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Impact of Environment Temperature Changes Upon Print Durability

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In order to evaluate the stability of bar code characteristics under operation, a study was carried out to determine the resistance of graphic element prints to the impact of temperature changes and resistance to mechanical action (friction). The print resistance to mechanical action depends on the properties of the printing ink and the print material. For the study, flexographic bar code prints on different types of paper were made by using water-base and ultraviolet-hardening (polymerising) inks. Research has shown that Vellum paper is less suitable for bar code printing with water-base or ultraviolet inks as it gets considerably rubbed off during the first five minutes of mechanical impact (optical density decreases from 1.35 to 0.91). Rafla Coat paper is much more suitable for bar code printing with ultraviolet inks as in this case the largest optical density is obtained. In addition, this paper is resistant to mechanical impact after temperature changes.

Keywords: bar codes, print resistance to mechanical impact, printing technology.

1. INTRODUCTION

Bar codes (BC) are printed in different ways and a wide range of materials is used for that.

A number of researchers have studied BC identification errors caused by the print surface roughness or other factors [1, 2]. Highly distinguishing BC reading abilities [3 – 5] and the duration of decoding [6], as well as spectral characteristics of BC images of different colours and materials [7] have been identified. The quality of printing elements has been studied by numerous specialists of printing and publishing technologies [8 – 11]. However, the available results are not sufficient to evaluate the stability of BC element durability parameters under cyclic environment temperature changes. The present paper is a continuation of the work described in [12]. It deals with resistance of bar code prints to mechanical impact.

2. EXPERIMENTAL

In order to evaluate the stability of bar code characteristics under different operation conditions, the resistance of graphic element prints to temperature changes and mechanical impact (friction) after the temperature changes was studied. The print resistance to mechanical impact depends on the properties of the printing ink and the print material. Therefore, for the research, specimens printed by flexographic method on different types of paper with the application of water-base and ultraviolet-hardening (polymerising) inks were used.

The specimens were printed by two types of machines: "ARSOMA EM-280 ks" and "GALLUS E-280". When supplying paper to the printing machine "ARSOMA EM-280 ks", the paper tension was 31 N, when rolling it was 22 N, while in the printing machine "GALLUS E-280"it was 34 N and 23 N, respectively.

In the printing machine "ARSOMA EM-280 ks" water-base (WB) ink Hydrokett-2000 Svart-Black HDP071 (producer "Akzo Nobel Inks") was used, while in "GALLUS E-280" – UV-hardening ink Black Proc Exure 50000/EXC (producer "Arets Graphics"). For the printing process raster (anylox) rollers, made by Praxair, were used: ST1719405 24LPC 3.7 cm^3/m^2 and ST1719702 340LPC 3.4 cm^3/m^2 (the latter only on Raflacoat paper with UV ink).

The samples were printed on "Raflatac" paper, five sorts being selected from nine (the criterion for the selection was the roughness dispersal on the surface). The following sorts were chosen:

VELLUM – non-coated, wood-free, supercalendered paper;

THERMAL TOP – standard sensitivity thermopaper with a double protective layer;

PHERMA MATT – supercalendered, wood-free paper with extra coating;

RAFLACOAT – supercalendered, medium-gloss, wood-free white paper, coated during production;

PP WHITE – white glossy bio-oriented synthetic film.

The operational properties of the paper were tested by sharply changing the temperature (see the temperature change cycle curve in Fig. 1). Initially the sample was placed in a freezing chamber with the temperature of –37 °C. The print was kept at this temperature for 180 s, and after that moved to a heater maintaining the temperature of 42 °C. The duration of the trial cycle was $t = 387$ s.

The principal scheme of the experimental device used for studying the resistance of a graphic element print to mechanical impact is shown in Figure 2. The test specimen holder 2 is placed on a disc 3 (at the distance of $r = 0.1$ m from the disc axis). Three specimens 4 are glued to the disc 3.

The chosen cinematic scheme of the device allows the specimen to develop planetary movement, and the relative linear velocity of any specimen point is uniform and can be determined by the dependence, respectively, $v_1 = \omega_1 \times r$ (where ω_1 is the angular velocity of disc 3). The specimen holder is subjected to different load values by changing pressing force P to the disc.

