ORIGINAL SCIENTIFIC PAPER
RECEIVED: 23-07-2012
ACCEPTED: 29-09-2012

ACTA GRAPHICA 207

Evaluation of Voids on Shrink PVC Film

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Abstract:

Gravure is one of the most widely used processes for printing on shrink films, the reason being its consistency for longer runs. However, such printing is accompanied by new challenges. The presence of gels, black specks and other contaminations in these films does not allow the surrounding area to print, thus resulting in print void. The occurrence of this defect in a considerable amount or size on the area of interest leads to the rejection of printed stock that involves wastage of inks, solvents and time. The research involves the investigation of the effect of gravure process variables on the minimization of print voids in Shrink PVC film. The gravure process variables viz. viscosity, pressure, speed and hardness were identified for the indirect laser cylinder. It was established that hardness had a significant impact on minimizing the voids, while viscosity-hardness interaction played another important role. The results showed the reduction in void area with lower viscosity, higher pressure, lower speed and higher hardness.

Keywords:

Shrink PVC, Voids, Gravure, Process variables,Roughness.

1. Introduction

The quality of a printed product is perceived by a customer whose judgment involves various aesthetics aspects and other visual preferences. It is therefore important to be aware of how a customer perceives a particular image. The presence of void in the solid areas of an image may not be perceived by the customer, while a small void present on the face of a lady may directly influence the perception of the customer and lead to the rejection of the label. The severity of the defect depends upon the perception of the customer and defect orientation *(Kaukonen, M., 2006)*. A key issue that needs to be addressed while printing on shrink films is the printability. The printability is determined by an optimal ink transfer from the gravure cell to the substrate that depends on several gravure process variables. The roller pressure has a significant effect in minimizing the void area while the tone, stylus, speed and solvent appeared to be important *(Neff, J. E., 2009)*. The voids referred to in this study were the blank spots on the printed film. The uncovered areas in the print are the result of imperfection in the PE surface, poor wetting and elevations. The uncovered areas related to elevations are due to non-uniform corona treatment *(Mesic, B., Lestelius, M., Engstrom, G., 2008)*. Plasma treatment increases the surface area of the substrate which reduces the contact angle, thus improving wettability. The surface roughness and surface energy are responsible for improvements in adhesion and printability *(Rajendra R. Deshmukh and Narendra V. Bhat, 2003)*. Print quality depends on the interaction between minor defects in ink coverage and the topographic characteristics of the substrate *(Mettanen, M., 2010)*. The elements of print quality, such as density, dot deformation, dot gain, edge sharpness and mottling were predicted by determining the "printability coefficient" *(Laurent, Girard Leloup, 2002)*. Bohan, Claypole and Gethin studied the effects of process parameters on product quality. Ink viscosity was found to be the most significant factor affecting print quality. The doctor blade angle was influential while the doctor blade load and impression pressure had little impact on print quality (*Bohan, Claypole, and Gethin, 2000*). The amount of ink transferred increases with the increase in viscosity and decreases with the increase in speed and pressure on the porous substrate *(Elsayad, S. et al, 2002)*. Jimmy Vainstein carried out an experimental research to determine the optimal press speed on flexo process for shrink labels. The decrease in press speed improves the adhesion of ink onto the substrate *(Vainstein, J., 2005)*. Eduard Kuesters explained the significance of hardness of impression cylinder on print quality for porous substrate. The hard roller does not affect the nip width irrespective of the pressure applied; it thus minimizes the web speed variation and compensates for the irregularities in rough paper *(Kuesters, E., 1972)*.

The aim of this project is to minimize the void area up to 50% from the baseline by varying gravure process variables and generate a solution by process enhancement.

