, while the greatest screen elements were obtained at the voltage of -1450V. The lowest tone areas (10% screen value) have the following diameters of the screen elements after changing the voltage: $d_{1250V}=55,99\mu\text{m}$, $d_{1300V}=54,68\mu\text{m}$, $d_{1350V}=55,19\mu\text{m}$, $d_{1400V}=56,61\mu\text{m}$, $d_{1450V}=58,14\mu\text{m}$.

In this way the maximal deviation of $\Delta d_{1250-1450V}=3,46\mu\text{m}$ was achieved. In the area of 20% screen value the following values of the screen elements were achieved by the variation of the voltage: $d_{1250V}=83,61\mu\text{m}$, $d_{1300V}=82,55\mu\text{m}$, $d_{1350V}=83,93\mu\text{m}$, $d_{1400V}=83,43\mu\text{m}$, $d_{1450V}=86,69\mu\text{m}$. Herewith the maximal deviation of $\Delta d_{1300-1450V}=4,14\mu\text{m}$ was achieved. In the area of 30% screen value the following values were obtained: $d_{1250V}=103,33\mu\text{m}$, $d_{1300V}=103,18\mu\text{m}$, $d_{1350V}=107,02\mu\text{m}$, $d_{1400V}=105,32\mu\text{m}$, $d_{1450V}=108,29\mu\text{m}$. The maximal deviation was $\Delta d_{1250-1450V}=5,11\mu\text{m}$.

The inking density of the reproduced screen element is not standardized. That means that the central part of the screen dot has greater inking density than the peripheral one. The influence of the voltage change of the developing equipment on reflectance of the characteristic screen element (area of 20% screen value) is presented in figure 7. The influence of three voltages from the surface of $200\mu\text{m}^2$ is presented.

Fig. 6. Presentation (10x increase) of the black screen elements formed after changing the voltage of the SQU roller $\Delta V=200V$, together with the presentation of average changes of the screen dots

Reflectance of the reproduced screen elements can be described by Gauss distribution, where the sagging defines the maximal inking density. To cancel the printing substrate the sensitivity threshold of 60% was determined. By varying the DEV drum (Fig. 7a) it was noticed that the voltage of -350V had given the greatest and the darkest dot ($R_{Max}=43,06$), while the voltage of -500V gave the smallest and the lightest dot ($R_{Max}=44,77$). It is characteristic that the dot obtained by the voltage of -200V had great density and the small diameter (peaked form).

Fig. 7. Reflectance of the characteristic black screen elements formed with different developing equipments; a) voltage variation of the DEV drum b) voltage variation of the RR roller c) voltage variation of the SQU roller

After the first developing phase (DEV drum) the screen dots had not low enough reflectance (grayish tone) and they had to be additionally developed. Voltage variations on RR roller result in more laid down reproduced screen elements. Screen elements were greater and darker with a broad peak surface. The voltage of 0V gives the smallest and the lightest dot ($R=43,77$), while the voltage of -250V gives the greatest and the darkest dot ($R_{\text{Max}}=32,97$). It is characteristic that the screen dot obtained with the voltage of -125V is equally dark as the dot with the voltage of -250V, but with much smaller peripheral part. (aureole).

By the voltage deviation on SQU roller (Fig..7c) different thicknesses of the screen elements were obtained. In this connection the rule is valid that the lower negative voltage of SQU roller gives smaller diameter. The standardized inking density is characteristic for these dots (maximal reflectance). With the voltage of -1450V the darkest dot was obtained ($R_{\text{Max}}=32,81$), while the lightest dot was obtained with the voltage of -1350V ($R_{\text{Max}}=34,18$). It is characteristic that the screen dot obtained with the voltage of -1350V has a blunt peak which gives the good contrast and the screen value reproduction.

5. Conclusion

Developing process on the photoreceptor consists of three systems (and phases): dev. drum, rev. rollers, and squ. roller. The aim of three developing phases is continuous reduction of thickness of liquid ink layer. Voltage variations ($\Delta V=200V$) on each system will differently influence image formation and appearance of the print. Voltage modification during of the second developing phase (developer rollers) will allow largest manipulation of color ($\Delta E_{\text{RR}} = 10.01$). Optimal results are achieved by a voltage of -125 V. Average screen element (obtained from the calculations based on 196 elements) has an average diameter of 56.9 μm with a maximal reflectance of $R_{125}=33.50\%$. Effect of voltage on the optical color density is significant, what is evident from the deviation of the reflectance of the screen elements ($\Delta R=10.87\%$).

