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Analysis of UV varnish for textured effect

Shrikant Tora[1], *Sanjay Sharma*[2] *and Pratik Borude*[3]

[1] 14/110, Gandhi Nagar, Akkalkoat Road, Solapur, Maharashtra, India-413006 shrikant.tora@yahoo.com
[2] Jabalpur, MP, India-482001 sanjay_shm@yahoo.com
[3] Pune, Maharashtra, India-411009 pratik.borude.1994@gmail.com

Abstract

Packaging and especially printing industry is experiencing an exponential growth in terms of customer demands. Owing to these demands, UV varnish is playing a major role, which is preferred over lamination due to environmental issues and cost. The UV varnish can give gloss or matte finish. Textured effect on the surface can be achieved by blending gloss finish over matte. Various textures can be achieved by varying the blend of solutions, ratio, viscosity, surface tension, etc. Among varnishing parameters that affect the results are UV-lamp intensity, speed of varnishing and screen ruling of anilox cylinder. The texture created in such a manner, needs to be evaluated with respect to the topographic index to find an optimum combination of the parameters to achieve a particular textured pattern.

Keywords: surface finish, topographic index, offset printing, coating process parameter, image analysis

1. Introduction and background

The UV varnishing is a technique, widely used in packaging and label printing finishing for protection and enhancement of the printed surface and also for achievement of textured effect. Sanyal (2015) states that flexographic UV printing is proved to give the consistent result as the ink has the right viscosity and amount of the pigment, in comparison to solvent-based and water-based inks. The UV inks cure quickly, meaning that products can be finished more rapidly, enabling higher throughput and fast turnaround, even on two-sided jobs. In-line UV printing is notable for the superior results it can achieve on difficult substrates, from uncoated paper and board to foil and especially plastic, including synthetic papers, static cling vinyl and lenticular. The ability to “lay down” layers of opaque white or metallic ink, and then print over it in a single pass, merely hints at the versatility of the UV process. The UV inks are 100 % solid inks while the solvent-based are 20–30 % solid (Kipphan, 2001) and water-based inks have over 40 % solid content (Verspoor, 2005). So, to achieve the same effect, UV technology uses fewer and less waste of UV inks and consumables. With the help of UV inks, one can reach to higher printing speed and improved production efficiency. In UV printing, specially formulated inks are exposed to ultra-violet radiation, which causes them to harden instantly on top of the substrate. The result produces high levels of gloss or dull coating, vivid color and vibrant detail with superior rub resistance and no post-cure dry back – even on soft, uncoated sheets – making UV the technique of choice for applications like luxury cosmetics and chic wine labels. The UV curing technology is showing an upward trend in printing industry. It is not used only in traditional processes; this technology has also been applied in new techniques such as UV inkjet and hybrid printing.

Modern offset lithographic presses built for packaging and label printing are often equipped with one or two coating units with drying and/or curing systems. Machines with two coating units after the printing units can be used for applying two different varnishes, i.e. glossy and matte; when applying one on the other, it may be coating of waterborne primer and UV varnish over conventional oxidatively drying inks, or coating special types of varnishes to achieve texture effect on the varnished print surface (Kipphan, 2001; Heidelberg, 2008). Coating unit on offset lithographic press is technically based on printing unit in flexography.

Creating a texture effect became market trend and a customer need as packaging had grown up vastly and different printing technology advancements boosted up the growth and implementation of new concepts. Texture effect is best achieved by UV curable inks and coatings. Texture or drip off is the effect obtained by combination of two different types of varnishes, i.e. duct or release varnish and flexo coater gluable varnish. This newly introduced finishing effect is widely appreciated and used as a brand protection feature in the print-packaging houses.

Investigations of texture effect and methods of its characterization are known for decades. Duong (1983) patented surface texture effect obtained by using different UV light sources under different atmosphere conditions, particularly suitable as floor and wall coverings. Texture effect on the surface of paintings was studied and characterized by Cai and Siegel (2002). The texture effect, created on offset press equipped with coater in three different ways is described in KBA publication by Kleeberg (2006), while properties of coatings and substrates are explained by the same author in 2007 KBA publication (Kleeberg, 2007). Surface topography of coated papers was studied by Velho and Santos (2010), using different methods including laser profilometry and scanning electron microscopy with image analysis. Karlović et al. (2012) studied distribution of different particle sizes and their correlation with surface gloss of aqueous coatings in printing. The main goal of our research was aimed to optimize the printing and coating process used to obtain texture effect on offset press with coater and UV curing system and method for characterization of print samples with texture.

