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WEAR ANALYSIS OF THE OFFSET PRINTING PLATE'S NON-PRINTING AREAS DEPENDING ON EXPLOITATION

Živko Pavlović, Dragoljub Novaković, Tomislav Cigula

Original scientific paper
One of the most important features in lithography is the stability of the printing plates during the printing process. The offset printing plates are mainly built of aluminium foil which is processed to obtain surface structure needed for printing process requirements. Printing plate is during printing process under mechanical and chemical influence of the machine parts and chemicals used which change printing plate's surface leading to deterioration of printing quality. This paper investigates wear of the printing plate's nonprinting areas by the printing process. For this purpose analysis of the surface was made by evaluating SEM micrographs, roughness parameters and surface free energy. Results of this study showed that nonprinting areas are reducing their surface free energy and roughness with the increase of the imprints made. This investigation has given a new insight in the wear process of the non-printing areas which could lead to improvement of the printing plate's wear resistance.

Keywords: *CtP, material wear, non-printing areas, print run, surface free energy, surface roughness*

Analiza trošenja slobodnih površina ofsetne tiskovne forme u ovisnosti o eksploataciji

Izvorni znanstveni članak
Za postizanje kvalitetnog otiska nužno je osigurati stabilnost tiskovne forme tijekom otiskivanja cijele naklade. Tiskovne forme za ofset najčešće se izrađuju od aluminijske folije koja se površinski obrađuje s ciljem stvaranja površinske strukture nužne u procesu otiskivanja. Tijekom otiskivanja tiskovna forma dolazi u kontakt sa strojnim dijelovima te kemikalijama koje utječu na njenu površinsku strukturu i vode k smanjenju kvalitete otiska. Cilj istraživanja bio je utvrditi trošenje slobodnih površina tiskovne forme uzrokovane procesom otiskivanja. Istraživanja su obuhvatila analizu površinske strukture vizualnom ocjenom SEM snimaka te određivanjem parametara hrapavosti te slobodne površinske energije slobodnih površina. Rezultati istraživanja su pokazali da se procesom otiskivanja smanjuje hrapavost i površinska energija slobodnih elemenata što dovodi do smanjenja njihove funkcionalnosti. Ovo istraživanje je pokazalo trošenje slobodnih površina u procesu otiskivanja i dalo novu predodžbu uzročnika što je nužno za razvoj tiskovnih formi s ciljem povećanja otpornosti prema trošenju.

Ključne riječi: *CtP, hrapavost površine, naklada, slobodna površinska energija, slobodne površine, trošenje materijala*

1 Introduction

Offset printing is a most commonly used printing technique today. It is characterised by two features, printing ink is carried from the printing plate on the printing substrate by the blanket cylinder and the printing and non-printing areas are in the same plane. The difference between printing and non-printing areas on the printing plate is achieved by opposite physical-chemical properties. Non-printing areas are hydrophilic which enables them to attract water based solution – fountain solution while non-printing areas are hydrophobic and oleophilic to attract printing ink but in the same time repel fountain solution [1]. Lithographic printing plates are mainly made of aluminium foils. In order to improve the fountain solution adhesion and to enhance the adhesion of the photosensitive coating during the printing process [2] the foil needs to be roughened by electrochemical graining and anodic oxidation [3, 4].

Roughening of the aluminium surface and forming of thin aluminium oxide film is necessary for a number of reasons: it enlarges the functional properties of the surface and causes better fountain solution adsorption, better adsorption of the photosensitive coating, it enlarges the functional properties and causes better ink adhesion, during the reproduction process it increases stability of the fountain solution and printing ink on the non-image and image surfaces, respectively. It ensures better mechanical properties of the printing plates and thus, longer print runs with the plates [5].

The functional properties of the printing plate are highly influenced by the surface structure and its characteristics, making the topography characterization very important for many applications since the roughness of the surface is a significant engineering factor [2].

