OPTIMIZATION OF INK LAY IN UV FLEXOGRAPHIC PRINTING

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ABSTRACT

Some of the factors affecting ink lay in UV flexographic printing have been studied using a statistical design of experiments. The image analysis technique is utilized to characterize the solid print lay (leveling) on two substrates, plastic film and paper board, with different surface topography.

Graphical optimization demonstrates how anilox engravings and printing pressure settings can be selected for improved ink lay while avoiding excessive pressure that may damage gray scale reproduction.

INTRODUCTION

Relatively new, UV flexographic printing is an already well established and fast growing technology. Its success in different areas including flexible packaging, folding cartons and label printing can be attributed primarily to the excellent durability of highly crosslinked reactive components used in a UV curable ink. Good adhesion on a wide variety of plastics is the single most attractive feature of these inks.

It is not a secret that flexography is regarded as inferior to offset or gravure as far as print quality is concerned. The major problem of this technology is the limited gradations of the gray scale. Typical flexographic scale would not have acceptable resolution below 20% or higher than 80% screen areas. Practically, in most cases, an interval of gradations is even narrower.

UV flexography on the other hand can offer much better print quality than its conventional analog. Solventless UV flexo inks are much higher in viscosity than solvent or water based inks. Higher viscosity and very short (fraction of second) dwell time between printing and complete cure under UV light prevent UV flexo inks from excessive spreading on the printed surface. Low ink spreading improves print quality, producing very well defined dots with low gain in the highlights. Also, it helps to avoid filling between dots in the darker areas of the printed image. UV curable inks are also much stronger than conventional inks due to higher pigmentation. They can be applied with very fine anilox rollers, in some cases up to 1000 lines/inch (lpi), with a very low cell volume. This, too, improves resolution of the process printing. Well reproduced 5 % and 95% screen areas are perfectly achievable with UV flexo inks.

A problem, however, arises when large solid areas are printed. Low spreading and short dwell time are two major negative factors affecting uniformity of the ink lay. While printing solids, individual micro portions of the UV ink, transferred from adjunct cells onto the printing plate and then to the substrate surface, have to spread, crossing a distance equal to half of the width of the wall between anilox cells. In addition, it has to happen in less than 0.2-0.5 sec before they are exposed to UV light. If they fail to cross this distance and form a continuous ink film, pinholes are going to be seen on the solid areas of the printed image. Pinholing has been one of the major problems since introduction of UV flexo several years ago.

FACTORS AFFECTING INK LAY

Improvement of the ink lay, like many other printing problems, may be achieved by altering ink chemistry and rheology. Two types of UV flexo inks are available on the market today. Free radical acrylate based UV flexo inks are more common, while novel epoxy based cationic inks are rapidly finding their application among UV flexo printers. Regardless of the selected chemistry, UV flexo ink compositions must have high color strength, yet must exhibit good flow characteristics and low thixotropy. Some aspects of UV flexo ink formulation and their effect on printability have been discussed before and, therefore, are excluded from this discussion.

Proper selection of anilox rollers, printing plates and press conditions have a very strong impact on the print quality. The following press set up variables can affect ink lay:

- Plate selection;
- Anilox roller engraving;
- pressure between anilox and plate (ink pressure);
- pressure between plate and substrate (print pressure)

Surface characteristics of the printing plate are extremely important since it is the first surface to carry ink droplets transferred from the anilox cells. Plate selection is dictated by ink chemistry, i.e. cationic or free radical, may require a different plate material. If a wrong plate is selected, reactive diluents present in UV curable ink may swell and soften the plate causing deterioration of print quality.

The size of the anilox cell and the number of cells per square area determine the distance between ink droplets. Coarse anilox rollers have very big cells and wide walls between them while larger number of more shallow and closer placed cells is a feature of the fine anilox roll. It is common in the flexographic printing to adjust ink and print pressures in order to improve ink lay. Excessive print pressure, known to be helpful in ink leveling, is not very desirable due to increasing dot gain (especially in highlights) and extensive plate wearing.

It is not uncommon to observe a screen like pattern over the solid areas with a magnifying glass on some commercial UV flexo jobs. Optimization of the press conditions is, therefore, very important for achieving the highest print quality, e.g. pinhole free ink lay on the solid areas of the print. One of the complications of the optimization in this case is the lack of measurable and quantitative criteria for ink lay. Optical density of the solids is, probably, the most accepted parameters of the print quality. It is questionable whether or not the densitometer is an adequate tool to assess lack of uniformity of the ink lay since the measured print area is very small. Sometimes, print gloss may be an indication of the ink lay though other factors, such as ink film thickness and reflection from the substrate surface, can affect accuracy of the gloss readings.