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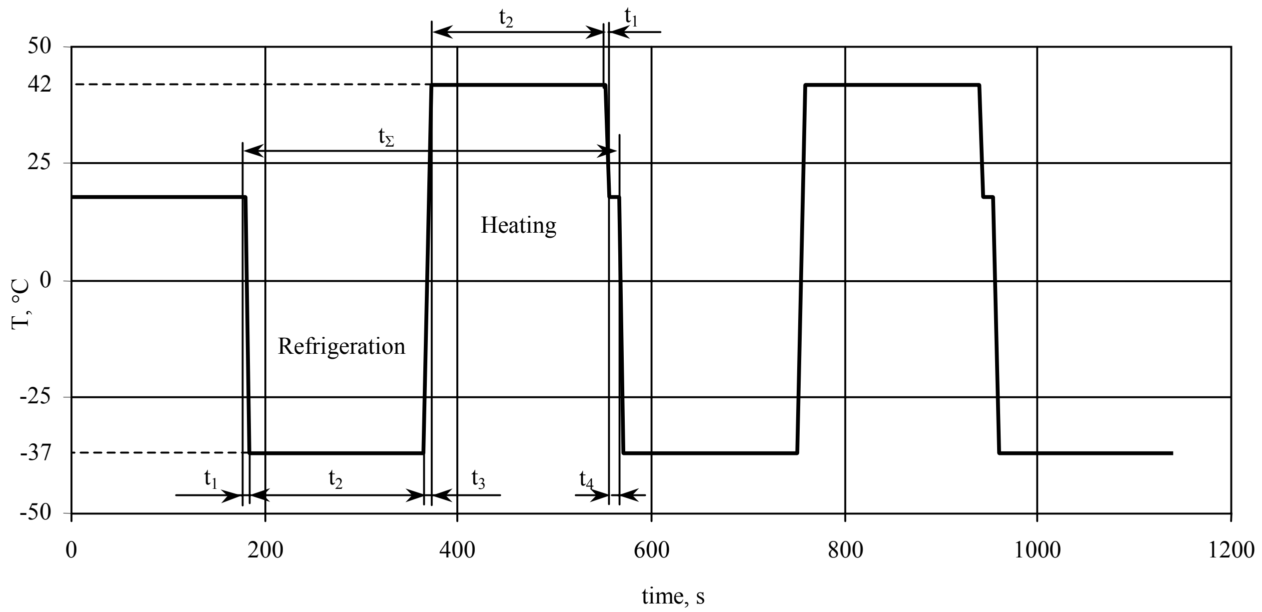

Fig. 1. Curve of temperature change cycle of BC prints: t_1 = 5 s, t_2 = 180 s, t_3 = 7 s, t_4 = 10 s, t_Σ – temperature change cycle

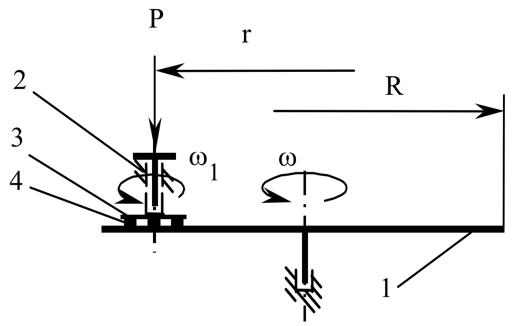

Fig. 2. Scheme of experimental device for studying resistance of graphic element print to mechanical impact (friction): 1 – disc; 2 – holder; 3 – specimen disc; 4 – specimens; *P* – load; ω, ω_1 – angular velocities of the disc and specimen disc, respectively

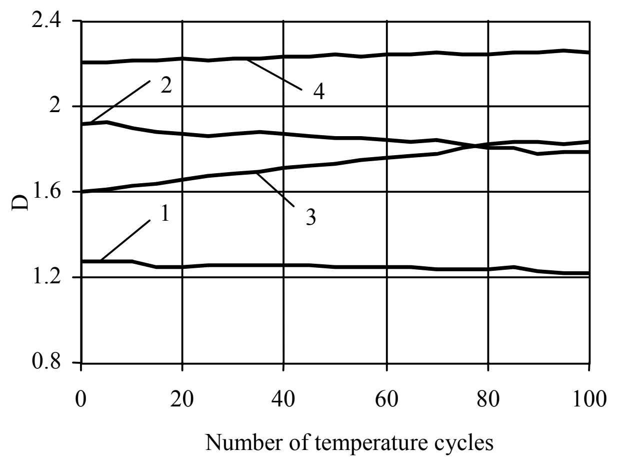

Fig. 3. BC optical density dependence upon the number of temperature cycles. Printed with water-base inks: 1 – Vellum paper, 2 – Thermal Top paper, 3 – Pharma Matt paper, 4 – Rafla Coat paper

The resistance of graphic elements to mechanical impact was studied on the experimental device as follows:

- by changing the pressing load from 147.15×10^{-3} to 441.45×10^{-3} N/cm^2 every 73.58×10^{-3} N/cm^2;
- by choosing the relative linear velocity discretely from the available options: 0.17 m/s; 0.35 m/s; 0.47 m/s or 0.82 m/s;
- by changing the duration of the mechanical impact upon the specimen.

