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Print Quality of Ink Jet Printed PVC Foils

Autors

[1]Nemanja Kašiković*, [1]Rastko Milošević, [1]Dragoljub Novaković, [2]Mladen Stančić, [1]Stefan Đurđević

[1]*University of Novi Sad, Faculty of Technical Sciences, Graphic Engineering and Design, Novi Sad, Serbia*

[2]*University of Banja Luka, Faculty of Technology, Graphic Engineering, Banja Luka, Bosnia and Herzegovina*

**E-mail: knemanja@uns.ac.rs*

Abstract:

Digital printing technique is used for a wide variety of substrates, one of which are PVC foils. Samples used in this research were printed by digital ink jet printing technique using Mimaki JV22 printing machine and J-Eco Subly Nano inks. As printing substrates, two different types of materials were used (ORACAL 640 - Print Vinyl and LG Hausys LP2712). A test card consisting of fields of CMYK colours was created and printed, varying the number of ink layers applied. Samples were exposed to light after the printing process. Spectrophotometric measurements were conducted before and after the light treatment. Based on spectrophotometricaly obtained data, colour differences ΔE2000 were calculated. Results showed that increasing number of layers, as well as the right choice of substrates, can improve the behaviour of printed product during exploitation.

Keywords:

PVC foils, Digital printing, Printing quality, Lightfastness

1 Introduction

Digital printing technology is well known for its possibility to print on various substrate materials such as: paper, plastics, textiles, ceramics, metal, wood, glass and many other materials (Adam and Robertson, 2001). Substrates with irregular surfaces and with different thicknesses can be successfully printed using this printing process that contributes to its wide applicability. The most frequently used plastic material within this printing technology is PVC, self-adhesive foils that are commercially available either in rolls or sheets of different formats and colors. However, it can be successfully printed onto hard PVC material as well. Beside mentioned substrate, digital printing technology can be used for printing on polyethylene material, which is used for plastic bags manufacturing.

One of the numerous applications of digital printing technique is for car windshield labels. These prints are exposed to light and other environmental influences, which has a great impact on product quality, mostly because it causes printed color change. This can impose big problems because product's final quality cannot be predicted (Herascu et al., 2008). For determining light fastness these standards can be used: ISO105 – B02, ISO105-B01-1999, ISO105-B03 -1997, ISO105-B04-1997, ISO105-B05-1996, ISO105-B06-1999, ISO105-B07:2009, ISO105-B08:1999.

A lot of researchers use ISO105 – B02 standard (Vizárová, et al., 2011; Varesano and Tonin, 2008; Goren¬šek, et al., 2008; Erkan, et al., 2011; Zarkogianni et al., 2010; Riva et al., 1999; Gun and Tiber, 2011). The color differences between samples, exposed and unexposed to light, are usually determined visually, by the blue wool reference. However, visual judgment cannot provide information accurate enough in all circumstances. The more objective way to measure colour difference changes for different colour fastness test (light, wash, rub) is a spectrophotometric method that was used by several researchers (Kan, et al., 2011; Rat, et al., 2011; Mikuž, et al., 2005).

With spectrophotometric measurements, colour difference can be calculated based on colour characteristics measured by instrument after printing process and after light exposure. Numerous formulas were developed for the purpose of color differences estimation, such as basic ΔE76, more advanced CMC (l : c) (Clarke, McDonald and Rigg, 1984), BFD (l: c) (Luo and Rigg, 1987), CIE 94 (CIE, 1995) and the most recent one CIE ΔE2000 (Kim and Nobbs, 1997). All color difference formulas use the Euclidean distance in a device independent color space (ΔL*, Δa*, Δb*) (Luo, Cui and Rigg, 2001). Newer color difference formulas are extended to address perceptual non-uniformities while retaining the L*a*b* color space. There is an ongoing debate that of the formulas gives the best results. Vast majority of the researchers is claiming that the CIE ΔE2000 to be the best one (Kočevar, 2006; Xu, Yaguchi and Shiori, 2001; Gabrijelčić and Dimitrovski, 2007; Gabrijelčić and Dimitrovski, 2009).The aim of this research is to determine how PVC materials characteristics and a different number of printed ink layers affect light fastness, as well as print quality.

