Enabling Expanded Color Gamut and In-line Coating Processes

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Abstract

Most four-color printing processes that are extensively used in electrophotographic (EP) applications today are based on the SWOP (Specifications for Web Offset Publications) colorants. Although, this set of colorants offers many advantages, it fails in many aspects as it does not deliver many often requested colors in digital printing. For example, most corporate identity colors cannot be faithfully reproduced with the available gamut possible with this color set. Most attempts to increase the color gamut by selecting high chroma colorants only provides marginal improvements. At the same time these colorants can have high impact on toner performance developer life. Many of the limitation of a four color system can be addressed by a adding fifth module in the digital color press. One such digital press now commercially available, is NexPress 2100. By proper selection of fifth color DryInk™ or toner, and utilizing pentachrome process, Nexpress 2100 digital press manages to expand color gamut on demand while still continuing to utilize the standard CYMK toners. The result is a low cost solution to matching most colors that are often demanded by customers. With the availability of fifth module, it is also possible to use it to apply a clear overcoat in an intelligent manner. Such a coating process is truly in-line and offers efficient workflow solutions. Clear Overcoats provides superior protection and enhance many image quality attributes. Many capabilities and limitations of fifth module will be presented. Impact on EP process and color gamut by the colorant selection will also be discussed.

Introduction

Color electrophotography began with the use of three basic subtractive primary colorants. The goal was to achieve the largest color gamut that could be obtained from a particular set of cyan, magenta and yellow toners. As the technology and the public acceptance of color EP grew, more effort was placed in the pigment selection process. Depending on the spectral absorption characteristics of a color set, only a limited number of standard color chips can be created. By selecting pigments that have minimum overlap in spectral absorption curves and higher chroma, a greater number of colors can be reproduced. In order to reduce color toner usage and to create a more acceptable black for text output, it became necessary to employ a four-color process by introducing a black to the three primary colors. Advances have been made in colorant selection that have resulted in better light stability and minimized possible health hazards.

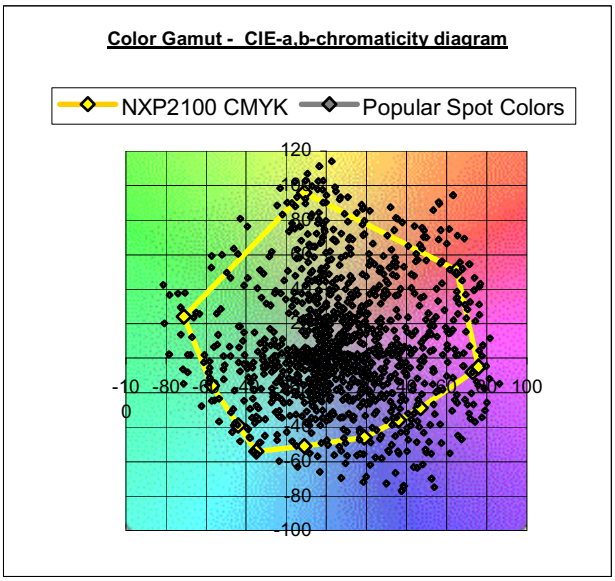

Figure 1. An a-b* chromaticity plot showing many popular spot colors that lie outside the color gamut capability of a four-color digital printer*

Even with all the improvements in dispersion technology, it has not been possible to expand color gamut sufficiently to satisfy the needs of print shops where customers demand many popular colors that are outside the available color gamut. For example, as shown in Fig. 1, many corporate colors and spot colors fall outside the color gamut capability of a typical four-color toner set.

Typically, it only possible to deliver 45 to 55% of the standard color chips with a CYMK process. Color gamut can be slightly affected by various factors that include substrate, print density, uniformity and gloss. But color reproduction with a four-color process is still not satisfactory. If digital printing hopes to make inroads into off-set printing, it has to enable print shops to create the same documents that they are currently producing with standard lithographic inks.

