Digital Proofing of Spot Colors for Flexo Packaging

Sangmeshwar. L. Sangmule[1], Veronika Lovell[2],

Alexandra Pekarovicova[1], Paul D. Fleming[1]

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Abstract

Spot colors have a wide range of applications in commercial as well as packaging printing. Accuracy in spot color matching and its consistency depend on the premedia software. Digital printers used for the proofing are also crucial to the quality control process. Due to the advancements and development in digital printers, inks, proofing substrates, and systems, the spot color proofing can be much cheaper compared to the conventional method. Currently, premedia software does not have ways to deal with spot color overprints, and therefore, there is no way to predict final spot color in the case print order changes. This research was aimed to study the reproduction of the spot colors with the help of premedia software such as SmartColour™ iVue, Adobe Photoshop, and a raster image processor (RIP) through inkjet printers for flexo packaging.

A test chart was created with three different types of spot color inks—red, green, orange—through ProfileMaker 5.0.8. This test chart was printed on a Comco Commander flexographic press with different print sequences on C1S and SBS board. The CIE L*a*b* values of printed test charts were measured using MeasureTool software with an X-Rite i1-iO scanning spectrophotometer. The spot colors were proofed on a semi-matte substrate printed on two different Epson Stylus Pro printers. This substrate was printed, using different prepress and color management software: SmartColour™ iVue, Photoshop, and full RIP. Finally the CIE L*a*b* values for the press and digital printed test chart were compared and for different print sequences ΔE values were calculated, considering the press sheet as a standard, which showed that the proofing of the

[1]Center for Ink and Printability, Department of Paper Engineering, Chemical Engineering and Imaging Western Michigan University, Kalamazoo, MI, 4909-5462; sangmeshwar.l.sangmule@wmich.edu

[2]Sun Chemical Corporation, 30110 S Wixom Rd, Wixom, MI 48393; veronika.lovell@sunchemical.com

spot color and its reproduction through SmartColour^{TM} iVue was better compared to RIP software and Adobe Photoshop.

Introduction

Spot colors are colors which are made by special mixing of colorants of the inks to create a particular shade (Pekarovicova, 2009; Chung, 2008; Suchy, 2005; Wu, 2007). These spot colors are used for the trade name building, company logos, or product branding in packaging industry. Due to advancements in premedia software, instead of using single opaque spot color, the trend of printing overprints of spot color is increasing. As spot colors are mainly used for the packaging industry, therefore maintaining consistency and accuracy of spot colors or overprint of spot colors, right from prepress to press, is the most important from the point of view of brand of company or its logo. This accuracy and consistency of colors are dependent on the printers used for proofing, color management system (Sharma, 2004; Hulsman, 2000), media, inks used for proofing printers, and finally the printing process used. In the case of overprinting of spot colors, a few print attributes, such as tone value increase, trapping, opacity or transparency, and print order, i.e., sequence of the printing color on press, also affect the accuracy, consistency, and reproducibility of the final color on press. The results were produced by evaluating color difference between the colors from press versus the proofing devices as well as by studying the effect of print order on the color consistency and accuracy. Three different proofing strategies were tested for correctness in generating solids tones and overprints of spot colors

Spot Colors

Spot colors are also known as special colors and are not part of a process ink set (CMYK). They are manufactured by pre-mixing the colorants to attain certain color renditions. These colors are defined by printed samples or CIE L*a*b* values. These L*a*b* values are independent of the printing press or device. Use of spot color in addition to CMYK increases the color gamut; this increase in color gamut allows more choice from a wider range of colors. Spot colors are used without CMYK for specialty jobs, such as decorative laminates, or for specialty packaging applications printing. Generally, the spot color inks are opaque as opposed to the process colors. Spot colors have been used in all printing processes because many times the process colors ink could not produce a specific color required by the customer. Trademarks, product branding, logos of the companies, or package branding are the areas utilizing spot color inks. In many cases, only one color is printed (e.g., Coca Cola label), thus it is simple and easy to maintain the accuracy and consistency of the spot color. Overprint color is obtained when two or more colors overlap, and the process of printing two or more colors overlapping is called "overprinting" or "trapping" of colors. Overprinting could be of two or more process colors or spot colors. Use of two or more spot colors gives advantages over process colors for brand building and specialty jobs printing.

