Printability of PVC and PP Substrates by Screen Printing

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Abstract: *Since screen printing is a well-established and viable printing technology, it had been developing continuously and dynamically. Considerable development was brought by the appearance of UV inks and UV dryer units. A reasonably thick layer of ink can be deposited by this technology, this property makes it ideal for printing a wide range of substrates (wood, metal, textile, glass, paper, plastic). This unique printing process has the potential to penetrate to market segments other than the ones being traditionally in the scope of graphic industry, such as advertising. Technological development induces the demand for producing a wide range of tonal values. Our research work focuses on the evaluation of the factors influencing print quality of halftones produced using two different screen ruling: 36 l/cm and 60 l/cm. Test charts were printed on PVC and PP substrates using 36 l/cm and 60 l/cm screens ruling. Optical measurements were performed to determine density values, TVI curves, color differences to investigate the factors influencing tone reproduction quality.*

Keywords: *screen printing, PVC and PP substrates, TVI, color differences*

Introduction

Screen printing is one of the oldest printing processes. While its theory and tools did not change significantly, the technology underwent a considerable improvement during its history, and continues to develop in the 21st century as well. Screen printing allows deposition of a thick layer of ink onto the substrate, enabling the use of ideally any kind of substrate. In case of this technology it is increasingly important to choose the right screen ruling according to the estimated viewing distance. Despite the significant technological development halftone screen printing remains a challenge. Factors influencing quality are in close interaction with each other [1]. For the optimal output it is necessary to control these factors more or less independently to produce high density screen prints in high quality. Tone values of the screen print are primarily influenced by the density of the mesh and thread weight. In practice the smallest dot will determine the usable highest screen ruling. However, the ways toward this objective are seldom based on solid findings, but rather on experience and experiments [2] [3].

Experimental

Squeegee

The squeegee blade has outstanding influence on the sharpness of the print, choosing the improper type of blade may become the source of many problems. Rectangular blades are ideal for producing sharp images. Another important feature of the blade is its hardness, for quality test prints minimum 85-90 Shore hardness value is recommended. The hardness of the blade will influence abrasion resistance and chemical durability against solvents, as well as the extent to which the blade bends during printing [4] [5]. The applied blade was very hard (90° Sh) with rectangular profile.

Screen printing mesh

Resolution of the mesh is the capability of reproducing a halftone pattern with a given screen ruling (l/cm). Mesh count and the ratio of the thread diameter to the mesh-opening are primarily responsible for the optimum resolution. Meshes with larger mesh-opening than thread diameter are suitable for producing high resolution images. Thread diameter itself determines smallest printable dot size. This parameter has to be chosen carefully before raster image processing [6] [7]. For our investigations prints were produced using PET 1500 150/380-31Y PW type high modulus, plain weave monofilament polyester mesh manufactured by SEFAR (table 1.).

Table 1: Mesh properties

SEFAR monofilament mesh	
Ruling, l/cm	150
Thread diameter, µm	31
Mesh-opening, µm	29
Fabric thickness, µm	37
Mesh tension, N/cm	12
Dot area, %	15-80
Smallest printable dot, µm	80-100

Rheological properties of the ink also play an important role in producing detailed halftone prints. As a unique feature of the screen printing process, rheological behavior of the paste together with the mesh wettability properties will influence print quality. In case of printing small dots the thread may block the dot opening preventing the paste from being transferred to the substrate. This problem is most likely to occur in highlight areas. Bounding regions of the tonal range are hard to implement with this printing process [8].

Photo emulsion

The stencil form was created using CPS ULTRA COAT diazo-photopolymer emulsion. This type of "dual cure" diazo-sensitized emulsion is highly resistant against water and solvent based inks. The drying process of the stencil form was controlled accurately, the coated screen was kept in a dark place free of dust, with low humidity in horizontal position. Constant temperature (max. 30 °C) and good ventilation also improve the drying process. The thickness of the emulsion layer was measured by Elcometer 345 coating thickness gauge at five different locations; the average value was 43.25 microns.

Screen printing ink

ULTRAFORM UVFM, a UV curable ink for graphical screen printing applications was developed by Marabu corporation for plastic substrates. Generally UV curing screen printing inks are solvent free, have high mechanical and chemical resistance and short curing time [2]. Our test prints were cured with a 100 W UV lamp, travel speed inside the drying unit was approximately 27 m/min; manufacturer specifications allowed for 100-120 W power and 25-30 m/min travel speed. Before printing the next color, test prints were stored properly for drying.