Most of these problems can be addressed by adding more colors to the standard four-color toners. Several digital printers are now available that have incorporated additional

modules to expand the color rendering capabilities. The choice of colorant added to the mix plays an important role in realizing the expanded color gamut. All this has to be achieved within the basic requirements that are demanded from a toner so as to not affect the reliability of the machine. Selection of fifth module colorants and the benefits of the pentachrome process will be discussed in this presentation.

Another problem that faces digital printers is to provide adequate print protection. Unlike offset inks, toner does not penetrate the substrate and is fixed above the surface. This inherently exposes the fixed image to physical damage that can be caused by abrasion and scuffing. The damage can occur during finishing, mailing or routine handling of the digital print output. The problem is aggravated further by the fairly brittle resins used in toners in order to achieve high speed fusing and efficient pulverizing. With the availability of a fifth module in a four-color press, it is possible to use a clear toner to provide an in-line coating process that provides protection for digital prints and enhances image quality.

Color DryInks for Fifth Module

To complement the four-color process, the choice of colorant used in the fifth module can be considerable and has a large impact on the potential parts of the color gamut volume. One of the printing industry standards for color matching is provided by Pantone® (1). The basic recommended colors that are mixed to provide more than a thousand color combinations are provided in Table 1.

Table 1. Pigments used in inks to produce basic Pantone® colors

Pantone Basic Colors	Color Index	Chemistry
Yellow	PY 12,13 or 174	diarylide yellows (12, 13, 174)
Yellow 012	PY 12	diarylide yellows (12, 13, 174)
Orange 021	PO 34	disazopyrazalone
Warm Red	PR 53:1	β-Napthol pigment Ba lake
Red 032	PR 2 or 112	Napthol AS reds; 2 yellower than 112
Rubine Red	PR 57:1	BONA pigment Ca lake
Rhodamine Red	PR 81:1	PTM salt of Rhodamine 6G
Purple	PV 1	PTM salt of Rhodamine B (PV 1)
Violet	PV 3	PTM, PM salt of Methyl Violet
Blue 072	PB 1	PTM, PM salt of Victoria Pure Blue B
Reflex Blue	PB 61	alkali blue (triarylcarbonium sulfonate)
Process Blue	PB 15:3 or 15:4	β–copper phthalocyanine (15:3 and 4)
Green	PG 7	chlorinated copper phthalocyanine
Black	Carbon Black	
Transparent White	Titanium Dioxide	

Many of the colorants that are listed in Table 1 are not good choice for toners because of how they affect the charging behavior. For example, all rhodamine salts are extremely positively charging and thus create charging issues for negative polarity toners. Also, the benzidine based pigments (diarylide and disazopyrazalone) have been cited to have heath concerns.[2-4]

One of the main considerations for fifth color selection has to involve the colorants that are often requested by a customer. In the absence of any standardized data, several surveys were conducted to determine the most popular and common spot/highlight colors.

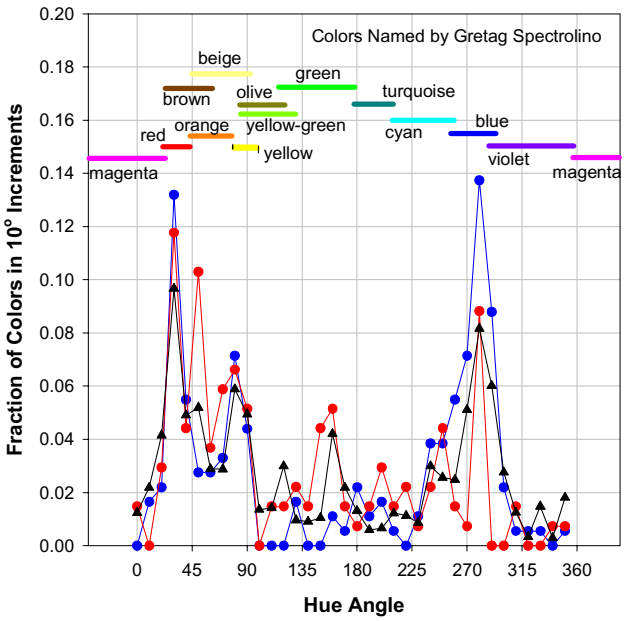

Figure 2. Distribution of popular colors shown in 10° hue angle increments

One survey was based on the top corporate identity colors used in industry. Another was based on the usage of various printing inks that are commercially sold by several major ink manufacturers. The third survey was based on the frequency of requests for spot colors in jobs submitted to several NexPress 2100 digital printers over a period of several months. The distribution of requested colors is shown in Figure 2. The results of the survey indicate that, not surprisingly, blue and red are the most popular and often requested colors. Green color constitutes a distant third choice. These colors also happen to be the ones that are very difficult to reproduce with the standard SWOP colorants. As a result, these three colorants make a logical choice for toners for digital printers with fifth module capability.