Proofing of Colors

In the printing industry, proofs (Calmer, 2006) are required for the final approval of the job from the customers. Therefore, it is very important for both printer and customer to have accurate and correct proofs before final printing. The proof must be able to reproduce the colors exactly the same as they will appear on press after printing. In order to have the mutual agreement and final acceptability of the proof, printers make a final proof and get approval from the customer, this is known as a "contract proof." As this contact proof decides the final outcome of the job on the press, it must be as close as possible to the final printed job on press, with respect to color and quality. The conventional method of proofing used by any printing process is tedious and much more time consuming. In the case of gravure printing, gravure cylinders are manufactured and prints for proof are taken using the same substrate and ink. This process is costly and more time consuming. Due to the advancement in digital printing, it is possible to print on digital printers and proofers short-run jobs with high quality and desired level of consistency in color at low cost. The unique properties of the inkjet printers to produce short-run jobs in a simple way makes their use more versatile for prepress proofing. The digital printer can create the prints, which can mimic the press proof using color management workflow, including ICC profiles for different devices such as scanners, monitors, and printers.

Principle of Inkjet Digital Printing

Inkjet printers print small droplets of ink (Bandyopadhyay, 2001; Brett, 2001; Cameron, 2006; Kipphan, 2001) which flow through an array of nozzles onto paper. Ink droplets are formed by controlling the pressure applied onto the liquid in the ink reservoir, as these ink droplets flows through the nozzle. Currently, many techniques are available for achieving this type of printing. Two main principles of inkjet printing are drop-on-demand and continuous inkjet printing. The inkjet digital proofing devices used for this project are an Epson Pro Stylus 7900 printer and an Epson Pro Stylus 9800 printer. These printers use the drop-on-demand technique to form droplets of ink on the substrate. The important feature of drop-on-demand technology is its ability to generate ink droplets only when they are required; due to this reason there is no need to control the excess droplets and their recirculation. To form the ink droplets electronically for these printers, piezoelectric technology is applied. It is a simple and widely used technique for inkjet printing. Using the phenomenon of the piezoelectric effect, small electronic pulses are given to a crystalline material, which expands it. The piezoelectric effect helps to generate the pressure pulses intermittently depending upon the electronic signals received. Mechanical simplicity, simple logic, low cost of hardware, and simpler ink formulation are a few of the advantages of the drop-on-demand technology. Slower dot ejections and sensitivity towards vibrations are the disadvantage of drop-on-demand.

Inkjet Digital Proofing System

An inkjet printer works with spectral data of the inks for printing a proof. Digital printing uses numbers for printing the color. Accuracy of matching the proof to press will depend on how accurately the digital color numbers can be altered in accordance with the printing characteristics. Use of color management allows ease of handling in digital color data processing, which can help to print digital proofs that mimic the printing press. Inkjet printers, substrates for printing (Bandyopadhyay, 2001; Cameron, 2006; Graindourze, 2001), inks, and controlling software of color management system are the main components of inkjet proofing systems. All these components affect accuracy of proof-press color matching in digital proofing systems. There are ongoing efforts to develop new proofing systems that will meet the requirements like simulation of color of paper, effect of gloss, spot color reproduction, and remote proofing.

