Developing Custom Colors in Hot Melt Jet Inks

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Abstract

In this paper, we present a rationale for the development of custom colors by blending selected single pigment jet inks. One of the routes to special or custom colors is to blend existing single pigment inks. This approach offers advantages but also places unique demands on the formulation. For example, all of the inks must be mixable in all proportions without affecting jetting characteristics and stability. After good primary colors have been selected and qualified, then commercial spectrophotometers and software are available for suggesting ìrecipesî for particular color inks. This hardware is extremely valuable but is limited in its ability to accurately predict the color of printed images. Examples of well and poorly matched recipes will be discussed. It is necessary to relate the color from ink fills to that printed by the specific ink jet printing system. We will discuss how special colors can be formulated in the lab and approaches to make this practical in an industrial or commercial environment. There are opportunities for increasing the gamut and range of blended colors in a digital printing system. One way to accomplish this expansion is to use additional single pigment inks.

Introduction

The first topic is the motivation for custom color, then our approach, some economic considerations particularly for customer-site ink mixing and opportunities for increasing color gamut by adding more inks.

Motivation

Spectra's customer for printheads and inks is planning to add spot color to already printed xerographic images. The application would be advantaged if the jetted color were no more expensive, considering all sources of cost, than adding color xerographically. There would additional advantages if we could offer options unavailable from xerography.

By using the same ink chemistry for creation of new color options, reliability and throughput of the system were, in principle, unaffected. The primary caveat was that new colors would be limited to the gamut available by mixing our existing primary inks. In addition, we offered rapid turn around on small volumes of custom ink colors.

The Application

The particular customer to be accommodated was Accent Color Sciences who manufactures and sells an add-on to high speed xerographic printing systems such as an IBM web system printing at about 300 feet/minute. Each ACS Truecolor Printing System has 2048 jets capable of 8 different colors. Each head moves independently, between print jobs, to a fixed position during the job. Each printhead can achieve more than 1 inch wide print zone. Heads can be stitched to provide wider print widths. Each printhead has its own reservoir. Printing is at 240 drops per inch onto a heated platen with a drop volume of about 95 picoliters. ACS markets 300 dpi systems also; consequently we need to consider printed ink color at 300 dpi as well as 240 dpi.

Each high speed printing system may print 1 or 2 million pages in a month using 10 or so kilos of ink. This places high demand on paper handling and on printhead reliability; printheads need to jet several hundred kilos of ink without failure.

The high speed system is a particularly good application for hot melt inks because they freeze almost instantly on the substrate, there is no water to dry, and the image quality is practically independent of substrate yielding good sharp images even on relatively low quality paper stock often used in bills and bulk mail.

The Approach

Because it is expensive to qualify entirely new inks, it would be most cost effective to start with 3 primary inks and require that these inks be mixable in all proportions. We are defining a primary ink to be colored with a single pigment or dye. Also a colorless diluting ink is required.

Considering dye-dye interactions such as co-precipitation, it ought to be easier to formulate with pigments, however, there are some considerations on mixing pigmented inks such as compatibility of dispersing agents. After adjusting the selection of pigments for compatibility of the overall formulation and studying the stability of mixtures over a range of concentrations, the final ink set consists of a good pigmented cyan and magenta and a dye based yellow.

Now it remains to mix these primary inks to get the desired spot color.

Steps in Developing a New Spot Color

The following are the major proces steps in developing a new spot color:

- Measure the desired color
- Use commercial software to propose a recipe
- Prepare first recipe and evaluate against target
- Adjust recipe to improve match
- Iterate recipe and evaluation as required
- Scale up recipe for evaluation in the printing system
- Iterate recipe and printing evaluation as required
- Scale-up recipe for production
- Ship new color ink

Look-up Tables

Dilutions of the primary colors are used in building look-up tables as inputs to our commercial software. We chose to make up about 8 steps, but it is possible to do with only 5. The diluting ink is not 100% transparent which is a draw back as it adds some color across the visible range.

Recipes and Color Matching

From plotting the gamut of the primaries and simple secondaries in a,b space (CIE L*a*b* convention), one can estimate the colors which should be obtained by mixing these inks.

First a target color proposed by the customer is measured. Then a small test recipe is prepared and compared to the target color. If the match is good, as illustrated in Table I, then sufficient ink is prepared to a printing test.