2. Methodology

A monotone layout was designed for gravure process that consisted of solid patches, step wedge and a wood grain pattern to evaluate the voids. The cylinder was prepared by indirect laser process that included 150 and 175 LPI, 18 and 22μ depth with 45° cell angle. The trials were run on a gravure machine with solvent based acrylic black ink for 50 microns shrink PVC cast film. The trials were initially conducted for 5 days at set press parameters and 50 printed samples per day were collected. The cell geometry with 175 LPI and 22μ depth was fixed based on density, dot gain, contrast and tone curve evaluation. The voids for the defined cell geometry in these samples were marked and captured using DIGITUS microscopic camera at 200x zoom and at 1280x1028 pixel resolutions. The captured void images were converted into binary in MATLAB and the total unprinted area was then calculated. The overall mean void area for all the days was calculated and thus considered as a baseline. The target was set to minimize the void area by 50% of the baseline. A full factorial

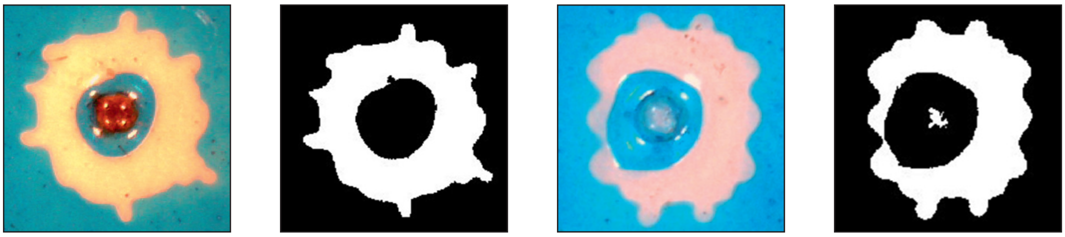

Figure 1. Conversion of Print Void into Binary

Experimental Design for the above-mentioned four parameters with high and low levels was performed. The significant factors and the best combination minimizing the void area were identified from coefficients, ANOVA, Main and Interaction plot. The results were validated by conducting the trials with identified settings for 5 days.

3. Data Analysis

The first step involved identifying the cell geometry. Based on the evaluation of density, dot gain, contrast, tone curve and visual assessment 175 LPI/ 22μ depth was finalized for further evaluation. The initial production runs was conducted for 5 days with 19sec. viscosity, 3 kg/cm^2 impression pressure, 100 m/sec speed, 70 Shore A impression roller hardness to determine the baseline for the Void area.

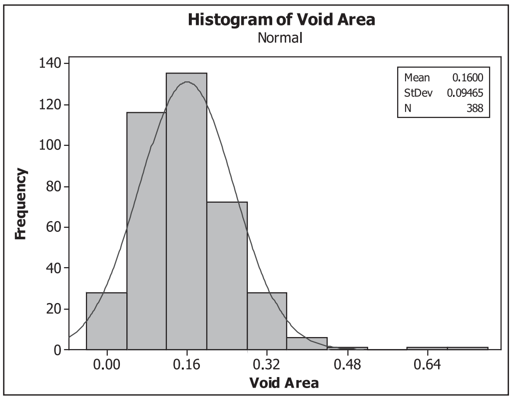

Figure 2. Void area concentration for Production Run

Fig 3: Elements in the sleeve for assessment of Defects

The void area was spread in the range of 0.04-0.7mm^2 with a major concentration between 0.1-0.25 mm^2 (Fig. 1) and considered an area of severity. However, voids with area above 0.4mm^2 were negligible. As the mean void area of the current state of the process was 0.1641 mm^2, it was considered the baseline and a goal was set to minimize this void area by 50%. The data was further split into 3 categories viz. 0.04-0.1mm^2 with 3 allowable defects, 0.1-0.25 mm^2 with 2 permissible defects and 0.25 plus mm^2 with no defects. Moreover, no defects were allowed on the text, logo, face, nose and the lips of the lady.

The 16 experimental runs per the design were then conducted on the gravure machine and 50 samples per run were evaluated for Cast PVC film. The statistics for the samples pulled out represented a variation in the void area calculated; hence the average of the void area was considered a response for evaluation.

From the table 4, hardness was found to be the statistically significant factor at 90% confidence level.