The needed surface properties of the printing form are achieved by processing of the aluminium foil. This process usually consists of several steps: cleaning, electrochemical graining, anodising, post anodic treatments and coating with a photosensitive layer. Cleaning, an alkaline or acid etching, is done to remove residual contaminations and the natural oxide film of the aluminium surface. The aluminium surface is roughened to a well-defined topography in the graining process. Nowadays electrochemical graining (EC-graining) has replaced mechanical graining due to its possibility to produce finer and more defined topographies. EC-graining is performed in acidic electrolytes, based on either hydrochloric acid or nitric acid. The surface topography after EC-graining consists of hemispherical pit-type craters with depths in the order of 2 μm to 10 μm, and is needed to ensure a good adhesion of the coating and to improve the water retentive properties of the surface. In anodization phase the freshly formed surface is mechanically and chemically stabilized with approximately 1 μm thick anodic film. Post anodic treatments differ between manufacturers but generally serve to improve the hydrophilic properties of non-printing areas [6, 7]. Photoactive coating enables image transfer on the printing plate by changing its solubility when irradiated by defined electromagnetic irradiation.

The aim of this study was to determine wear of the printing plate in the printing process. Wear of the printing plate is a significant factor in offset printing especially in the long run printing (newspaper, magazines and package printing). Investigations made so far stressed their interest on the printing areas i.e. wear of the photosensitive coating [8, 9, 10]. This paper shows investigation of the non-printing areas' surface changes which also have significant influence in image definition and imprint quality.

For this purpose, analysis of the surface topography on non-printing areas of the printing form using standard profilometric method as well as SEM micrographs for quantitative and qualitative characterization was made. In addition, surface free energy of the non-printing areas was calculated in order to get insight into the surface wetting properties.

2 Materials and methods

The lithographic printing plates used in this study were thermal positive printing plates of 0,3 mm thick AA1050 aluminium foil electrochemically roughened and anodized. They are manufactured according to stringent, standardized procedures [11] resulting in surfaces of controlled and reproducible roughness suitable for the purpose of this study.

The plates were made in a Computer to Plate system. Exposure was made by IR laser, irradiation of 830 nm wavelength and energy of 140 mJ/cm^2. Exposed areas (non-printing areas) of the photosensitive layer were removed from the plate surface by chemical processing in alkaline Kodak Goldstar premium developer. The developing process was made according to the standardized processing procedure at temperature of 22,3 °C, with the processing speed of 0,9 m/min and the processing time of 20 s. All the measurements presented in this study were made at five distinct circular sample areas (R=1,5 cm) from the non-printing area of the printing plate sample, positioned along the line of printing cylinder axes in the printing units and with center-to-center interval of 20 cm. This sampling was made to avoid possible local defects in the printing (differences in cylinder pressure, defect on the rubber blanket, ...). The profilometric measurements were made at the reference sample (printing plate which was not in the printing process) and on samples taken after a print run of 123 000, 177 000 and 300 000 impressions. Printing process was performed by the four colour web offset printing press, Komori 38 D which has the ability to print with heat-set printing inks, maximal printing areas of 1250×960 mm and top speed 36 000 prints per hour. The four primary colours of the subtractive colour synthesis were printed in the following sequence - black, cyan, magenta and yellow. In this research measurements were conducted on printing plate used for printing black colour and for printing yellow colour, they being first and last in the printing sequence, in order to determine the influence of paper dust on the printing plate characteristics. As the paper is transported through printing press some of the paper dust is assumed to be desorbed from the paper surface and therefore a smaller amount of it could come in contact with the printing plate in the later stages of the printing process sequence.

As this investigation is made on the non-printing areas the influence of the printing ink is ruled out because the printing ink does not come in direct contact with aluminium-oxide surface.

Since the investigation made by [12] showed that high depth of focus SEM can provide detailed topographical information about the surface, but cannot provide quantitative topographical information, we have observed and analysed printing plates, before and after the print run by a roughness meter (Time Group TR200) and by a SEM and thus combined the quantitative topographical information and the micrographs obtained by the SEM.

