Synergy between Printer, Ink, and Media for Digital Printing I: Effect of Vinyl Thickness has on Image Quality vs. Cost

William P. Kuhn, Larry Wallace, and Ed Silva, Cooley Group Inc., Pawtucket, Rhode Island, USA

Abstract

The billboard customers of Cooley Group noticed that printed image quality, dry-time, and ink adhesion are proportionally better with increasing vinyl thickness on the surface of our reinforced wide-format media.

To best serve our customers, and to position ourselves better in the marketplace, we undertook a study to determine the underlying cause of the quality difference and to identify whether the surface is smoother or the chemistry on the surface changes.

Our investigation relied heavily on quantitative image quality measurements and chemical analysis of the surfaces of prints made on various substrates with differing vinyl thickness.

This paper will detail our process in identifying the root cause of this change in image quality. Technical data will be presented and analyzed.

Introduction

Perfecting digital printing on wide-format (>99") media requires a synergy between the inkjet printer (Scitex, Vutek, NUR, etc), the ink (Sun Chemical, Vutek, NUR, Scitex), and the media (Vinyl, Styrene, paper, etc). The scope of this paper is to determine the effect of vinyl thickness has on print quality. It will not focus on the different types of inks or printers, or the different types of media or vinyl formulations. Future papers will attempt to investigate these variables.

Both dry time and ink adhesion improve with increasing vinyl thickness. However, adding thickness to the vinyl sheet has two major drawbacks: additional cost and weight.

Manufacturing costs are increased with the added resin content and handling the higher volume.

The additional costs caused by the added weight are compounded. The heavier billboards need to be shipped (the increased weight increases shipping costs) and handled (heavier materials may require additional manpower).

Although the added thickness to the vinyl membrane is more attractive to print, the compounded cost makes this vinyl less attractive.

A cross-section of the two different thicknesses was analyzed using microscopic techniques. The smoothness as well as the thickness on the front face was measured.

Infrared Analysis was used to measure the chemistry on the surface of the vinyl membrane via FTIR-ATR technique. The footprint of the ATR crystal is 3 mm^2, therefore only the vinyl chemistry was measured instead of the ink chemistry.

A machine vision-based handheld image quality measurement instrument (ImageXpress) manufactured by ImageXpert Inc. was used for the analysis of print samples in this study. In this set-up, the camera sends images to a laptop, which runs ImageXpert's proprietary image quality measurement software. The handheld device has a resolution of 10 microns per pixel. The size of the detector is 1024 × 768 pixels. We analyzed around 25mm^2 of the print sample area.

Data

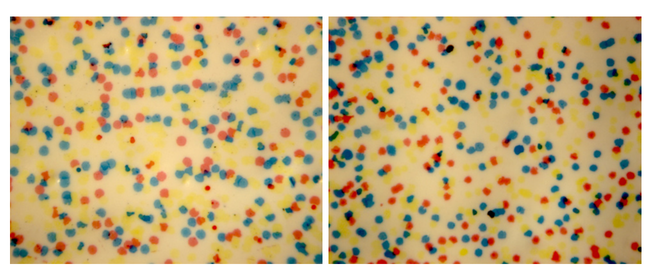
Due to time constraints, we could only get one customer to help us with this study. And the results that will be reported here are from only one printer.

12 oz and 14 oz membrane substrates were printed using a Scitex printer and a proprietary 4-ink system.

Image Quality

The four inks that are commonly used are black, magenta, cyan, and yellow. Patches of each of the four colors were printed between 10% and 100% coverage. The printer that was used in this study printed all four colors in each patch instead of just one (i.e. the magenta 10% square also contained dots of black, cyan and yellow inks).

Figure 1 shows a section of each 10% "magenta" patch printed on the 12 oz and 14 oz membrane.



12 oz 14 oz

Figure 1. 10% coverage area for 12 oz and 14 oz vinyl

To obtain quality and reproducible data, this study focused on the dots produced by just the magenta ink in the 10% "magenta" area as shown in Figure 1.

The magenta dots were isolated by filtering by size, axis ratio, gray value and threshold. Partial dots were excluded from this analysis.

The images were analyzed for dot size and uniformity.

For the magenta dots, the average area, average gray intensity, average axis ratio and total number of dots were measured in a 25 mm^2 window. The results are shown in the following tables.

Table 1: Magenta Ink Drops on 12 oz and 14 oz Membranes

Property	12 oz	14 oz
Avg. Area (mm^2)	0.028	0.022
Avg. Gray	90	87
Avg. Axis Ratio	0.89	0.89
Number of Dots	65	65

The average area is measured by averaging the areas of all of the magenta dots found and indicates the amount of ink that is dried on the surface.

The average gray intensity is a measure of darkness or lightness of the dots. It is measured in gray levels ranging from 0 to 255, where higher values indicate lighter dots.

Axis ratio is a measure of the shape of the dots (specifically, elongation) as shown in figure 2.

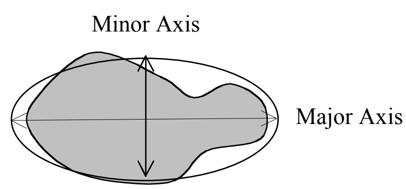


Figure 2. Geometric Evaluation of an Ink Droplet (Axis ratio)

Axis ratio is measured as a ratio of minor axis and major axis of the best-fit ellipse through each individual dot. For a perfectly circular dot the axis ratio will be 1. For any non-circular dot shape, the axis ratio will be lower than 1.