2. Materials and methods

Trails were carried out on an offset machine on metallized polyethylene terephtalate film (MET-PET) substrate, coated by UV varnish. The matte varnish was applied on the area where texture is required. Gloss varnish was applied over matte varnish by varying matte to gloss ratio. The effect of anilox screen ruling on texture has been tested by two different screen rulings. The UV-lamp intensity has been varied and the effect was measured and analyzed.

Texture effect on the substrate was achieved by the combinational application of lithographic offset print unit and coating unit with anilox roller responsible for metering of UV-varnish. Printing plate used in print unit consists of solid patch on it, by which the matte varnish was applied firstly on the substrate. Gloss varnish was then applied in coating unit metered by the anilox roller to create texture effect on the substrate surface after curing through UV curing system. Anilox roller plays significant role in texture finish and anilox screen ruling expressed in lines per inch (lpi) is one of the important factors to alter the finishing of textured surface.

A design of experiment (DOE) was conducted with four factors (Table 1) – anilox screen ruling, UV-lamp intensity, press speed expressed as impressions per hour (iph) and dot area. Two levels shall be considered for each factor. Thus, a general full factorial with four factors and two levels each was generated. Thus, 16 runs with two replicates were carried out.

Table 1: Process variables

Factors	**Value**	
	Low	**High**
Anilox screen ruling (lpi)	60	80
UV-lamp intensity (W/cm)	80	100
Press speed (iph)	7 000	12 000
Dot area (%)	50	100

Throughout the run, following press parameters have been kept constant:

- Ink and water balance
- Print density
- Color balance
- Printing pressure
- Registration

The evaluation of final results is based on topographic index. The higher is a value of this index, the more textured the finish is.

The overall methodology is as follows:

- Trials were carried out on 6 color KBA Rapida-105 offset printing press with coater, format: 28″ × 40″.
- The initial production runs with predetermined press settings were conducted for a few days to define the reference for the project.
- Printing parameters were set to 10 000 iph speed, 80 lpi anilox screen ruling, and 85 W/cm UV-lamp intensity.
- On the Gray back MET-PET 330 g/m^2 substrate, size: 936 mm × 606 mm, first matte and over it glossy UV varnish Toyo Ink Arets was applied.
- A full factorial DOE was conducted for 4 factors with 2 levels of each: anilox screen ruling, UV-lamp intensity, machine speed, dot area.
- The topographic index was evaluated by using EPSON V700 flatbed scanner and Verity IA Print Target image analysis software.
- The DOE was analyzed based on main effect plot, interaction plot, and analysis of variance (ANOVA) in order to identify the best combination of variables for texture effect, i.e. to draw the actual effect of all varying parameters on the response.

The identified best combination of variables were re-run to verify the analyzed results from the DOE and further checked for its consistency.

2.1 Measurements and testing

Figure 1: Reference image for texture effect on substrate surface

Figure 1 illustrates the textured finish of the trials being conducted. Tiny dots over the surface are of gloss varnish which is being transferred from anilox roller by coating plate over the matte varnish surface. This combination gives rise to the texture. The topography of the surface understood as the local deviations of the surface from the flat plane. The topography is also known as surface texture. The overall variations in topography are expressed as a topographic index. The printed-substrate topography was measured using the Verity IA Image Analysis software, which uses modified flatbed scanner to acquire an image of the substrate surface. EPSON V700 flatbed scanner was used for this purpose. Verity IA (2017) developed the proprietary Stochastic Frequency Distribution Analysis (SFDA) to describe visible surface features over relatively large surface areas. These variables yield undesirable qualities in paper, board, coating and other surfaces, particularly when additional operations, such as printing, coating or painting, were performed on these surfaces. The human eye can not detect small variations and large blotchy variations at the same time. The SFDA algorithm replicates the analysis and expresses the overall variations as an index number.