Table 1: Baseline data for Void Area

	Day1	Day2	Day3	Day4	Day5
Average Void Area (mm2)	0.1285	0.1737	0.1856	0.1553	0.1776
Std. Dev.	0.0968	0.0961	0.0976	0.0850	0.098
Baseline Void Area (mm2)			**0.1641**		
Average Std. Dev.			**0.0947**		

Table 2: Main Experiment for Cast PVC film

Run Order	Viscosity	Pressure	Speed	Hardness	Void Area (mm^2)
1	1	1	-1	-1	0.200501
2	1	1	1	1	0.204163
3	1	-1	-1	1	0.226390
4	-1	1	-1	-1	0.162236
5	1	-1	1	1	0.117953
6	1	1	-1	1	0.111582
7	1	-1	1	-1	0.199854
8	-1	1	1	1	0.127168
9	-1	-1	-1	-1	0.169184
10	1	-1	-1	-1	0.226390
11	-1	-1	1	-1	0.171614
12	-1	1	1	-1	0.204702
13	-1	-1	1	1	0.149979
14	-1	1	-1	1	0.143415
15	-1	-1	-1	1	0.139455
16	1	1	1	-1	0.204163

Table 3: High and Low-levels of Factors for Experimental Run

Factors	High-level (+1)	Low-Level (-1)
Viscosity (sec)	21	17
Pressure (kg/cm2)	3.5	2.5
Speed (m/min)	120	80
Hardness (Shore A)	80	60

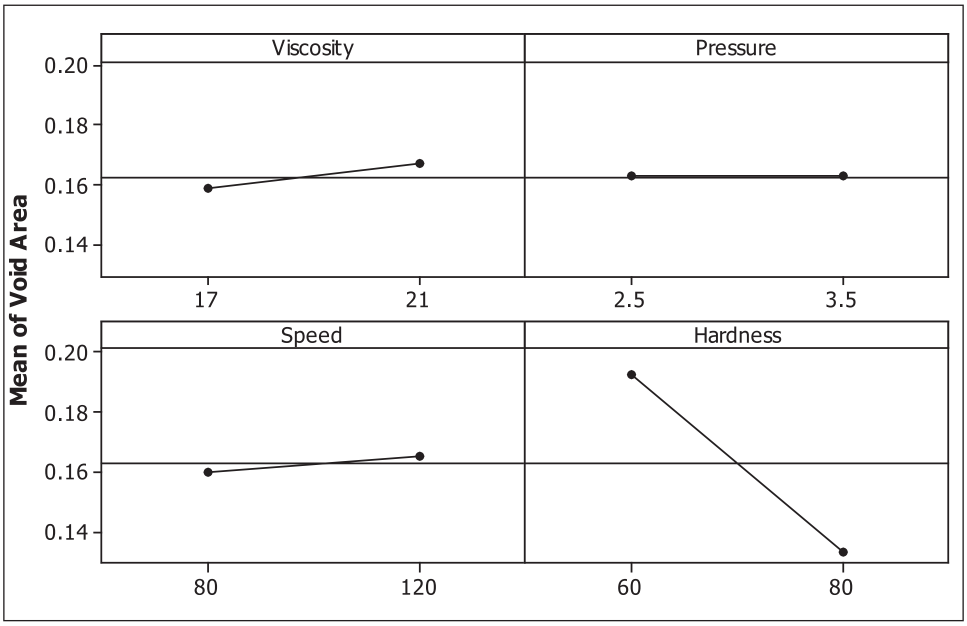

Figure 4. Main Effects Plot for Void Area

Table 4: ANOVA Table for Void Area

Estimated Effects and Coefficients for Void Area (coded units)					
Term	Effect	Coef	SE Coef	T	P
Constant		0.16270	0.004862	33.47	0.000
Viscosity	0.00846	0.00423	0.004862	0.87	0.424
Pressure	0.00011	0.00006	0.004862	0.01	0.991
Speed	0.00553	0.00276	0.004862	0.57	0.594
Hardness	**-0.05926**	**-0.02963**	**0.004862**	**-6.09**	**0.002**
Viscosity*Pressure	-0.00171	-0.00086	0.004862	-0.18	0.867
Viscosity*Speed	-0.00427	-0.00213	0.004862	-0.44	0.679
Viscosity*Hardness	-0.02233	-0.01117	0.004862	-2.30	0.070
Pressure* Speed	0.01112	0.00556	0.004862	1.14	0.305
Pressure*Hardness	-0.00103	-0.00052	0.004862	-0.11	0.920
Speed*Hardness	0.00002	0.00001	0.004862	0.00	0.998