Print Media for Proofing

Print media (Bandyopadhyay, 2001; Cameron, 2006; Graindourze, 2001) properties are important from the point of view of ink and paper interaction and achieving desirable color matching quality and reproducibility. Color gamut and color stability of proofing systems are completely dependent on the combination of ink and media and predetermine color gamut and color stability of proofing systems. Therefore, final color matching quality and detailed rendering quality is dependent on the print media, namely their physical properties. These physical properties help to control ink penetration, and ink spreading and absorption. Thus porosity of the substrate decides the penetration of ink droplet into the fibrous network. The ink receptivity of the paper network determines how well the ink interacts with the paper. Print defects like feathering and bleeding may be observed, so in order to avoid these print defects, the ink droplets must absorb quickly. To have better control on the strike in or absorbency of inkjet ink droplets, print media usually have a coating layer on its surface. Absorbency of ink is determined by the smoothness or roughness of the surface print media, pore structure, and surface energy. Low roughness and porosity give low absorbency of the ink, resulting high ink holdout, and glossy print along with high print density. Whereas high roughness gives more ink absorbency, which results in more penetration of ink vehicle into the pores, giving a dull and matte finish to the print. Properties like gloss, optical density, dot shape, image brightness, color, drying time of ink, and its compatibility with surface depend on the coating layer are very important. They also play a significant role in lightfastness and water fastness of the print.

Printer Control Software

Generally, to control the inkjet printer, two kinds of software are used. One is the inkjet printer driver, which is provided by the printer manufacturer, and the second is third-party raster imaging processor software, i.e., RIP software. Which kind of workflow is to be used is dependent on the end application, whether RGB or CMYK workflow will be employed. Printers that are controlled by the printer driver software print the data files in RGB mode. The RGB printer is controlled by three channels. These printers convert the RGB image sent by the user into the internal CMYK separation using proprietary transformations that are unavailable to the user. PostScript printer drivers and third-party RIP software are able to process the data directly. Vector and raster data are interpreted for a specific PostScript printer either in RGB or CMYK mode by a Postscript interpreter or the third-party raster imaging processor (RIP) software. When a job is to be processed, it is sent to the RIP software where the PostScript page description is interpreted and then vector and raster images are converted into bitmapped data files. This conversion of image into bitmapped data files helps to interpret and control commends of the output. Therefore, a RIP can control the CMYK inks directly, which leads to a more precise and accurate digital color reproduction.

A RIP performs three main functions, which are handling color management, creating halftones, and preparing the color separations for the device. The RGB components for each pixel of the original image are converted to CMYK or a spot color component through the color separation process. In order to have predictable and repeatable results through the printer, a majority of the RIPs also have functions of device calibration and linearization processes. Due to linearization processes, the inkjet printer is able to print the right amount of ink onto the substrate, which ultimately helps in obtaining a larger color gamut. Most accurate color matching can be obtained by integrating third-party ICC-profiling software and hardware along with the RIPs with the linearization process. Use of built-in color management functions helps in defining the color space in software at prepress and RIPing stage to attain the optimal end result.

SmartColor iVue plug-in can be installed as an option in Adobe Photoshop and Illustrator. The software is based on the RGB workflow and addresses the printer through the color managed The software is equipped with the SmartColour Color Picker (Figure 1), which enables using a specific ink on a discrete substrate and predicts color appearance of an actual print. The color picker allows individual selection of colors for any spot element, either from brand-specific libraries or general libraries. All libraries contain colors from common substrates and print parameters allowing selection among those colors that can be achieved on press. The iVue software enables one to predict how the job will look on the press with a specific substrate and printing process used for it. It is enabled by. Global Shade Library is equipped with various color shades, which were developed by previously proofed, printed, and measured inks for particular substrates and printing processes.