The impact of NexPress Red, Blue and Green DryInks on color gamut was measured and the results are reported in Table 3 using a standard paper with 3 dE tolerance. In these measurements, the fifth color was not used as spot color but rather as the 5th color of a pentachrome process. The results show that there is a significant increase in color gamut volume when any of these three colors are added to a standard CYMK color set. Unlike the standard dedicated spot colors, the pentachrome process can produce many more standard spot colors by mixing various levels of the CYMK colors that are already present in the digital printer. This is not only more efficient, but allows colors to be reproduced that may belong to a different color matching standard.

Table 3. Effect of Various 5th Color Toner in Pentachrome Process

Condition	Gamut Volume	# of Std Spot Colors within Gamut	% of Standard Spot Colors in Gamut
CMYK	475070	593	52%
CMYK + 3 dE	595890	746	65.60%
CMYKG + 3 dE	682390	805	70.80%
CMYKR + 3dE	661655	795	69.90%
CMYKB + 3dE	673312	804	70.70%
CMYKRGB + 3dE	870779	972	85.50%

It is possible to change the DryInk in the fifth module so as to provide enhanced gamut in an area of particular hue angle that may be required by the printing job. With this flexibility, it is possible to match more than 85% of standard spot colors. The choice of color toner for the fifth module does not have to stop at just red, blue and green. Other colors can be easily added to create a truly flexible five-color process that will reproduce nearly all of standard spot colors that are requested by customers.

Clear DryInk for Fifth Module

With the availability of a fifth module in a press, a clear toner can be used along with the standard CYMK toners. Although, the clear toner would not increase the color gamut capability of the printer, it can provide several benefits. These include:

- Abrasion resistance
- Scuff resistance
- Resistance to damage in mailing equipment
- Protection during post-finishing
- Resistance to food and liquids
- Uniform Gloss
- No differential gloss
- Improved granularity
- Spot Coating

Depending on the requirements, these clear toners can be electrostatically deposited in a small area of the image, or applied as flood coating all over the image. By covering the color toners that form the image underneath, clear DryInk prevents the loss of image content and thus provides protection to abrasion and scuffing. Images were tested for abrasion and scuff by using standard tests. In Figure 3, results from a Taber Abrasion Tester show the improvement provided by the clear overcoat by preventing the loss of color toner as indicated by the absence of density loss. Similar results were obtained with various rub tests[5-6] on images with and without the clear overcoat. The smudge resistance of the prints was markedly improved when a protective coating had been applied to the print.

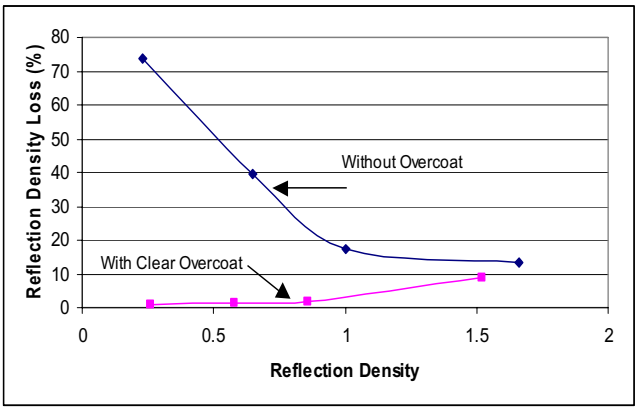

Figure 3. Results from Taber Abrasion tester showing increased image protection provided by clear overcoat.