Uniformity of the ink lay can be much more accurately measured using image analysis techniques [2,3]. In this case, a large area of the printed image can be scanned into a computer and analyzed, based on differences in lightness between areas with a high ink coverage and a white area (neat or uncovered substrate). Differences in lightness are represented numerically by the number of bits per pixel with 256 gradations of the gray scale from 0 for completely black to 255 for completely white. This data can be analyzed statistically and used to characterize the image.

Quite often flexo press adjustments, including selection of the anilox rollers and pressure settings, are performed intuitively without clear guidelines that would relate them to the print quality parameters. Also, different substrates require individual press adjustments depending on the nature and topography of the printed surface. All these inspired us to investigate how some of these factors affect the quality of the printed images and what needs to be done in order to improve it.

EXPERIMENTAL

All printing experiments have been carried out on a Reprotest F-1 from IGT, flexographic tester equipped with a UV light unit from UV Process Supply (***Figure 1***). The major elements of this tester are plate cylinder with replaceable photopolymer plate, selection of anilox rollers, doctor blade assembly, rubber printing cylinder and substrate carrier. Both ink pressure between anilox and plate and printing pressure between plate and printing cylinder can be adjusted in the

DISCUSSION

Printing on Plastic Film

Perturbation (trace plots) are useful tools to assess the effect of variable factors on experimental parameters. Trace plots illustrating main effects of individual factors (without interactions between them) on color density, gloss and ink lay (standard deviation) are shown on ***Figure 2 (a, b*** and ***c)***. Printing pressure has a positive effect on all 3 evaluated parameters, while ink pressure is practically irrelevant in chosen intervals. In all cases, 450 lpi anilox appears to have a more negative effect on these parameters than coarser anilox rollers.

Printing pressure has the steepest upward slope on the ***Figure 2a*** indicating its major positive effect on the ink leveling. Printed images on this film can have very uniform lay with Standard deviation as low as 1.6. It can be attributed to the very smooth surface of the film, though very uneven prints are produced if printing pressure is too low. It was surprising to find a negative effect of the finer anilox on the ink lay in this case. This result indicates that simple line count is not always an adequate characteristic of anilox roller. Cell volume and configurations, as well as anilox' material (200 and 325 lpi rollers are steel while 450 is ceramic) may significantly change ink release/transfer affecting print quality. These factors, perhaps, require further investigation.

Overall, these experiments suggest that when printing on films, printing pressure is the single most efficient element of the press set up that can help to eliminate pinholing and improve the appearance of the printed image.

Printing on Paper Board

Ink's transfer onto and spreading over the paper board surface is much different from the plastic film due to differences in their chemical nature and micro unevenness. These differences are reflected on the results of the second experiment (***Figure 3a, b*** and ***c***).

When printing on paper, anilox engraving has the strongest effect on print density: a coarse anilox allows us to achieve significantly higher density probably because a large portion of the ink released from the anilox cell exceeds the volume of the board's micro profile, easily filling it. Smaller portions of the ink transferred from the low volume cells of the fine anilox have approximately the same size as voids on the printed surface. The printed surface is not completely filled in this case, and, therefore, print density is much lower. Both ink and print pressure have little effect on density compared to anilox selection.

range between 0 and 500 N while printing speed can be gradually changed between 0 and 1.5 m/sec.

Two different substrates were selected for this study:

- White high density polyethylene film - gloss 40;
- SBS coated board supplied by James River Corporation - gloss 16

CRF57414R/F, high strength an UV flexo cationic cyan ink from Sun Chemical was used for printing. This ink had apparent viscosity of 500 cps at 250 s^{-1} and 25°C. Highly compatible with the cationic chemistry, the Epec photopolymer plate was used in all experiments.

Two series of experiments were carried out using a statistical design program by Stat-Ease®. A full factorial design (9 runs with 3 replicates at 0 point) was used for the first part (printability on film study), and combination of full factorial and response surface designs (28 runs total) were performed on SBS board.

The factor design matrices are the same in both series (***Table 1***). The lowest pressure level of 100 N represents a "kiss impression" while 500 N is a relatively high level for both ink and print pressure settings. The following anilox rollers, representing 3 levels of this design, were used to carry out printing experiments:

- 200 line/inch (lpi), 11.5 ml/m2 cell volume, steel;
- 325 (lpi), 7.5 ml/m2 cell volume, steel;
- 450 lpi, ceramic roller

All printing runs were performed at 1 m/sec speed.

The 3 following parameters are used to assess quality of the printed image:

- Optical Density measured with X Rite 418 densitometer;
- Gloss measured with BYK portable glossmeter at 60° angle using statistical mode;
- Ink lay was characterized by the standard deviation of the pixel intensity variations measured and calculated using Image Pro® computer program. Lower numbers indicate more uniform and even ink lay.