The analysis provided detailed information on the roughness of the samples. The roughness of the tested sheets was studied by taking microscopic images of samples at approximately 60× magnification. The data to be gathered was both variables and attributes. The samples were unwound and cut with caution; finger marks were avoided by use of gloves. The cut sheets were placed on scanner bed for scanning through Verity IA Print Target v3 software. The sheets were scanned at 1200 pixels per inch (ppi) and analyzed through the topographic index measurement routine. An Area of Interest (AOI) of size 70 mm × 55 mm was selected from the scanned images and then analyzed through the SFDA algorithm employing suitable settings and profile. The results from software applications were compared and correlations between the results were found.

3. Results and discussion

The data collected from the initial production runs on MET-PET (Table 2) showed mean topographic index of 570 for 100 % dot area, hence it was considered as reference. The target was set to maximize texture effect and verify its consistency.

Table 2: Baseline data for topographic index

Sample no.	Topographic index
1	495
2	590
3	560
4	520
5	715
6	679
7	553
8	552
9	505
10	533
11	576
12	498
13	576
14	590
15	610
Average	570

3.1 Topographic index analysis

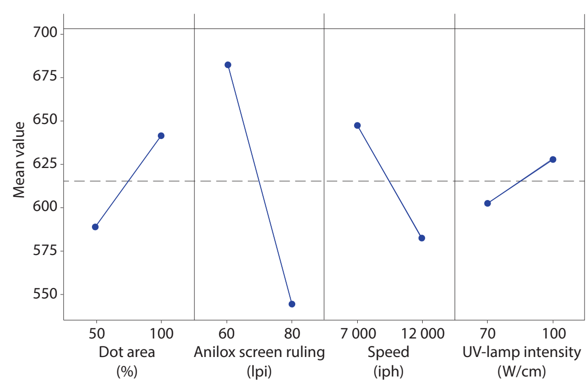

Figure 2: Effects of process variables on topographic index

Figure 2 indicates that topographic index was maximized at higher levels of dot area and UV-lamp intensity, and at lower levels of anilox screen ruling and press speed.The plot also indicates that all the factors are significant as represented by their slope. Lower printing speed corresponds to higher dwell time in nip where the spreading of varnish is high due to prolonged contact period which results in higher topographic index. The higher speed develops more shear rate and concurrently high shear stress induced in the varnish making it resistant to spreading after transfer onto the substrate.

Thus, increase in speed shows lower topographic index. The higher the dot area, the higher amount of matte varnish is released. Therefore, higher dot area results in higher topographic index. Similarly, lower anilox ruling releases more gloss varnish as the cell opening and cell volume is higher on anilox. Therefore, the lower the anilox screen ruling, the higher the topographic index.

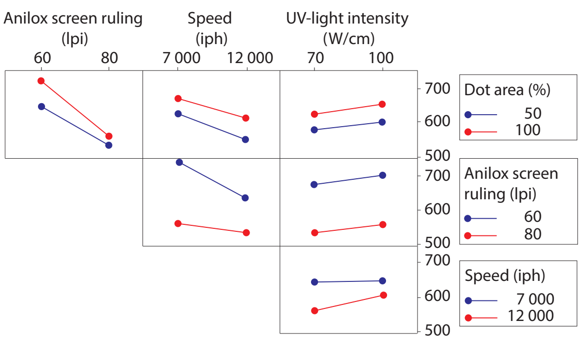

Figure 3: Interaction plot of process parameters for topographic index

Figure 3 indicates that the highest topographic index is obtained at 7 000 iph speed, 60 lpi anilox screen ruling, 100 W/cm lamp intensity and 100 % dot area. The interaction of dot area and speed showed almost parallel, only slightly diverging lines, which indicates the slight degree of interaction. Also, the interaction of dot area with UV-lamp intensity and anilox screen ruling with UV-lamp intensity showed only a bit diverging lines. The interaction of dot area with anilox screen ruling, anilox screen ruling with speed, and speed with UV-lamp intensity shows non parallel state which indicates the significant interaction between them.