Printing materials

We have chosen two plastic sheet substrates that are frequently used in industry: VIKUNYL PVC (#1) and VIKUPRON polypropylene (#2). Our test chart comprised of a 10 step CMYK wedge, RGB full tone patches, Arial and Times New Roman text 24-6 pt size. Test prints were produced with 36 l/cm and 60 l/cm screen ruling on a SVECIA PC semi-automatic flat-bed press; 10 copies were printed with both resolutions. To improve the appearance of the printed image special screen angle values were applied: C (97.5°), M (157.5°), Y (82.5°), K (127.5°).

Methodology

Tone value increase (TVI) and color differences were measured on the test prints. We used X-RITE SPECTROEYE spectrophotometer (380-780 nm spectral range, 0°:45°a measurement geometry, 4.5 mm aperture diameter, D65 filter).

Results and Discussion

Properties of the plastic substrates

The physical properties of the plastic substrates were investigated first. Surface smoothness was measured using Beck instrument. Surface tension values were determined with a set of test pens (32-40 mN/m), both substrates passed the test at 36 mN/m. Substrate properties are listed in table 2. The PVC substrate (#1) is the heavier, it has very smooth surface and optimum printability properties. PVC substrates are strong, rigid, and resistant to many organic and inorganic chemicals. The lighter PP substrate (#2) has surface pattern.

Table 2: Substrate properties

Property	Foil #1	Foil #2
caliper, mm	0.3	0.3
weight, kg/m^2	0.44	0.39
smoothness, s	85.0	11.8

Tone value increase of CMYK prints

Table 3: Measured optical density values of CMYK process colors on substrates printed with 36 l/cm and 60 l/cm resolution

Prints	**Optical density**			
	C	M	Y	K
Proof	1.20	1.59	1.15	1.61
#1 (36 l/cm)	1.14	1.62	1.16	1.47
#1 (60 l/cm)	1.14	1.62	1.09	1.52
#2 (36 l/cm)	1.17	1.61	1.30	1.47

Density values measured on different substrates vary to a larger extent than the values on the same substrate with different screen ruling. The best match with the digital proof was achieved in the case of the PP substrate with 60 l/cm ruling. Density values of the magenta ink show the smallest variation and differ the least from the values of the proof.

Curves of tone value increase (TVI) were measured on the 10-100% process color tone patches of the test chart (figures 1 and 2). Tone value increase was higher in the case of the PP substrate and with 60 l/cm ruling.

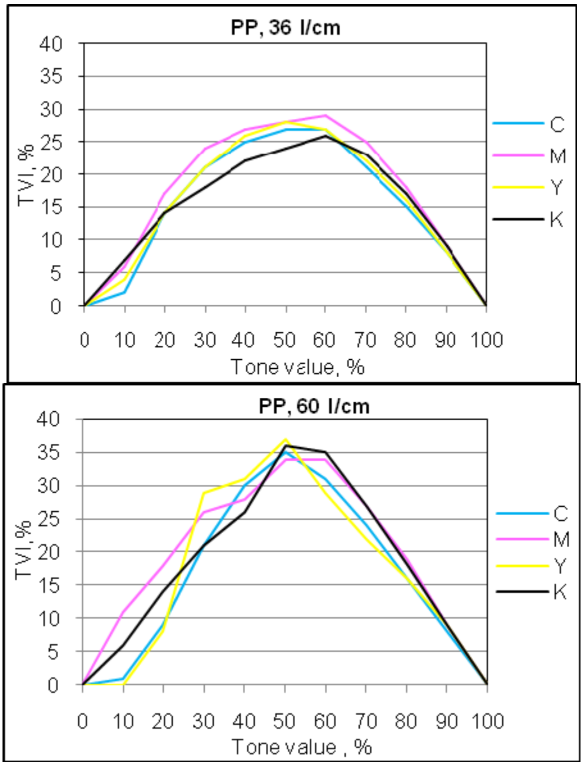

Figure 1: TVI curves of process colors on PP substrate printed with 36 l/cm (left) and 60 l/cm (right) screen ruling