2 Material and methods

In this research two types of PVC foils were used (Avery 2920QM and LG Hausys LP2712), both printed with Mimaki JV22 – 160 digital ink jet printer and J-Eco Subly nano inks. The used inks are dispersed digital ink dyes for direct ink jet material printing, which have good fastness properties, which makes them suitable for outdoor products printing.

Two different types of PVC foils were selected as printing substrates, where both foils have identical composition and color (transparent), but different thickness (Avery 2920QM - 60 μm; LG Hausys LP2712 – 80 μm). It is important to point out that both substrates are intended for outdoor exploitation, where according to the manufacturer specifications, the usability of these materials is up to two years for outdoor application. For the purpose of light influence treatment investigation, custom test chart was developed (40 × 10 cm). The test cart consisted of four fields sized 10 × 10 cm; first field – 100 % cyan, second field – 100 % magenta, third filed – 100 % yellow and fourth filed – 100 % black.

Digital ink jet printing machine Mimaki JV22 – 160 provides the possibility to print multiple ink layers, used to print test charts in five different number of ink layers. Therefore, the analysis included these ink volume variations in combination with artificial light exposure effects on printed colour changes.

Printed samples were subjected to the environmental factors in Xeno Test chamber Alpha from Atlas, to obtain light and environmental impacts on colourfastness. The exposure and other process parameters (temperature, relative humidity, irradiance), used to provide data for printed materials behaviour under simulated accelerated ageing, were kept constant and programmed according to the standard values for these types of tests. The accelerated ageing and weathering tests were followed by instrumental evaluations with the aim to determine the colourfastness.

For instrumental measurements, Techkon SpectroDens (Illumination type D50, standard observer angle 2°, measurement geometry 00/450, measurement aperture 3 mm) was used. Measuring was repeated five times for each sample and results shown are the mean values. CIE L, a and b colour coordinates were determined for each sample, as well as the colour differences values using CIE ΔE_{2000} formula, between samples after printing and after light exposing. Forty samples were analysed altogether, twenty samples of each material varying colours and number of ink layers (after printing process as well as after light exposing).

3 Results and discussion

After printing process the colour coordinates CIE L (lightness), a, b, were determined for printed samples with different ink layers number. Results in Table 1 show color differences (calculated using colour difference ΔE_{2000} formula) between the samples printed using five ink layers (reference