3.2 Statistical analysis for topographic index

Table 3 for the topographic index on MET-PET substrate indicates that all the main factors are significant as the *P*-values are below *α* value of 0.05. The *F*-statistic provides an indication of the calculated values by dividing the factor mean square (MS) by the error MS. The larger *F*-statistics with $P < 0.05$ from the ANOVA table confirms the significance of all the main values and interaction between the anilox screen ruling, press speed, UV-lamp intensity and dot area at 95 % confidence interval. The coefficient of determination (*R-Sq*) indicates how well the model fits the data and is calculated by dividing regression sum of squares by total sum of squares. The higher percentage of *R-Sq* indicates 99.55 % of the variability being explained by the model. The *R-Sq*(adj) is a useful tool for comparing the explanatory power of models with different numbers of predictors. The value increases only if the adding of existing factors improves the model to expected change. The *R-Sq*(adj) of 99.20 % indicates the significant improvement of the model by using four factors. It is evident that slight difference between *R-Sq* and *R-Sq*(adj) indicates significant regression of the model by using four factors. The *R-Sq*(pred) indicates how well the model predicts responses for new observations and is calculated from predicted error for sum of squares (PRESS) statistics. The highest *R-Sq*(pred) of 99.42 % indicates that the model predicts new observations nearly as well as it fits the existing data. The lack-of-fit with $\alpha > 0.05$ indicates that the data fits well in the model. The lack-of-fit value of 0.066 represents the accuracy of the model and indicates good predictive ability of regression model. Anilox screen ruling and speed are highly significant while dot area and UV-lamp intensity are important factors in increasing the topographic index.

Table 3: ANOVA table for topographic index (DF – degrees of freedom, SS – sum of squares within groups, MS – mean square witin groups, F-value – ratio of two sample variations, P-value – criterion for level of significance)

Source	*DF*	Adj *SS*	Adj *MS*	*F*-Value	*P*-Value
Model	7	259 238	37 034	759.47	0
Linear	4	251 890	62 972	1 291.39	0
Dot area (%)	1	27 848	27 848	571.09	0
Anilox screen ruling (lpi)	1	160 140	160 140	3 284.04	0
Speed (iph)	1	58 084	58 084	1 191.14	0
UV-lamp intensity (W/cm)	1	5 818	5 818	119.30	0
2-Way interactions	3	7 348	2 449	50.23	0
Dot area (%) × Anilox screen ruling (lpi)	1	4 848	4 848	99.42	0
Dot area (%) × Speed (iph)	1	820	820	16.82	0
Anilox screen ruling (lpi) × Speed (iph)	1	1 680	1 680	34.45	0
Error	24	1 170	49		
Lack-of-fit	8	636	80	2.38	0.066
Pure error	16	534	33		
Total	31	260 408			

Summary of model: *S* = 6.98306 *R-Sq* = 99.55 % *R-Sq*(pred) = 99.42 % *R-Sq*(adj) = 99.20 %

The interactions of anilox screen ruling and speed play a significant role in enhancing topographic index.

3.3 Confirmation and consistency for topographic index

The best settings 7 000 iph press speed, 60 lpi anilox screen ruling, 100 W/cm UV-lamp intensity and 100 % dot area as obtained from the interaction plot were confirmed by conducting a press run and then checked for its consistency by re-running for a few days.

Table 4: Production, verification and consistency run for topographic index

Trial	Topographic index	Std. dev.
Production run	570	62.67
Confirmation run	802	17.38
Consistency run	799	21.34

From Table 4, a significant improvement is evident from production run to consistency run in topographic index for MET-PET substrate. The comparison between production run and consistency run shows that topographic index is maximized by 40 %.

4. Conclusion

The research work was focused on investigation of offset process parameters, namely the anilox screen ruling, press speed, UV-lamp intensity and dot area, on texture effect. The texture effect was analyzed by the measurement of topographic index. The higher the topographic index, the higher is the textured finish. The production runs were conducted at 80 lpi anilox screen ruling, 10 000 iph press speed, 85 W/cm UV-lamp intensity and 100 % dot area to identify the reference for texture. The target was set to maximize the topographic index from the reference. The data was analyzed by main effect plot, interaction plot and ANOVA to identify the best set of process parameters maximizing the topographic index. The highest topographic index was identified at lower anilox screen ruling and press speed (60 lpi and 7 000 iph) and higher UV-lamp intensity of 100 W/cm and dot area of 100 %.

The results revealed an improvement of 40 % at the identified settings from the reference. The findings of this study shall reduce the complexities of defect occurrence by implementing the optimized press settings. It shall also help the printers to maintain consistency in reproduction; thereby increasing the productivity and profitability.

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