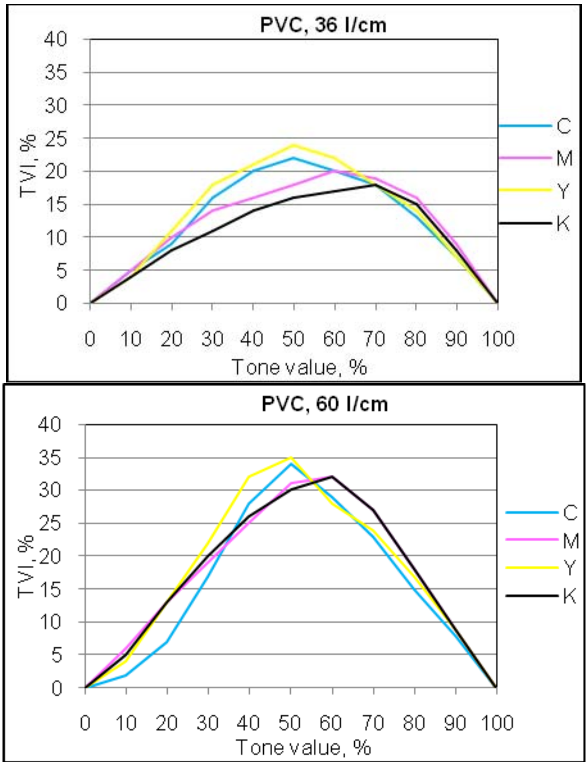

Figure 2: TVI curves of process colors on PVC substrate printed with 36 l/cm (left) and 60 l/cm (right) screen ruling

Colorimetric Properties

We used the measured CIELAB values of the full tones of process colors (CMYK) to investigate colorimetric differences between our test prints. The print run comprised of 10 individual prints produced by the same printing form. Average color differences (ΔE^*_{ab}) between the test print process color patches are shown in table 3, the largest values are near the just noticeable threshold level. In the comparison of the average CIELAB values of the test prints (table 4) substrate #1 with 60 l/cm resolution was chosen as a reference, because it produced the highest chroma (C^*) with both magenta and yellow colors. Differences are near threshold level, except for the case of yellow process color where large differences occur, in agreement with the variations in density values. Table 5 shows the differences between substrates printed with the same resolution and between prints on different substrates printed using the same resolution. Changing the substrate or the screen ruling induces the largest shifts in yellow color.

Table 3: Average color differences of process color full tones between the mean and the 10 test samples

Prints	Color difference (ΔE^*_{ab})			
	C	M	Y	K
#1 (36 l/cm)	1.03	0.77	0.82	0.26
#1 (60 l/cm)	0.80	0.29	0.44	0.33
#2 (36 l/cm)	0.47	0.50	0.53	0.32
#2 (60 l/cm)	0.25	0.34	0.49	0.20

Table 4: Color difference values of average test prints, substrate #1 with 60 l/cm resolution was chosen as a reference

Prints	Color difference (ΔE^*_{ab})			
	C	M	Y	K
#1 (36 l/cm)	1.15	1.64	4.61	0.93
#1 (60 l/cm)	-	-	-	-
#2 (36 l/cm)	1.09	1.69	6.77	1.81
#2 (60 l/cm)	1.89	0.60	1.23	2.63

Table 5: Color differences between prints on different substrates with the same resolution (upper rows) and between prints with different resolutions on the same substrate (lower rows)

Prints	Color difference (ΔE^*_{ab})			
	C	M	Y	K
#1-#2 (36 l/cm)	0.97	3.02	2.59	1.36
#1-#2 (60 l/cm)	1.89	0.60	1.23	2.63
#1 (36 l/cm- 60 l/cm)	1.15	1.64	4.61	0.93
#2 (36 l/cm - 60 l/cm)	1.58	1.10	5.70	0.96

Conclusion

In our study we investigated screen prints on two types of plastic substrates, printed on the same press with two different screen rulings. We found that with higher screen ruling higher TVI values were produced, as well as in the case of the less smooth polypropylene substrate with surface pattern. Density values of the yellow color varied considerably relative to the other process colors, this behavior reappeared in the colorimetric data. Switching between substrates and screen ruling caused only threshold level color differences.

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