Gloss, like density, depends on the film thickness and has a very similar impact plot, though print pressure has a more visible positive effect on the paper than plastic film. Excessive ink pressure appears to be a negative factor.

All 3 variables demonstrate strong impacts on the ink lay. Both high pressure and fine anilox with closely placed cells clearly improve ink lay, reducing the Standard deviation. These results suggest that correct selection of the anilox roller is a more crucial factor for printing on rough board and paper than on smooth plastic film.

Increasing ink pressure has a strong negative effect on the uniformity of the printed image. This factor, being irrelevant for printing on the film, becomes a strong negative element of the press set up when printing on the board, especially for the ink lay. This phenomena needs further investigation.

It is worth noticing that the lowest Standard deviation readings on the board are still 30-50% higher than the lowest readings recorded on the film, indicating that overall lay on the film is much better than on board. This is another confirmation of the well known theory that the topography of the printed stock strongly influences quality of the printed image and cannot always be compensated by the press setting.

Graphical optimization of these experiments is presented on ***Figure 4***. Relatively high density (over 1.70), acceptable gloss (45) and standard deviation less than 3 can be achieved with 450 lpi anilox while both print and ink pressure would not exceed 200 N. This type of the press setting can be very beneficial if both solid and screen areas are printed with the same plate. Good lay on solids is going to be accompanied by low dot gain on the screen areas of the print.

CONCLUSION

The quality of the UV flexo printed image can be significantly affected by the press set up. The uniformity of ink lay, the most challenging area of UV flexo printing, can be improved by proper selection of the anilox roller and pressure settings. Pinhole free printing is achievable without major sacrifice of print density and gloss. The efficiency of different press setting factors, i.e. anilox selection, ink and print pressure, may differ depending on the nature and topography of the printed substrate.

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APPENDIX

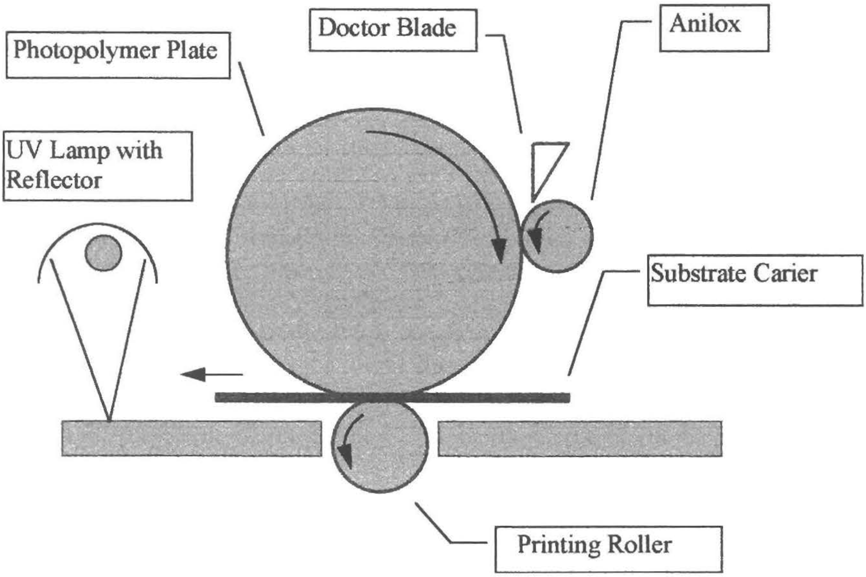

Figure 1 IGT Reprotest F1 with UV curing unit

Table 1 The factors of Experimental design

Experimental Factors	Units	-1	0	+1
Anilox	Lpi	200	325	450
Ink Pressure	N	100	300	500
Print Pressure	N	100	300	500