The SEM micrographs of the samples were made by JEOL JSM 6460 LV scanning electron microscope. To assure the uniform electrical properties and to avoid the charging/discharging of aluminium oxide surfaces, the printing plate samples were gold coated by ion sputtering (coating was 15,0 nm thick and with density of 19,32 g/cm^3). The images were taken at working distance of 15 mm, spot size of 35 nm and at voltage 20 kV with magnification 2000×.

The profilometric parameters were measured with the Portable Surface Roughness Tester TR200 [13] provided with a diamond tip of 2 µm radius. The TR200 is capable of evaluating different roughness parameters: *Ra, Rz, Ry, Rq, Rt, Rp,* R_{max}*, Rm,* R_{3z}*, S, Sm, Sk, tp*, and hybrid parameters: primary profile (*P*), roughness profile (*R*), and *tp* curve (material ratio M_r), all defined according to the pertinent ISO standards [14, 15]. The relevant measurement's parameters were: sampling length: 0,80 mm, traversing speed: V_t = 0,5 mm/s, measuring range: ± 20 µm, and resolution: 0,01 µm ~ 0,04 µm.

The measured surface roughness parameters used in this study are compliant to the geometric product specification standards [16, 17] and listed below:

- *Ra* – average surface roughness:

$$Ra = \frac{1}{l}\int_0^l |y(x)|\mathrm{d}x \tag{1}$$

- Rz_{DIN} – mean value of the single roughness depths Z_i:

$$Rz_{DIN} = \frac{1}{n}(Z_1 + Z_2 + ... + Z_n) \tag{2}$$

- *Rv* – maximum depth of profile valley (Fig. 1)
- *Rp* – levelling depth, distance between the highest peak and the reference line (Fig. 1).

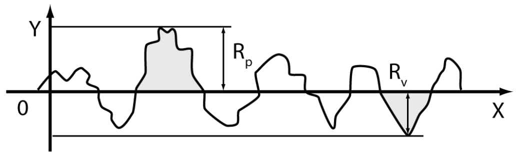


Figure 1 Profile parameters *Rp* and *Rv*

Production of aluminium foil suitable for printing forms includes processing by rolling procedure, which results in the characteristic structure of the surface in the direction of rolling. Lines that occur on the surface are not desirable in further preparation of aluminium and require special treatment to reduce their negative impact on the surface roughness [18]. Therefore, the measurements of surface roughness of the printing forms are carried in *x* and *y* direction, i.e. in the direction of aluminium rolling and perpendicular to the direction of rolling.

To determine surface properties of the investigated samples, measurement of the contact angle was performed. Contact angle measurements were performed by a videobased, optical device, DataPhysics' OCA30. This device enables static and dynamic characterization of liquid/solid interfaces by contact angle measurement procedure. *Sessile drop* method was used for measuring contact angle.

Characterization of the printing plate's surface properties was made by the application of the three reference liquids of known surface tension (Tab. 1). Results of the contact angle measurements enable calculation of the surface energy, its polar and dispersive part.

Table 1 Surface free energy (γ_{lv}) and its dispersive (γ_{dlv}) and polar (γ_{plv}) components and viscosity of liquids

Liquid	Surface free energy γ /mN/m		
	γ_{lv}	γ_{dlv}	γ_{plv}
Diiodomethane (Ström et al.)	50,8	50,8	0,0
Glycerol (van Oss et al.)	64,0	34,0	30,0
Water (Ström et al.)	72,8	21,8	51,0

Surface energy calculation was made using the Owens-Wendt-Rabel and Kaelble (OWRK) analysis method.

This method is developed from Young equation and the fact that surface tension can be divided on the polar and dispersive part [19, 20].

$$\frac{(1-\cos\sigma)\cdot\sigma_{s}}{\sqrt[2]{\sigma_{dl}}}=\sqrt{\sigma_{ps}}\sqrt{\frac{\sigma_{pl}}{\sigma_{dl}}}+\sqrt{\sigma_{ds}}\,, \quad (3)$$

where σ_s is surface tension of the solid, σ_l is the surface tension of the liquid, σ_d dispersive part of surface tension, σ_p polar phase of surface tension [20].