S = 0.0194465 R-Sq = 90.01% R-Sq(adj) = 70.03%

Analysis of Variance for Void Area (coded units)						
Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effects	4	0.014456	0.014456	0.0036139	9.56	0.015
2-Way Interactions	6	0.002578	0.002578	0.0004296	1.14	0.454
Residual Error	5	0.001891	0.001891	0.0003782		
Total	15	0.018924				

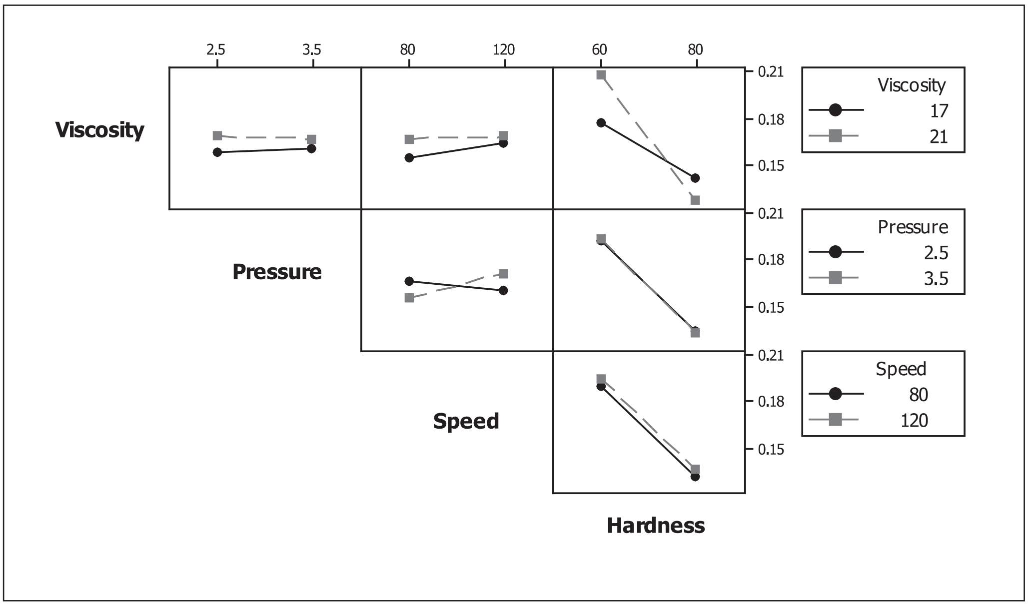

Figure 5. Interaction plot for Void Area of Cast PVC film

The main effect plot (fig. 4) shows that hardness has a major impact in minimizing the void area. The hard impression roller will generate higher net force at the nip and may try to squeeze the gel present in the film, thus leading to the reduction in void area. Lower viscosity also had a bigger effect on reducing the void area. At higher viscosity, drying is probably too fast, hindering the ink in transferring completely out of the cell. The pressure and the speed were found to be insignificant as individual effects on the response.

It is observed from the interaction plot (fig. 5) that though Viscosity, Pressure and Speed were not significant as a main effect at the 90% confidence level, but their interactions still played an important role in the reduction of Void area. At lower speed, the dwell time in the nip is longer and with higher pressure it will allow easy flow of ink from the cells. The decrease in viscosity along with increased hardness will spread the ink and help to cover the surrounding areas of the elevated portion in the substrate.

4. Results and Discussions

The ANOVA, Main-Effects and Interactions revealed the optimized factors as 17 seconds viscosity, 3.5kg/cm^2 pressure, 80 m/min speed and 80 Shore A hardness for 175 lpi and 22 µ cell depth minimizing the void area. Optimized factors were then re-run on the Gravure machine 5 days for verification.