Table 1. Spectrophotometric measurement results after printing process

Sample	L	a	b	ΔE_{2000}
A-C-1	51.25	-36.30	-52.98	26.02
A-C-2	40.10	-26.65	-57.72	15.29
A-C-3	33.85	-18.30	-58.26	8.93
A-C-4	29.13	-12.23	-57.52	4.13
A-C-5	25.47	-6.75	-56.91	-
A-M-1	46.00	75.65	9.62	18.98
A-M-2	39.67	74.24	29.20	8.93
A-M-3	36.42	71.45	36.45	4.52
A-M-4	33.80	69.22	39.60	1.86
A-M-5	31.61	66.80	38.78	-
A-Y-1	88.21	-3.73	94.46	10.40
A-Y-2	85.67	3.84	101.50	6.10
A-Y-3	83.27	9.55	101.26	2.71
A-Y-4	81.34	12.84	100.59	0.59
A-Y-5	81.18	14.02	101.61	-
A-K-1	8.93	2.38	-2.32	4.95
A-K-2	4.55	-0.39	-3.15	0.76
A-K-3	4.35	-0.48	-2.79	0.55
A-K-4	4.01	-0.36	-2.59	0.26
A-K-5	3.69	-0.24	-2.56	-
L-C-1	49.44	-33.17	-56.59	25.85
L-C-2	38.53	-21.16	-61.00	15.10
L-C-3	32.44	-12.72	-61.05	8.72
L-C-4	27.93	-6.26	-60.54	3.76
L-C-5	24.64	-1.61	-59.63	-
L-M-1	44.87	75.96	4.74	19.62
L-M-2	38.37	73.56	23.21	9.81
L-M-3	35.40	70.76	32.07	4.89
L-M-4	32.52	67.78	36.33	1.47
L-M-5	30.96	65.88	36.91	-
L-Y-1	88.07	-7.55	78.97	9.68
L-Y-2	85.52	-1.98	92.65	5.33
L-Y-3	84.32	2.07	96.44	3.00
L-Y-4	82.65	5.12	97.77	1.05
L-Y-5	81.94	6.87	97.66	-
L-K-1	8.21	3.10	-4.52	5.35
L-K-2	3.97	-0.14	-2.66	0.30
L-K-3	3.80	-0.26	-2.52	0.34
L-K-4	3.72	-0.25	-2.41	0.32
L-K-5	3.60	-0.04	-2.49	-
Note: letters A and L represent materials, C, M, Y and K – colours, 1, 2, 3, 4 and 5 – number of layers				

sample) and the other samples, printed with four, three, two and one ink layer.

Results presented in Table 1 show that increasing number of ink layers during print process leads to decreasing of lightness in all 40 samples. Therefore, the colour difference value will rise with a change of ink layer number. The biggest values of ΔE_{2000} were calculated for samples printed with cyan and magenta. Lower values of ΔE_{2000} were calculated for yellow printed samples, and the lowest values of ΔE_{2000} were calculated for black colour.