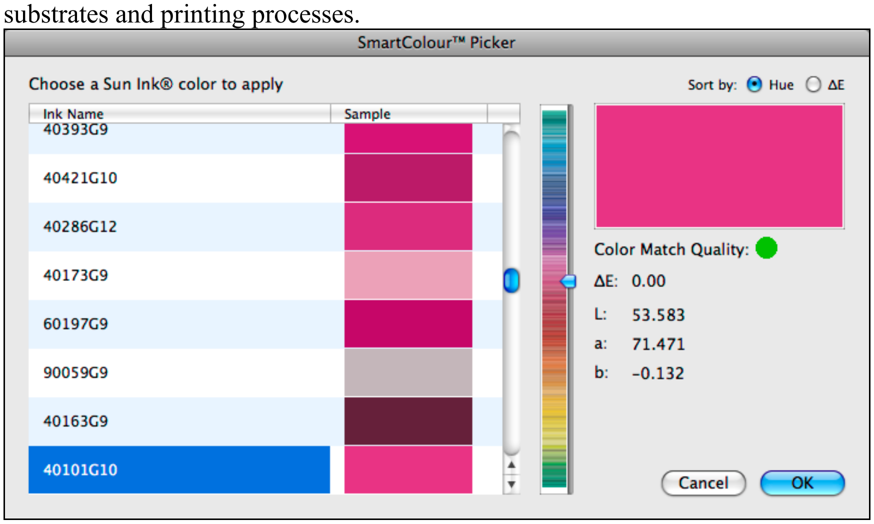

Figure 1. *Example of SmartColour iVue Color Picker with the Gravure Library Shades.*

Color Management Requirements for Proofing

The following are the requirement of color management and contract proofing:

- Consistency of reproduced color: All proofs reproduced from same image or data must look the same in image quality, as well as in color reproduction.

- Color gamut: At least the color gamut of all the printing presses (litho, gravure, and flexo) must be covered by the digital proofing machine.

- Color fastness: The output generated by the proofing machine must not change or fade its color for at least 3 months.

The basic requirement of color management in imaging is calibration, characterization, and adjustment (conversion) of all the devices used in the entire workflow. This helps to reproduce color images more accurately and close to the original. Apart from color consistency and accuracy of proof, cost-effectiveness and reliability are other basic needs for the proofs.

Methodology

For this project, a special test chart, called ROG iO, was created, with three different spot color inks—red, orange, green—through ProfileMaker 5.0.8. For the flexo trial, the inks used were Sun Chemical's solvent-based spot colors: orange, green, and red. The substrate used in the press run was one side coated solid bleached sulfite board (C1S).

Table 1. *Physical properties of the C1S- SBS board.*

	Physical Properties of the C1S-SBS Board			
Sr. No.	**Property**	**Instrument Reading**	**Unit**	**Value**
1	Emveco Roughness	Emveco	microns	1.08
2	PPS Roughness	PPS (1000 CP)	microns	1.52
3	Opacity	Technidyne	Percentage	94.3
4	Brightness	Brightimeter	Percentage	85.58
5	Caliper	Technidyne	mils	14.32
6	Gloss @ 75^0 angle	Technidyne	Unit	56.4
8	CIE L* a* b* values	X-Rite i1-iO	Unit	95.8, -0.60, 4.35

Flexo Pressrun

The test chart ROG iO has 264 patches with solid patches and tone steps in 10% dot for each color; along with this it has different overprints of the three inks. These overprints are of two- and three-color overprints depending on the channel. The test target is shown in Figure 2. Flexographic photopolymer plates with the 150-lpi resolution were used for printing the test chart on the Comco Commander flexo press in the WMU Printing Pilot Plant, with different print orders of spot colors on the C1S SBS board. The CIE L*a*b* values of the test chart were measured using MeasureTool software, using an X-Rite i1-iO scanning spectrophotometer. These CIE L*a*b* values were considered as reference values (treated as standard) for proofing overprints on the digital printers.