3. RESULTS AND DISCUSSIONS

3.1. BC Resistance to the Impact of Temperature Changes

The bar codes chosen for the experiment were printed at the speed of 75 m/s. The optical density of the specimen was measured by densitometer Viptronic 0477. The measurements were done every 5 cycles of the temperature change. The results obtained are shown in Figures 3 and 4.

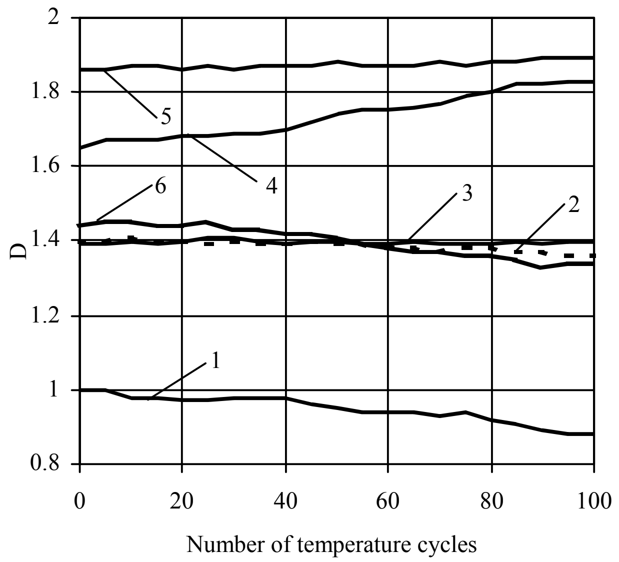

Fig. 4. BC optical density dependence upon the number of temperature cycles. Printed with ultraviolet inks: 1 – Vellum paper, 2 – Thermal Top paper, 3 – Pharma Matt paper, 4 – Rafla Coat paper, 5 – Rafla Coat paper (340 lpc liniature raster roller was used for printing), 6 – PP White film

Fig. 3 shows that when using water-base inks for printing, the optical density of bar codes printed on Vellum (Fig. 3 curve 1) and Thermal Top (Fig. 3 curve 2) paper slightly decreased ($\Delta D = 0.05$ and $\Delta D = 0.12$, respectively), while the optical density of BCs printed on Pharma Mart (Fig. 3 curve 3) and Rafla Coat (Fig. 3 curve 4) increased $\Delta D = 0.23$ and $\Delta D = 0.05$, respectively.

In Fig. 4 one can see that when ultraviolet inks are used, the optical density most prominently decreased when the bar codes were printed on Vellum (Fig. 4 curve 1) and PP White (Fig. 4 curve 6) paper ($\Delta D = 0.12$ and $\Delta D = 0.10$, respectively).

The optical density of BCs printed on Thermal Top, Pharma Matt and Rafla Coat (Fig. 4 curves 2, 3, 5) changed insignificantly, however, it increased most when Raffla Coat paper (Fig. 4 curve 4) was used ($\Delta D = 0.19$).

3.2. BC Resistance to Mechanical Impact (After Sharp Temperature Changes)

During their lifetime BCs are subjected not only to mechanical action, but also to temperature changes, therefore the specimens after sharp temperature changes were subjected to mechanical impact according to the method described in Section 2. The results obtained are presented in Figures 5 and 6.