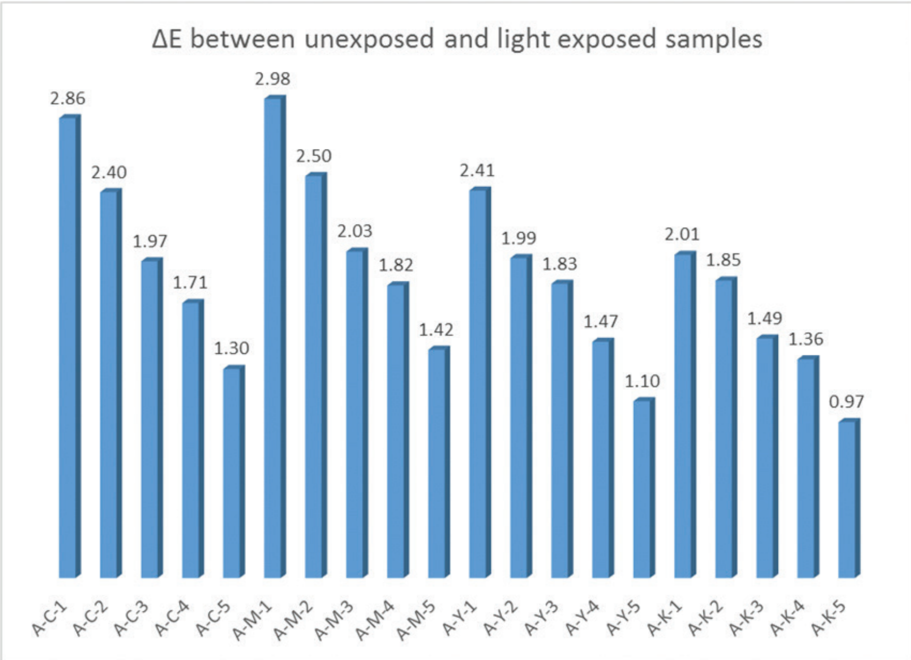

Figure 1. ΔE_{2000} values between unexposed and light exposed samples - Avery

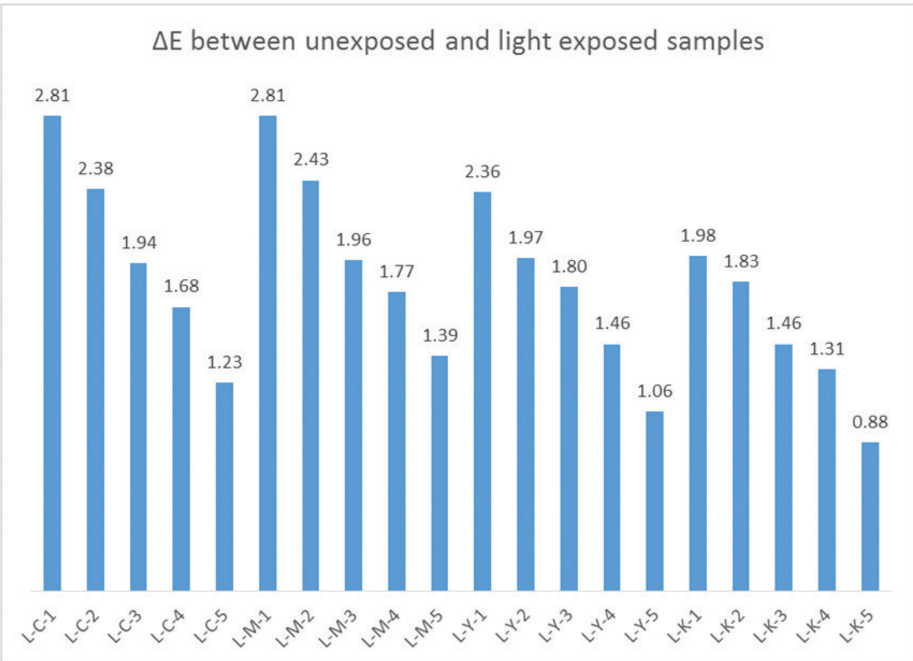

Figure 2. ΔE_{2000} values between unexposed and light exposed samples - LG

Based on the linear tendency of lightness it can be assumed that further increase of an ink layer number will increase value ΔE2000 also.

Those samples had been exposed to light according to ISO105-B02 standard (method 2) (temperature, lightness, moisture). After light exposure, the spectrophotometric measurements were conducted to determine how the exposure to light influenced printed ink colour.

Values of ΔE_{2000} are grouped according to substrates and presented in Figure 1 and 2.

Both figures indicate that increased number of ink layers during printing cause better light fastness compared to samples printed with a lower number of ink layers. This can be concluded since the minimum value of ΔE_{2000} was marked after light exposure of the sample printed with five ink layers, while the highest ΔE_{2000} value was recorded after light exposure of the sample printed using one ink layer (for all samples). Also, colour differences values are slightly lower for samples printed on LG substrates.

4 Conclusion

The influence of light on printed materials has been a research topic for many researchers. The use of digital ink jet printers enables multi-pass printing with a different number of ink layers. This research focused on a spectrophotometric assessment of the influence of multiple printed ink layers and light fastness of samples printed on PVC foils. Exposure to light of PVC printed samples showed that increased number of ink layers increases light fastness. The lowest ΔE_{2000} values were recorded on light exposed samples with five ink layers while the highest ΔE_{2000} values were obtained for samples printed by only one ink layer. This can be explained by a greater number of ink particles on the surface. Moreover, colour differences between samples printed with five ink layers and all other samples were calculated. The greatest colour difference was noted between samples with one and five ink layers, and the smallest one was obtained between samples printed with four and five ink layers, for each process color.

Characteristics of the substrate materials have been proven to have an important role for light fastness as well and, therefore, cannot be ignored. Samples printed on LG substrates showed lower colour differences values which is in relation to material thickness.

According to results of the research, it is recommended to take into consideration substrates as well as a number of ink layers when choosing digital printing techniques in order to achieve high print quality. If extended colourfastness is needed, additional layers of the ink can be applied to the substrate material.

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