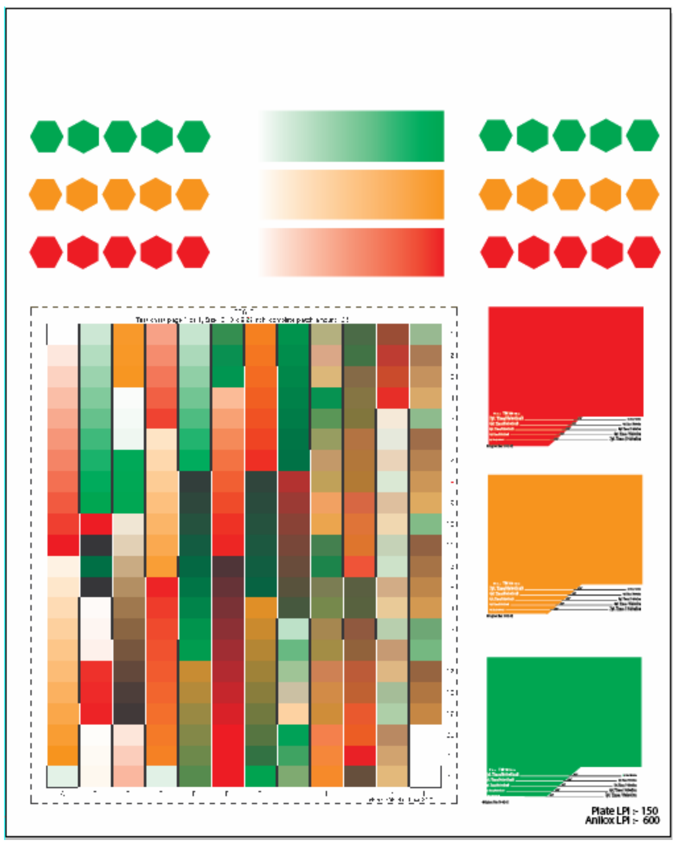

Figure 2. *Test Chart ROG iO for Flexo Press Trial.*

Proofing Methodology

For proofing purposes, the Epson Semimatte substrate was used for both the printers, i.e., Epson Pro Stylus 9800 as well as on the Epson Pro Stylus 7900. The test chart ROG iO was printed though different workflows: the SmartColour^{TM} iVue, Photoshop, and a RIP software. The tone value increase (dot gain values) obtained on the press were applied in all the tested workflows. Only SmartColour^{TM} iVue has an option to input tone value increase per channel to achieve more accurate and consistent color reproduction. The opacities of inks were calculated from printing the colors over the BYKO charts on a K-proofer and the X, Y, Z values were measured for each ink on the X-Rite i1-iO scanning spectrophotometer. These calculated opacities of inks were entered in Photoshop and RIP software for developing of the same design. SmartColour^{TM} iVue applies opacity based on the information plugged in when certain ink system is chosen. ICC profiles were created for each substrate and printer. In the case of the RIP software, the printers were linearized and calibrated with the built-in tool provided by the software.

The CIE L*a*b* values of all test charts printed on two different digital printers with different software were measured and compared to the press sheets overprinted test chart. The level of accuracy for spot color matching was computed in terms of color differences, DE_{2000} and $DE_{cmc\ (2:1)}$.

Results and Discussion

The project was focused more towards finding the right substrate and proofing printers that will help to digitally reproduce the overprints of spot colors for flexo packaging more accurately and consistently. Along with this, the ability of each proofing software package and digital printer capability to reproduce the overprints of spot colors was evaluated.

Overall Comparison of Two Digital Printers for Spot Color Reproduction

As mentioned earlier, the spot color reproduction depends on the digital printers used. In this work we used Epson Stylus Pro 7900 and Epson Stylus Pro 9800 for proofing the test chart with the same substrate. The difference in two printers is in their inking system. The Epson 7900 has “high definition range” (HDR) ink technology with extra green and orange inks in addition to the traditional CMYK set, while Epson 4800 has UltraChrome K-3 technology CMYK set only.

Figure 3 shows the comparison and performance of two different printers for the reproduction of the spot colors considering single-color, two-color and three-color overlap for the test chart on the same proofing substrate. For this purpose the two different delta values i.e. ΔE_{2000} and $\Delta E_{CMC\ (2:1)}$ were calculated for all the 264 patches for all the proofs produced on these two different printers.