The number of dots is simply a measure of how many magenta dots were found in the 25 mm^2 area that was analyzed on each captured image.

Surface Analysis

Cross-sections of the 12 and 14 oz membranes were captured using a Zeiss high-powered microscope and Axiovision software. The magnification was set at 32x with a 1.6x lens. The unit bar of 20mil is shown on the bottom right of the images shown in Figure 3.

Visually the surface of the 14 oz membrane is significantly smoother than the 12 oz. The data supported this assessment: The peak to valley distance is much less (50%) in the 14 oz membrane.

When viewing the surface, the 12 oz membrane has a dimple appearance in the middle of the fabric (9 x 9) squares, whereas the 14 oz membrane does not.

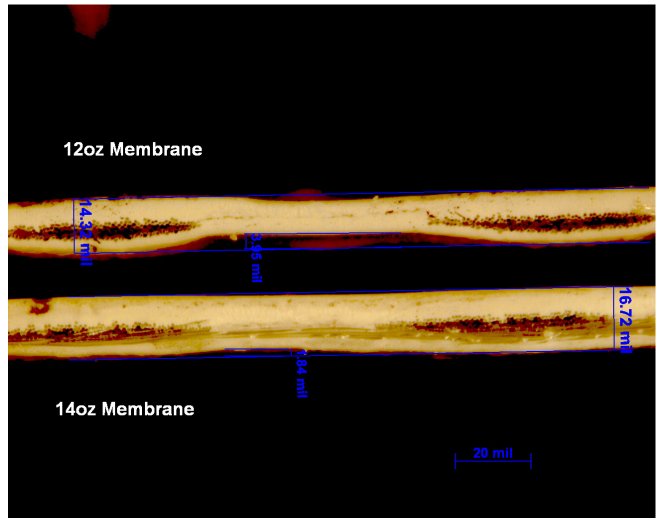


Figure 3. Micrograph cross-sections of 12 and 14 oz vinyl

Both the 12 oz and 14 oz vinyl billboard materials were analyzed for surface chemistry using a Mattson FTIR-ATR technique. At a resolution of 4 cm^{-1}, the absorbance between 600 cm^{-1} and 3000 cm^{-1} was collected. The laser interferometer measures the vibration caused be rocking, bending or stretching of each chemical bond present on the surface (<2 µm). Chemical differences can be determined by measuring the ratio of absorbencies for each frequency. Copies of the FTIR scans are available from the authors and will be distributed at the conference.

Discussion

Image Quality

The data presented in Table 1 shows that the average area of the magenta dots printed on the 14 oz vinyl membrane was lower compared to that of the magenta dots on the 12 oz membrane. Since we printed the same print file with the same printer with the same ink, it is safe to assume that the printer deposits the same amount of ink on both membranes. So, the data shows that the ink dots have a lower average area on the vinyl with the higher thickness. From this it is safe to assume that the higher amount of ink is absorbed into the thicker vinyl substrate. (Future papers can address the effect formulation has on the printing quality). The higher absorption allows the ink to dry faster (less surface area) and also provides better print resolution for the print media.

The average gray was higher (therefore lighter) for the magenta dots on the 12ox membrane than then 14 oz membrane.

The magenta dots on the12 oz membrane and the magenta dots on the 14 oz vinyl membrane had identical axis ratio values.

The number of magenta dots is almost similar for both the 12 oz and 14 oz membrane. This is expected since we printed the same print file on both membranes.

In addition to the measurements compared in the table, one additional analytical method was applied. The ImageXpert software can show the profile of gray-levels between any two locations in the image. We used to tool to inspect how the gray levels changed across the width of the dots. It appears that there is a significantly higher gray scale (lighter areas) at the perimeter of the 12 oz as compared to the 14 oz membrane. This would indicate that the sharpness of the color dots is greater on the 14 oz vinyl.

Surface Analysis

Overall, the peak to valley distance for the 14 oz membrane is 50% of the 12 oz membrane. The cross section of the 14 oz membrane shows a smoother surface than the 12 oz membrane. However, it appears that this roughness (mainly on the backside) would not impact the variability in the ink drop distance on the front side.

The ATR results did not show a difference in chemistry between the 12 and 14 oz membrane. These differences would have been shown in a higher ratio between the vinyl peaks and any other chemical species (lubricants, etc). But there was no such difference. This result would indicate that surface chemistry has no effect on the absorbance of the ink drop.

Conclusion and Future Work

This study did not conclusively determine the root cause of the difference in dot spread/area between the 12 oz and 14 oz membrane. If the ink drop has the same volume when releasing from the printhead, why is the dot spread so different on the two substrates? Analytical data (ATR, microscopy) does not solve this mystery. Other analytical techniques are needed such as surface tension, printhead distance effects.

While digital printing is becoming more focused on the image quality and drying of the ink, the increase of cost to obtain this quality is not attractive to manufacturers. As a vinyl producer, it is desirable to control the cost by improving the quality of the vinyl without having to sell a higher weight substrate.

Appreciation

The authors would like to share their deepest appreciation for Kramer Graphics in Dayton, OH with printing the Cooley vinyl media and ImageXpert for assistance with the measurement and analysis of the pint quality.

Author Biography

Bill Kuhn is a Product Development Manager with Cooley Group, Inc. He is responsible for Digital and Sign Products since joining Cooley in 2004. Bill has a Bachelor of Engineering from Stevens Institute of Technology, along with a Master of Technology Management (MBA). He also has a Master of Science in Material Science from Rutgers University.