First developing stage removes the majority of the ink from the background surface. This phase does not significantly affect ink layer thickness of the print elements ($\Delta E_{\text{DEV}}=1.26$). However, the optimal voltage on developer drum is -350 V which will form elements with average diameter of 52.54 μm and maximal reflectance of $R_{350}=43.06\%$ on the 20% screen area. The voltage variation does not significantly affect the reflectance from screen elements ($\Delta R = 1.71\%$). Final development phase (squeegee roller) will stabilize the formed ink layer on photoconductor, eliminating possible toner dripping ($\Delta E_{\text{SQU}}= 0.94$). Optimal voltage on squeegee roller is -1350V, which will form the average print dot diameter of 55.19 μm , with a maximal reflectance of $R = 36.02\%$. The voltage variation does not significantly affect the reflectance from screen elements ($\Delta R = 1.37\%$).

It is evident that developing process with multiple developing devices isn't optimal, because it applies large quantities ink on the background and the solid area.

Future development of this technique should address this problem by reducing the total amount of ink on photoreceptor. For that purpose modular Ink Jet technology could be applied, where small nozzles could be used for selective application of tiny droplets on the photoreceptor that could be selectively directed (depending on the image position). That could lead to the integration of Electrophotography and Ink Jet printing technology.

6. References

- Drennan, B., (1997). *Indigo E-Print 1000+ graphic designer's companion*, Adams-Harmon Graphics Press, ISBN 10: 0964255251, Chicago, USA
- Fenton H.M., (2005). *On-Demand and Digital Printing Primer*, GATF Press, ISBN 978 0883624968, Pittsburgh
- Fleming, P. D., Cawthorne, J. E. & Mehta, F. (2003). Interpretation of Dot Fidelity of Ink Jet Dots Based on Image Analysis, *Journal of Imaging Science and Technology*, vol. 47, no.5, (September/October 2003), pp. 394-399, ISSN: 1062-3701
- Goldmann, G. (2004). *The World of Printers*, Oce Printing Systems GmbH, ISBN 3-00-001081-5, Poing, Germany
- Kipphan, H. (2001). *Handbook of Print Media*, Springer-Verlag, ISBN: 3-540-67326-1, Berlin, Germany
- Landa, B. (1994). Digital Color Offset -Today and Tomorrow , *Proceedings SPIE*, 2171: 2, Bares, J. (Ed.), pp 2-7, ISBN: 9780819414663, May 1994
- Lee, N.J. Hae R. J., Kyung Y. Y.& Young N.(2003). Development of Positive Charging Multi-Layered Organic Photoconductor for Liquid Electrophotographic Process, *IS&T NIP 19th International Conference on Digital Printing Technologies*, pp. 670, ISBN / ISSN: 0-89208-247-X, New Orleans, LA, September 2003
- Majnarić, I. Bolanča Z., Bolanča Mirković I., (2010). The influence of the accelerated ageing on the black screen element of the Electroink prints, **Journal of Physics: Conference Series**, pp 1-10, (1742-6596) 231 (2010)
- Majnarić I., Bolanča I., Bolanča Z. & Milković M.(2005.) Condition in Digital Printing of Packaging on the Print Quality, *International Conference on Digital Production Printing and Industrial Applications*, pp. 97. ISBN: 0-89208-256-9 Amsterdam, Netherland, 2005
- Majnarić, I. Bolanča S., Bolanča Mirković I., (2009). The Influence of the Developer Drum Voltage on Screen Dot Formation, *Proceedings 20th International DAAAM Symposium "Intelligent Manufacturing & Automation Focus on Theory, Practice and Education"* / B. Katalinić (ed.). pp.607. ISBN 978-3-901509-70-4, Vienna: DAAAM International Vienna, 2009
- Schein, L.B. (1992). *Electrophotography and Development Physics*, Springer-Verlag, ISBN 1-885540-02-7, pp.50 Berlin, Germany
- Yamana S. (2004). High-Speed Color Laser Printing; *Proc. IS&T NIP 20th International Conference on Digital Printing Technologies*, pp. 1, ISBN/ISSN: 0-89208-253-4, Salt Lake City, Utah, October 2004