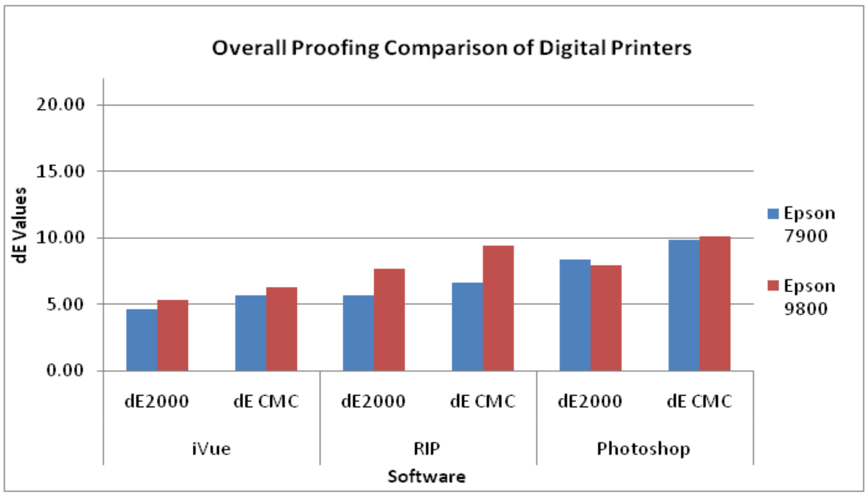

Figure 3. *Comparison of proofing efficiency of two different digital printers.*

It can be observed from Figure 3 that the reproduction of the spot colors by the Epson 7900 printers was slightly better compared to the Epson Pro Stylus 9800. The better color reproduction capability of the Epson 7900 is very probably due to the HDR ink technology, which has additional two colors. This is the main reason the DE values were less in both cases irrespective of the software used for proofing purpose. The presented results explain well that the use and technology of the digital printer affects the color reproduction and its consistency for proofing purpose.

Spot Color Reproduction Results for Single-Color Proofing

This part of paper discusses more about the reproduction of just a single spot color for two different printers and three different software. The ΔE values for all the single color were averaged for each printer and software and plotted as shown below for the two different ΔEs. Single color patches included solid patch and tones steps in 10 % step increments.

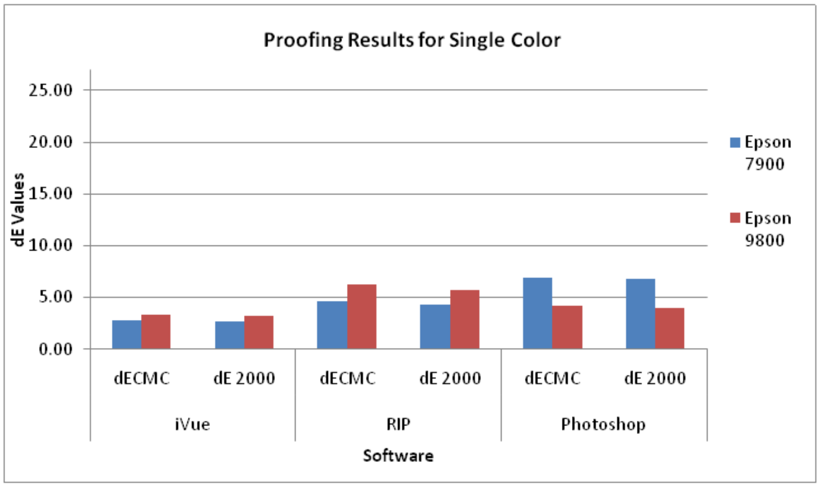

Figure 4. *Proofing results for single-color reproduction.*

Figure 4 clearly shows that workflow used in SmartColor iVue™ reproduced the single spot color more accurately compared to the RIP and Photoshop workflows on both printers. SmartColor iVue™ could reproduce the single color patches with ΔE CMC as low as of 2.7 on the Epson 7900 and 3.36 on the Epson 9800. As actual tone value increase observed on press for each spot color was entered into SmartColor iVue™, this helped to reproduce the single spot color more accurately. This option was not available in the RIP and Photoshop. Though the proofs for the RIP and Photoshop were obtained using the actual calculated opacities of the inks, the reproduction of single spot color on both printers showed higher values of ΔE CMC, which were in range of 5.5 to 7.7, and 7.8 to 8.3 for the RIP and Photoshop, respectively.