When a overcoat of clear toner is applied to an image, the uniformity of the print is dramatically increased. For digital output, the image gloss is low even on a highly glossy paper in areas where the print density is low. This is caused by the scattering due to islands of toner present on a smooth surface. At higher densities, islands of toners grow bigger until uniform high gloss is obtained. As a consequence, the differential gloss that is commonly observed even in uncoated offset images can be overcome with the use of a clear toner overcoat. Effects of a clear overcoat on differential gloss are shown in Figure 4 for various coated and uncoated papers. The clear overcoat provides a uniform gloss on all types of media because a uniform coating is applied over the entire image.

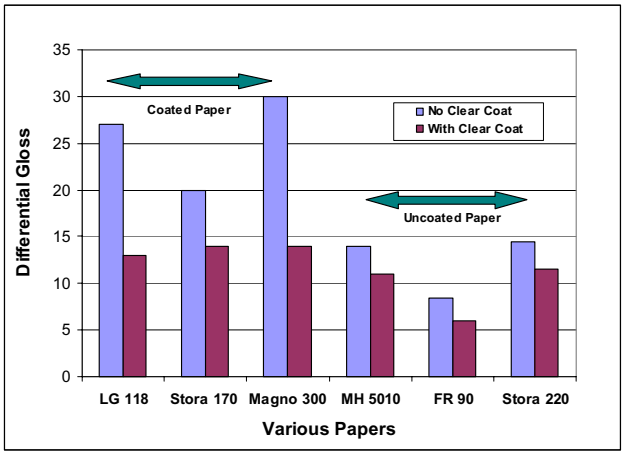

Figure 4. Improvement in differential gloss is demonstrated with the clear toner overcoat on various paper surfaces.

Advantages of Clear DryInk

Some type of overcoat is commonly applied in conventional offset printing presses for various reasons that include quick drying for improved throughput, gloss effects and print protection. Many of these coatings such as varnish or aqueous, are applied in-line. UV coating and lamination are typically carried out off-line.

Digital prints are often not as durable as offset. Many digital printers resort to off-line laminators or UV coating devices to impart sufficient durability to their digital prints. These coatings can be applied in-house if they own such equipment, but for many print shops the job must be outsourced. For example, print shop owners, if they own a offset press, pass their digital output through it to apply an aqueous coating. Not only are these time-consuming and expensive processes, many of the coating do not adhere properly to digital images because of incompatibility.

In digital color presses that have five modules available, many of these shortcomings can be avoided by the use of clear toner in the fifth module. This provides an in-line coating capability with the most efficient workflow. By eliminating off-line coating or outsourcing, coating for digital prints can be produced in a cost effective manner. With an in-line coating process, not only are the production times and hence the labor costs significantly reduced, but problems associated with mistakes caused during multiple "touching" events are also eliminated. Since the clear toner is compositionally similar to the color toners, there is no issue of coating problems caused by incompatibility. In addition to the improved durability against various types of mechanical damage, the in-line clear overcoat also provides improved resistance to spills and stains.

Conclusions

With the availability of a fifth module in digital color presses, the capabilities of the digital presses have been vastly improved. The addition of a fifth color toner allows access to large numbers of standard spot colors that cannot be reproduced by the CYMK process. The pentachrome process is superior to simply using a spot or custom color to the fifth station because it allows for much more matching of the standard spot colors. This is achieved by mixing them with the CYMK toners already existing in the digital press.

Clear toner can also be used in the fifth module to provide an in-line process for coating digital prints. By creating an efficient workflow the clear toner coating approach helps reduce cost and eliminate mistakes. Such coatings with clear toner offer improved protection and image appearance.

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Biography

Dr. Dinesh Tyagi received his Ph.D. degree from Virginia Tech in 1985 from the Department of Chemical Engineering. After one year of post-doctoral position there, he joined Eastman Kodak Company as a Research Scientist where he started working in the toner development area. He was promoted to Senior Research Scientist in 1989 and in 1993 he was appointed Research Associate. Following year he was inducted into Kodak's Distinguished Inventors Gallery. In 1999 he joined NexPress Solutions and has continued to work in the area of toners and electrophotography. He has over 70 patents worldwide.