From the table 6 and 2-sample T-test (Tab. 7), a significant improvement is evident from the production run to the verification run, both in terms of mean void area and standard deviation. The void area has reduced from 0.164 mm^2 to 0.0638 mm^2 which is well above the set target.

The mean void area achieved was well below the set target of 0.08 mm^2

5. Conclusion

The study focuses on identifying the vital process factors which play an influential role in minimizing the print void area on Cast PVC film. These findings contributed to optimize the process and to spot the best possible combination of process parameters. The hardness of the impression roller was found to be the most significant factor while the interaction of viscosity and hardness had an impact on reducing the void area. The target was set to reduce the void area by 50% from the baseline of 0.164 mm^2 i.e. 0.08 mm^2. However, after the process parameters were optimized at lower viscosity and speed with higher pressure and hardness, the void area was reduced by 61%, hence (0.16-0.0638)/0.16 = 0.61, thus improving upon the set target.

Table 5. Verification data for Mean Void Area

	Day1	Day2	Day3	Day4	Day5
Average Void Area (mm^2)	0.0599	0.0588	0.0700	0.0686	0.0615
Std. Dev.	0.0422	0.0457	0.0509	0.0745	0.0426
Achieved Void Area (mm^2)			0.0638		
Average Std. Dev.			0.0512		

Table 6. Comparison between Production and Verification Run

Trial	Viscosity (sec.)	Pressure (kg/cm^2)	Speed (m/min)	Hardness (Shore A)	Void Area (mm^2)	Std. Dev.
Production Run	19	3	100	70	0.164	0.0947
Verification Run	17	3.5	80	80	0.0638	0.0512

Table 7. Two-Sample T-Test amd CI

Two-Sample T-Test and CI				
Sample	N	Mean	StDev	SE Mean
1	50	0.1640	0.0947	0.013
2	50	0.0638	0.0512	0.0072
Difference = μ(1) - μ(2)				
Estimate for difference: 0.1002				
95% lower bound for difference: 0.0748				
T-Test of difference = 0 (vs >): T-Value = 6.58 P-Value = 0.000 DF = 75				