Surface tension and its polar and dispersive part is then calculated by observing equation (4) in graphic presentation of the function $y = mx + b$, where m is the square root of polar part of the solid's surface tension and b is the square root of dispersive part of the solid's surface tension.

Contact angles of referent liquids used for surface free energy calculation were the average of ten liquid droplets. Before contact angle measurements, samples of printing plate were washed out in distilled water in ultrasonic washing unit Bandelin Sonorex at temperature of 65 °C and dried at room temperature.

3 Results and discussion

3.1 SEM analysis

SEM micrographs were made to get visual indications of the printing plate's surface structure. The SEM micrograph presented in Fig. 2 shows the structure of aluminium oxide surface of the reference sample of printing plate. The surface of unused printing plate sample is characterized by high narrow peaks and deep and narrow pores. The surface of anodized aluminium oxide layer is uneven, the pore size and depth vary which is probably the consequence of electrochemical graining and anodization process conditions during the production process. On the other hand, this surface structure improves adsorption of the fountain solution in the printing process and gives the printing plate better mechanical properties [2, 5]. Some flat visible spots are probably the consequence of the processing in an alkaline solution [21].

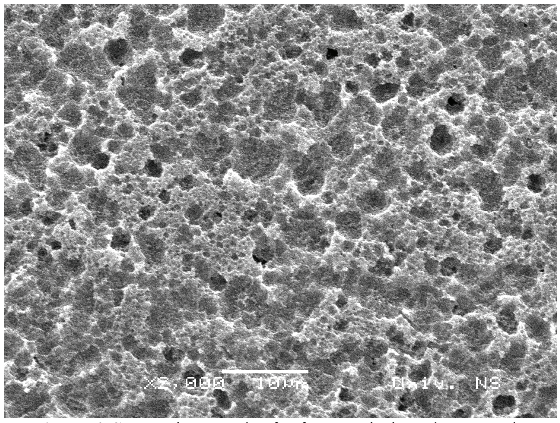


Figure 2 SEM micrograph of referent printing plate sample

It can be clearly seen that the surface of the printing form used in printing is different from the referent sample. The surface of the used plates is characterized by larger structures. The valleys of the printing plates for both colours, black and yellow, are probably filled with some particles of paper dust. The peaks visible in Fig. 2 are flattened by the printing process resulting in smoother surface.

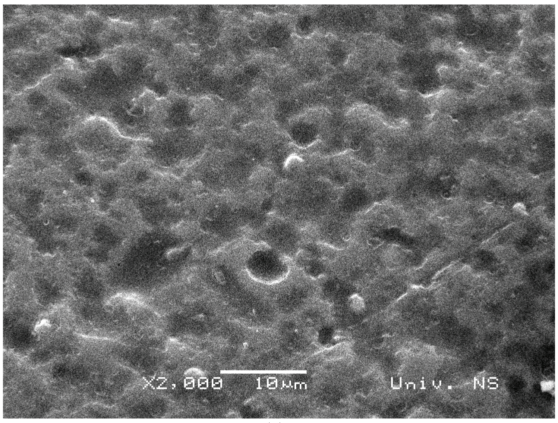
Comparing Figs. 3a and 3b, one could see that the printing plate for yellow colour remains rougher than the printing plate for black colour which could imply the influence of the printing sequence as mentioned before, black is the first colour printed and yellow is last, i.e. the amount of the paper dust is lowered by the paper transport through the printing machine.

In Fig. 4 samples of printing plates after 300 000 impressions are shown. The deformations of the printing plate's surface are even more visible compared to the Figs. 3a and 3b. The printing plates for both colours have similar surface structure (Fig. 4a and 4b).