Spot Color Reproduction Results for Two-color Overlap

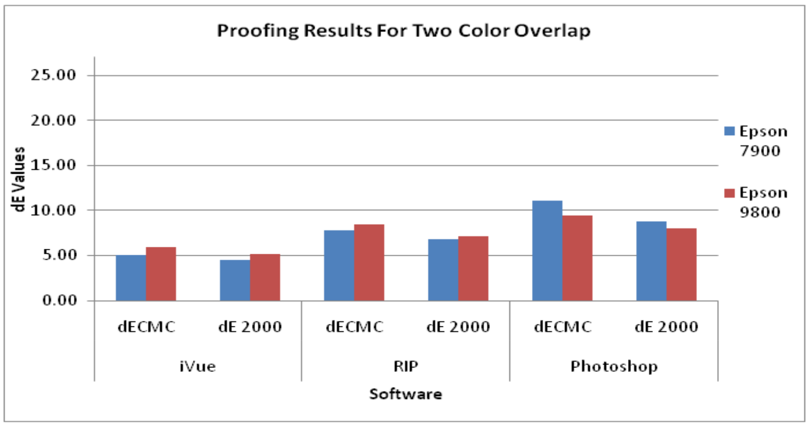

Figure 5. *Proofing results for two-color overlap.*

Now, considering the reproduction of two spot color overprints for three different software and two printers, the trend observed for reproduction of colors on digital printers was the same as that of single color, i.e., SmartColor iVue^{TM} produced better colors followed by the RIP and Photoshop. But, in this case the ΔE CMC values for all the software were higher compared to single-color reproduction. One of the reasons of these higher ΔE CMC values might be the ink sequence and trapping of ink on press that is very hard to be simulated in the digital workflow.

Spot Color Reproduction Results for Three-color Overlap

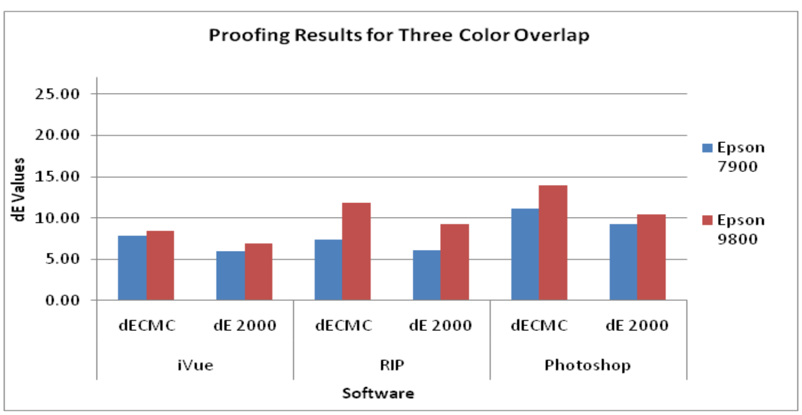

Figure 6. *Proofing results for three-color overlap.*

The color reproduction for three-color overlap for all the software gives the highest ΔE CMC values for both printers. The ΔE CMC and ΔE 2000 for three color overlap are tabulated in the Table 1.

Table 1. *ΔE Values for three various software on two different digital printers.*

Software	**iVue**		**RIP**		Photoshop	
ΔE	ΔECMC	ΔE 2000	ΔECMC	ΔE 2000	ΔECMC	ΔE 2000
Epson 7900	7.80	5.96	7.40	6.07	11.13	9.20
Epson 9800	8.41	6.91	11.82	9.30	13.90	10.40

Conclusions

From the results obtained from two different printers on the same substrate, it can be concluded that the ink technology used for digital printers affects the quality and consistency for reproduction of spot colors and their overprints. The accuracy and consistency can be improved with the latest ink technologies used for proofing purposes.

Considering the proofing systems for digitally matching of spot colors for flexo packaging—SmartColor iVue™ software produced the best results compared to RIP and Photoshop. As it produced the lower ΔE values on Epson 7900 and Epson 9800 digital printers, for all the channels of the test chart relative to the press sheet. SmartColor iVue™ was able to produce the lowest ΔE CMC for single spot color proofing.

Other than color management systems, proofing substrates, and digital printers, factors such as print sequence, trapping, and actual ink opacities also affect the reproduction of spot colors as it was clearly observed that the ΔE values were increasing as the number overprint colors increased.

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