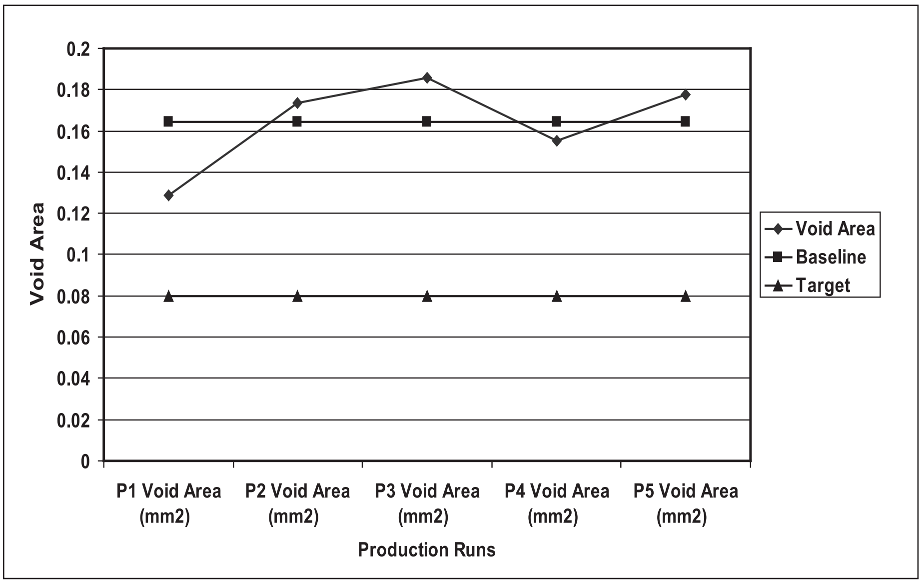

Figure 6. Mean Void Area Before Implementation of the Project

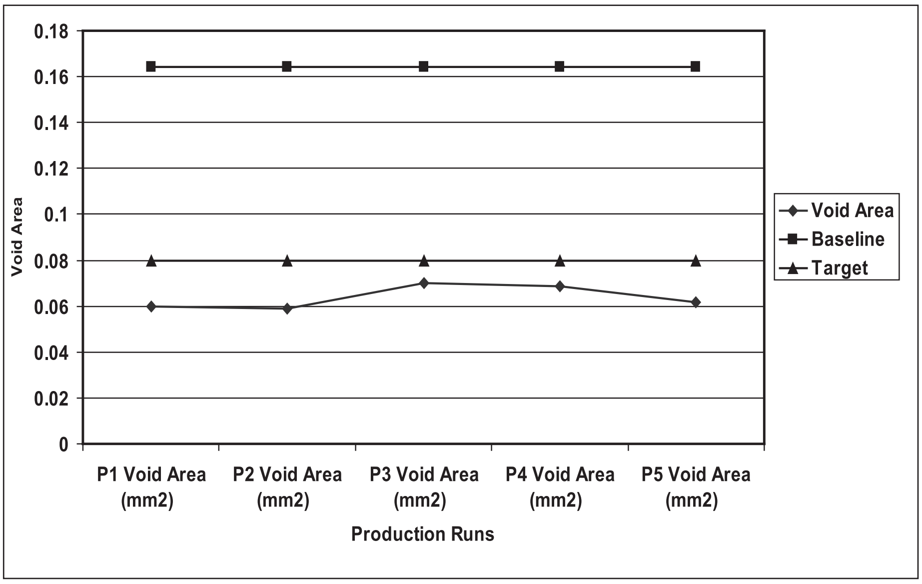

Figure 7. Mean Void Area After Implementation of the Project

Acknowledgements

The authors are grateful to OMNOVA SOLUTIONS INC., U.S.A for sponsoring the project.

The authors would also like to thank Mr. Bhaskaran, Shilp Gravures Ltd. Ahmedabad, for donating gravure cylinders, Mr. P. K. Gangiyan, Nano Inks & Coatings, Vapi, for donating inks, Mr. Makarand Joshi, K. D. Joshi, Pune, for donating impression rollers and Mr. Anirudha Khadakkar, Q.C Services for his timely support.

References

BOHAN, M.F.J., CLAYPOLE, T.C. AND GETHIN, D.T., 2000. The Effect of Process Parameters on Product Quality in Rotogravure Printing, Proc. IMechE Part B, Vol. 214, pp. 205-219, 2000.

ELSAYAD, S., ET AL., 2002 Some Factors Affecting Ink Transfer. Pigment & Resin Technology, Vol. 31(4), pp. 234-240.

KAUKONEN, M., 2006. Visual thresholds and Psychometric Scaling of Missing Dots and Mottling in Printing, M.Sc. Thesis, Helsinki University of Technology.

KUESTERS, E., 1972. Impression Cylinder for Gravure Printing Press. United States Patent 3685443.

LAURENT, L. G., 2002. Prediction of the Substrate Printability in Flexography by Using a New Established Printability Coefficient. In: 56th Appita Annual Conference, March 18-20, 2002. Rotorua, New Zealand.

METTÄNEN, M., 2010. Methods for Measuring and Predicting the Printability of Paper, Nordic Pulp & Paper Research Journal, Vol. 25, No. 3, pp. 391-404.

MESIC, B., LESTELIUS, M., ENGSTROM, G., 2008. Water Borne and Solvent-Based Flexographic Inks – Influence on Uncovered Areas and Ink Leveling on PE-Coated Paperboard, TAGA Journal, Vol. 4, pp.12-24.

NEFF, J.E., 2009. Investigation of the effects of process parameters on performance of gravure printed ITO on Flexible Substrates, M.Sc., Thesis, Georgia institute of Technology, Georgia.

RAJENDRA R. DESHMUKH, NARENDRA V. BHAT, 2003. The mechanism of adhesion and printability of plasma processed PET films. Materials Research Innovations, Vol. 7 (5), pp. 283-290.

VAINSTEIN. J., 2005. A Study of Conditions and Variables that affect the Printing of Shrink Films on Waterbased Flexography. Thesis (MSc.), Rochester Institute of Technology.