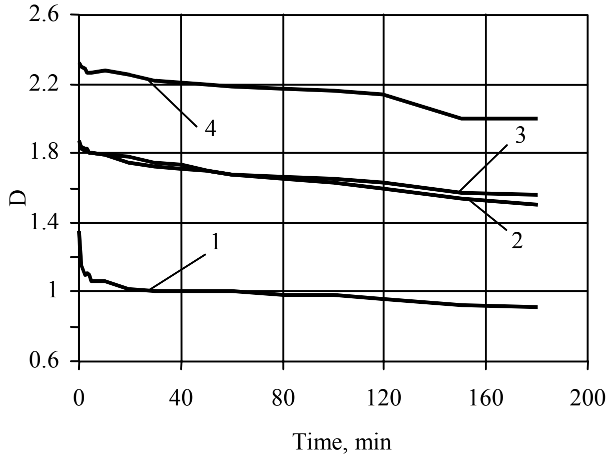

Fig. 5 Dependence of BC optical density upon the duration of mechanical impact (friction) after temperature change: $v_1 = 0.47$ m/s, $P = 441.45\times10^{-3}$ N/cm^2. Printed with water-base ink: 1 – Vellum paper, 2 – Thermal Top paper, 3 – Pharma Matt paper, 4 – Rafla Coat paper

Fig. 5 illustrates the results obtained in printing with water-base inks. It is obvious that after the temperature change the optical density of the bar codes decreases under mechanical impact. The study results show that optical density decreased most (from 1.35 to 0.91) in the element printed on Vellum paper (Fig. 5 curve 1), although the other prints, printed on Thermal Top, Pharma Matt and Rafla Coat paper, also got notably rubbed out.

Fig. 6 presents the results when ultraviolet inks are applied. One can see that after the temperature change the optical density of such bar codes changed only insignificantly under mechanical impact. The optical density of the element printed on Vellum paper (Fig. 6 curve 1) changed most (from 0.94 to 0.72), while that of the rest BCs, printed on Thermal Top, Pharma Matt, Rafla Coat and Rafla Coat (340 lpc), changed very little.

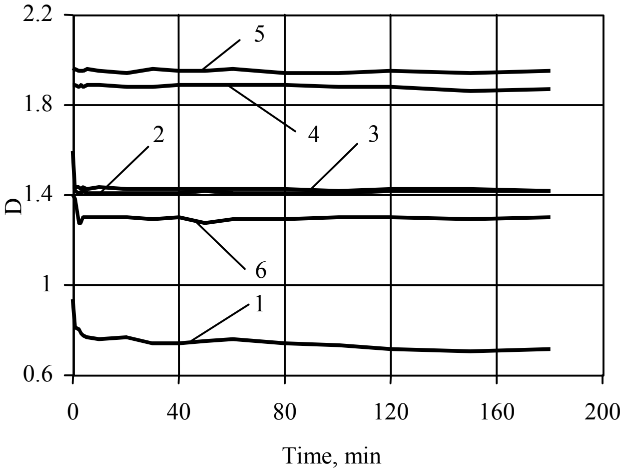

Fig. 6. Dependence of BC optical density upon the duration of mechanical impact (friction) after temperature change: $v_1 = 0.47$ m/s, $P = 441.45\times10^{-3}$ N/cm^2. Printed with ultraviolet inks: 1 – Vellum paper, 2 – Thermal Top paper, 3 – Pharma Matt paper, 4 – Rafla Coat paper, 5 – Rafla Coat paper (for printing 340 lpc liniature raster roller was used.), 6 – PP White film

While printing on Rafla Coat paper with UV inks, not only 240 lpc roller (Fig. 6 curve 4), but also 340 lpc roller (Fig. 6 curve 5) was used. The optical density is larger when using a bigger liniature raster roller, while the resistance to mechanical impact is similar to the case when 240 lpc raster roller is used, i.e., optical density changes insignificantly.

CONCLUSIONS

1. As a result of cyclic temperature changes from –37 °C to +42 °C, the optical density of the bar codes printed on Thermal Top paper decreased most, from 1.02 to 1.8 (when using water-base inks). The optical density of BCs printed on Vellum paper decreased from 1.0 to 0.88 (when using ultraviolet inks).
2. The optical density of BC elements printed on Rafla Coat paper increased (from 1.65 to 1.84) after cyclic temperature changes. In this process ultraviolet inks were used.
3. BC prints obtained by using water-base inks lose resistance to mechanical impact after cyclic temperature changes. Application of ultraviolet inks for printing BC elements increases resistance to mechanical impact in this case.
4. Vellum paper is less suitable for bar code printing with water-base or ultraviolet inks as it gets considerably rubbed off during the first five minutes of mechanical impact (optical density decreases from 1.35 to 0.91).
5. Rafla Coat paper is much more suitable for bar code printing with ultraviolet inks as in this case the largest optical density is obtained. In addition, a BC print made on this kind of paper is more resistant to mechanical impact after the BC elements were subjected to a cyclic temperature change.

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