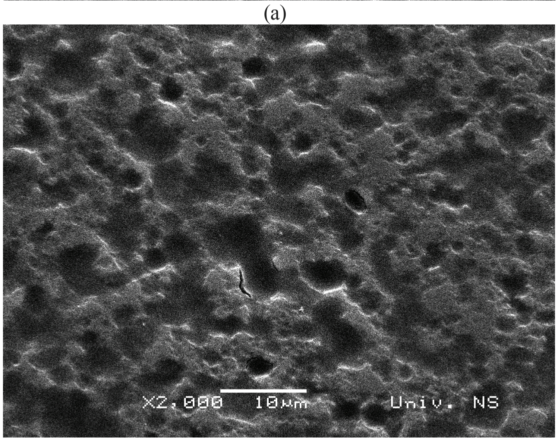
During printing process, printing plate is in contact with ink and fountain solution rollers and rubber blanket. In all those contacts there is friction present, which causes wear of the material (aluminium-oxide) as the rubber blanket has rough surface [22].

Comparing Figs. 3a and 3b to Figs. 4a and 4b, respectively, one could see that changes of the surface are smaller in comparison to the changes between unused printing plate and the one after 123 000 imprints.

This behaviour is probably the consequence of wear resistance of the aluminium-oxide after highest peaks are removed as seen before in research of the printing areas [10].

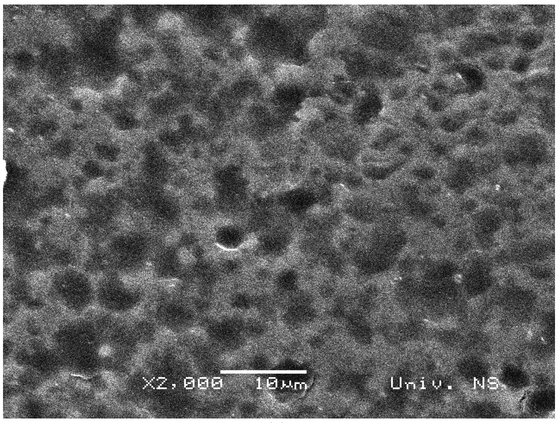


(a)

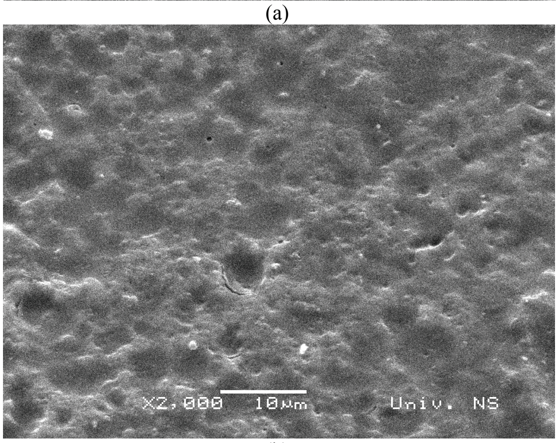


(b)

Figure 3 SEM micrograph of printing plate samples after 123 000 impressions for b) black colour and c) yellow colour



(a)



(b)

Figure 4 SEM micrograph of printing plate samples after 300 000 impressions for a) black colour b) yellow colour

3.2 Results of the roughness parameters

Changes in surface topography seen on the SEM micrographs were quantified by measuring roughness profiles of the printing plate's non-printing areas.

Results of the roughness parameters *Ra* are presented in Fig. 5.

Average roughness (*Ra*) with the print run decreases faster on the printing plate for black colour and after 123 000 imprints decreases by nearly 25 %. After the first high decrease, *Ra* of the printing plate for black colour is nearly constant by increasing the number of imprints made.

On the other hand, *Ra* of the printing plate for yellow colour shows linear decrease in dependence on the print run length. Roughness parameter *Ra* decreases at different speed but to the same value at the printing plate after 300 000 imprints. This behaviour indicates higher impact of the paper dust on the printing plate for black colour at the beginning of the printing process.