Table I. Recipe and Results for Blue 300

	L*	a*	b*	C*	h*
Target	41.8	-4.8	-45.1	45.4	263.9
10 g Test	41.4	-4.3	-44.5	44.8	264.5
Printed at 240 dpi	51.6	-11.2	-42.2	43.7	255.2

It is common to see that the printed sample differs both from our drawdown and from the target. To quantify these differences we are using a simplistic of color difference, delta E. This is calculated as

$$\Delta E = \sqrt{(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})} \qquad (1)$$

This method of calculation does not always relate well to perceived color differences and it has been recommended that the chroma values be weighted to have the calculation correspond more closely than does this simple approach. An alternate calculation used to improve the uniformity of the color difference equation is the CIE 1994 Color Difference Equation

$$\Delta E_{94} = \sqrt{(\Delta L^*/k_l S_l)^2 + (\Delta C^*/k_c S_c)^2 + (\Delta H^*/k_H S_H)^2)} \qquad (2)$$

Table II. Recipe and Results at Two Printing Densities

	L*	a*	b*	C*	h*
Target	59.7	63.2	29.2	69.7	24.6
10 g Test	51.9	62.3	28.9	58.6	24.9
Printed at 240 dpi	60.7	51.6	23.1	59.7	30.2
Printed at 300 dpi	55.1	61.6	25.5	66.7	22.5

These results highlight the importance of generating color match samples with an approach that duplicates the actual printing process used by the customer. When ACS prints at 240 dpi the ink does not completely cover the substrate, leaving some white space which strongly affects the measured and perceived color.

A common method for evaluating color in printing inks is to apply a thin uniform layer of ink onto a standard substrate. The layer is generally applied with a wire-wrapped rod which enables very consistent ink thickness. This works for hot melt inks and is practical for use on a manufacturing line. Use of drawdowns eliminates the printing system as a source of color. Drawdowns for printing inks can be made with reproducibility better than 0.5 delta E. This target is not easy to achieve with hot melt inks but use of automated equipment can yield controls as good as delta E of 0.8.

It remains to correlate the color as measured for a drawdown with the printed result.

Color Control for Incoming Inks

Not only does printing affect the color, but also one needs to control incoming ink so that color shifts due to bulk differences are minimal. Delta E of 3 is typically the criterion for color control for very high quality standard printing inks. Our experience is that this is workable for jetted hot melt inks but not infallible. In particular hue control seems more important for cyan than for yellow and magenta.

Economics of Color Blending

Having an ink set designed for color mixing reduces some of the expense inherent in inventorying many ink colors. Large batches of the primary colors can be used to prepapre just the right amount of the target ink color. The turn around time for mixing 30 to 50 kilos of a given color can be fast compared to the time required for customer approval.

Another potential approach to blending inks is to use color “kitchens” as are available in hardware stores to mix paints to order. This is viable if the primary inks are properly formulated but may be difficult to implement for jet inks because of filtration specifications. Hot melt inks may be even more difficult to work with than aqueous inks because of heating and mixing.

Opportunities by Adding Single Pigment Inks

If it is important to generate colors beyond the gamut of the 3 selected primaries, then additional single pigment inks are required. For example, Table III gives the recipe and result of our attempt to create a color similar to Pantone 021 with existing hot melt inks.

Table III. Attempt to Blend Orange 021

	L*	a*	b*	C*	h*
Target	67.2	57.2	65.5	86.9	48.9
10 g Test	66.9	43.6	58.3	72.8	53.2
Printed at 240 dpi	69.0	37.2	42.8	56.7	49.0

Our blended ink was far from the target color as measured by delta E and was muddy in appearance. We could not meet the customer's specification with this ink set.

In another ink set, a single pigment orange was qualified and then used to blend an excellent orange. It remains to be seen if the market for hot melt spot colors will justify the cost of adding a new orange single pigment ink to our current offering.

Conclusions

We have found that having a prepared set of blended inks can increase the competitive advantage for some products in niche markets. The range of colors can be engineered to meet the requirements of each customer. A well formulated ink set makes providing custom colors rapidly and cost effectively a reality. Expanding the gamut by adding more single pigment inks can possibly add new market opportunities, but these need to be weighed against cost.

References

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3. Gretag Ink Formulation V 2.0 (1996). All reported L*a*b* values were measured with Gretag SPM 55 spectrophotometer, D_{50} 2^{o} 45/0.