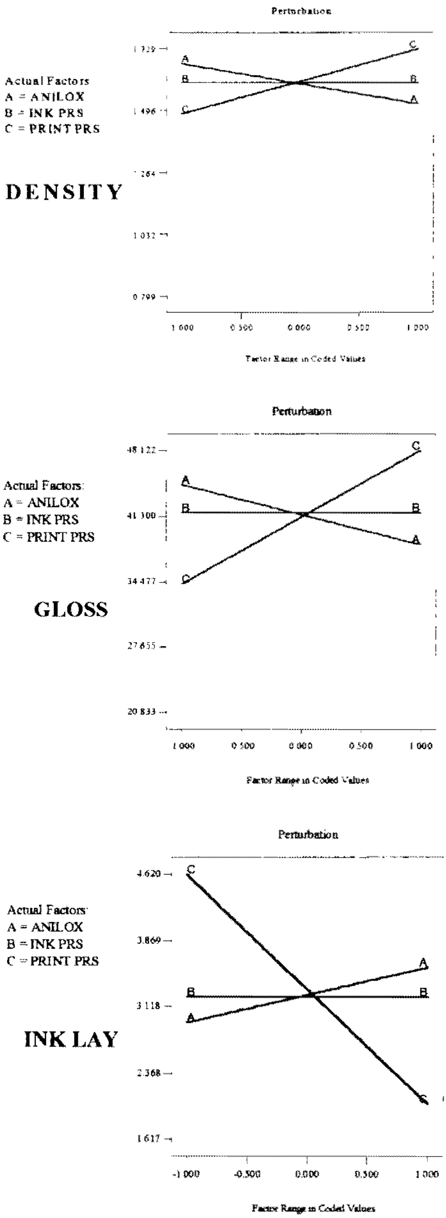

Figure 2a, b and c Printing on Film -Perturbation Plots

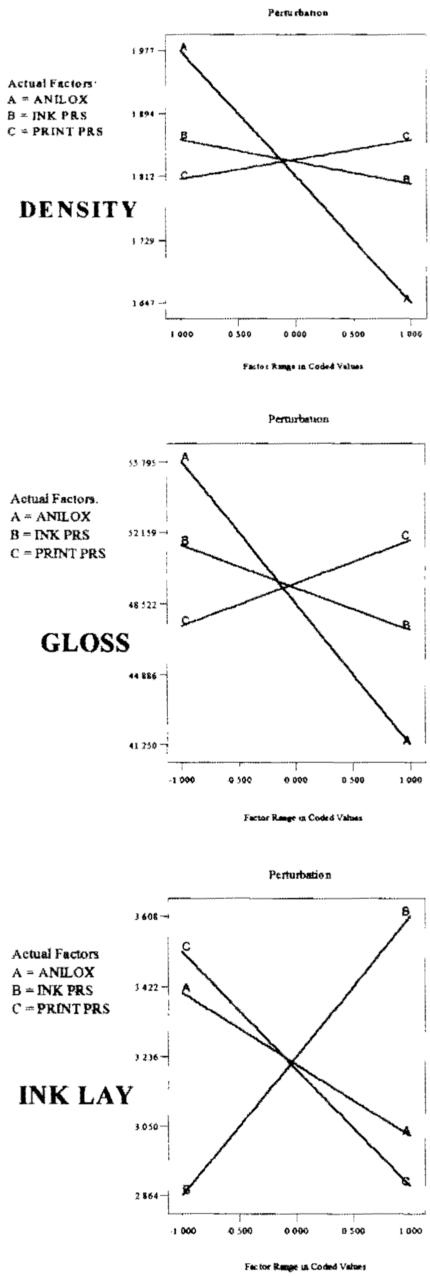

Figure 3a, b and c Printing on Board - Perturbation Plots

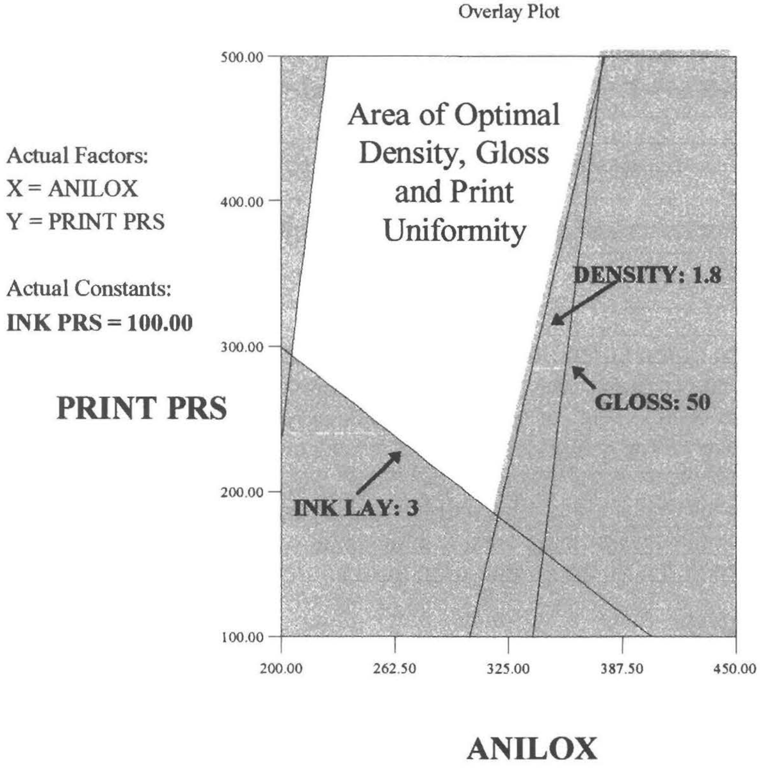

Figure 4 Printing on Paper - Graphical Optimization