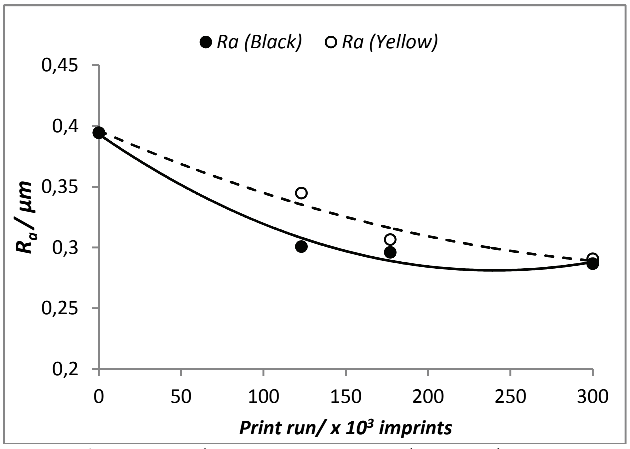


Figure 5 Roughness parameters *Ra* and *Rq* vs. print run

Better insight of differences in topography is given by parameters which differentiate behaviour of the peaks (*Rp*) and valleys (*Rv*).

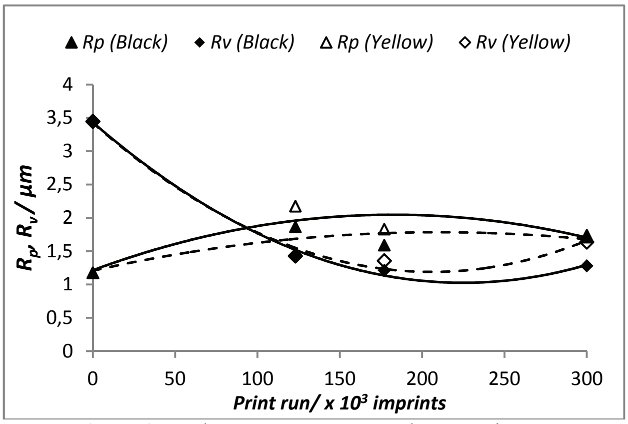


Figure 6 Roughness parameters *Rp* and *Rv* vs. print run

In Fig. 6 one could see that *Rp* is increasing its value for both samples, at the first third of the investigated printing run but the continuing printing process causes *Rp* to decrease. Both printing plates, for black and yellow colour, have similar behaviour of the *Rp* parameter. The printing plate for yellow has a slightly larger parameter value. These results imply that the printing process causes wear of the peaks, but the rough surface of the printing plate is uneven (Fig. 2) and linked with the rough surface structure of the rubber blanket could create new texture which would have higher peaks.

The *Rv* parameter decreases with the increase of the number of imprints made. Comparing results of the reference sample and printing plate sample after 123 000 imprints made one could notice a massive value drop of over 50 % (3,44 to 1,44 for black and to 1,42 for yellow). After this first high value diminishment, *Rv* stabilizes its value with a slight value decrease (Fig. 6).

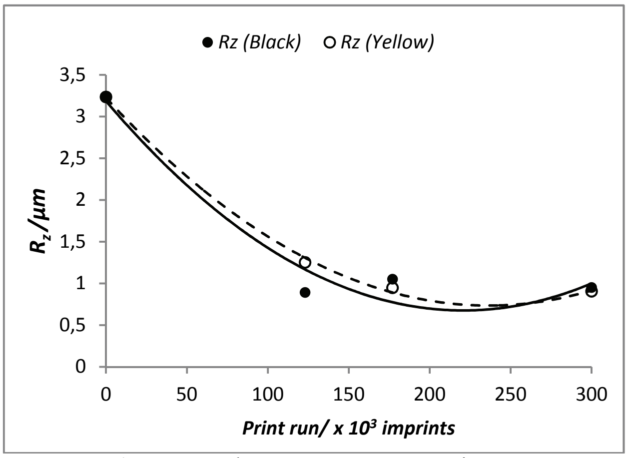


Figure 7 Roughness parameters *Rz* vs. print run

The results of the *Rz* parameter confirm SEM micrographs in Figs. 2, 3 and 4. The surface texture of the printing plate is highly influenced by the printing process at the start of the process (printing plate after 123 000 imprints) but then stabilizes and the roughness is slightly reduced on the printing plates for both colours. *Rz* parameter of the printing plate for black colour is after the first high decrease at printing plate after 123 000 imprints slightly increased at printing plate after 177 000 imprints to lower again at printing plate after 300 000 imprints. This behaviour of the printing plate for black colour indicates the role of the paper dust in surface roughness but also the influence of the fountain solution which also has the role of cleaning surface of the printing plate [23].

3.3 Results of the surface energy calculation

Higher change in the roughness parameters value on the printing plate for yellow colour is detected in higher decrease of the surface free energy value (Fig. 8).

Surface free energy (γ) of both printing plates decreases constantly with the increase of the print run.

Surface free energy of the black colour printing plate (γ_black) decreases linearly while the decay of the surface free energy of the yellow colour printing plate (γ_yellow) is larger like in the roughness parameters highest in the first third of the investigated printing run.

The decrease of the surface free energy is mainly caused by its polar component as dispersive component is almost constant (Fig. 7, γ_d). One could notice a slight increase in *Rv* and dispersive part of surface free energy on the yellow colour printing plate (γ_d_yellow) after 300 000 imprints which could indicate a lower amount of material (paper dust, other impurities) adsorbed on its surface.

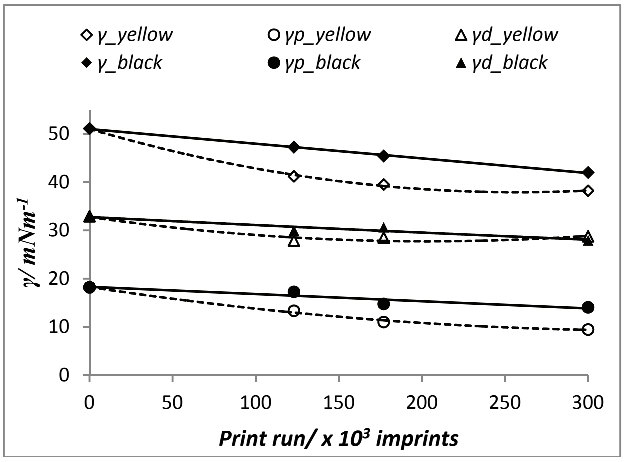


Figure 8 Surface free energy vs. print run

Decrease of the surface free energy, its polar part (γ_p) has a direct impact on the printing plate's usage in the printing. As said earlier, non-printing areas of the printing plate must have high level of wetting with water based fountain solution [24].

4 Conclusions

This investigation was made to determine the influence of the printing process on the printing plate's surface topography. The evaluation of the surface properties was made by making SEM micrographs, measurements of the roughness parameters and determination of the surface free energy.

Results of this study prove that surface structure of the non-printing areas of the printing plate change in the printing process. Deterioration of the surface roughness is not linear. High decrease of the roughness parameters at the beginning of the printing process indicates high influence of the paper dust which is also visible by difference in roughness of the printing plate for the black and the yellow colour.

Printing process also causes decrease of the surface free energy of the printing plate's non-printing areas which directly influences the amount of the fountain solution in those areas and consequently could reduce the quality of the imprints due to the paper extension or smaller ink saturation.

This investigation showed that when determining wear of the printing plate one should take into account investigation of non-printing areas as they are essential part of the printing process and are considerably changed by the printing process. On the other hand, printing sequence influences the non-printing areas wear which would imply the necessity of taking this factor into consideration in future research.

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Authors' addresses

Živko Pavlović, Assistant
Faculty of Technical Sciences
University of Novi Sad
Trg Dositeja Obradovića 6
21000 Novi Sad, Srbija
E-mail: zivkopvl@uns.ac.rs

Dragoljub Novaković, Prof.
Faculty of Technical Sciences
University of Novi Sad
Trg Dositeja Obradovića 6
21000 Novi Sad, Srbija
E-mail: novakd@uns.ac.rs

Tomislav Cigula, Assistant
Faculty of Graphic Arts
University of Zagreb
Getaldićeva 2
10000 Zagreb, Croatia
E-mail: tcigula@grf.hr