Weight-based Ink Trapping Assessment

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Abstract

The motivation to study weight-based ink trapping is to predict overprint colors in wet-on-wet printing. The Preucil formula and other density-derived ink trapping formulas require optical measurement of printed samples, including the measurement of the overprint, in order to compute ink trapping. Yet, ink trapping is obtainable by gravimetric or weight-based method without printing. By means of experimentation, we learned that ink trapping is proportional to the tack difference between the first-down ink (high) and the second-down ink (low). The average gravimetric ink trapping of uni-tack inks in wet-on-wet printing is 0.7 +/- 0.1. This research provides us with insights as we use the ink trapping values as a constant to predict the color of the overprint solid.

Introduction

In multi-color offset printing, a wet ink film is printed on top of the other wet ink film. As such, lesser amount of the second-down ink is transferred or trapped than if it is printed on to a dry ink film or unprinted area. As a result, ink trapping affects the hue of overprint colors. In addition, ink sequence also affected the hue of overprint colors.

When the "Overprint Fill" design feature is available in Adobe Creative Suites that allows one spot color overprinting to the other, there is no color management solution to ensure that the overprint solids, as displayed, correctly matched that as printed (IARIGAI, 2008). In order to display any overprint color in premedia software correctly, ink characteristics, ink trapping, and modeling of the overprint color have to be understood and developed.

Literature Review

Ink trapping is computed based on densitometry using the Preucil formula. As shown in Equation 1, ink trapping (t) is a function of the overprint (D_{op}), the paper (D_0), the first ink (D_1), and the second ink (D_2).

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In other words, ink trapping (t) is calculated when the rest of the quantities (D_0, D_1, D_2, and D_{op}) are known (CGATS.4, 2006).

$$t = \frac{D_{op} - D_1}{D_2 - D_0} \qquad \text{(Eq. 1)}$$

A problem with density-based trapping is that the wet-on-dry trapping does not yield 100%. This is because densities are not additive. To overcome the additivity failure, this research expresses density-based trapping, $t_{Density}$, as a ratio of the wet-on-wet trapping (t_{WW}) and wet-on-dry trapping (t_{WD}), as shown in Equation 2.

$$t_{Density} = \frac{t_{WW}}{t_{WD}} \qquad \text{(Eq. 2)}$$

The Preucil formula and other density-derived ink trapping formulas require optical measurement of printed samples, including the measurement of the overprint, in order to compute ink trapping. In other words, we have one equation with two unknowns, i.e., trapping and overprint. In order to predict overprint color, it is strategic that ink trapping (t) is a part of the ink characteristics and can be estimated independent of printed samples.

ISO 13656 (2002) defines a gravimetric procedure for determining the ink trapping based on the weight of the second-down ink applied to the first-down ink (either wet or dry) in comparison to that applied to unprinted substrate. The ISO ink trapping (t_{ISO}) can be expressed in Equation 3 where W_{WW} is the weight of the second-down ink applied to the first-down ink (wet) and W_{WP} is the weight of the second-down ink applied to unprinted paper.

$$t_{ISO} = \frac{W_{WW}}{W_{WP}} \qquad \text{(Eq. 3)}$$

Instead of using the weight of the second-down ink on unprinted substrate as denominator (ISO ink trapping), this research uses weight of the second-down ink on a dry first-down ink sample as the denominator (W_{WD}). We define Ink Trapping Ratio or t_{ITR}, as a ratio between the weights of the second-down ink in wet-on-wet ink transfer (W_{WW}) and that in wet-on-dry ink transfer (Equation 4). This is a normalized version of the ISO ink trapping formula where $t_{ITR}=1$ for wet-on-dry ink transfer.

$$t_{ITR} = \frac{W_{WW}}{W_{WD}} \qquad \text{(Eq. 4)}$$

As stated earlier, there is an advantage of weight-based ink trapping over optical-based ink trapping, i.e., weight-based trapping is carried out in an ink lab without printing. In addition, if we can condition the ink characteristics such that ink trapping approaches to a constant, we are one step closer to predicting the color of overprint solids.

Research Objectives

Process color printing differs from spot color printing in a number of ways. In process color printing, CMYK inks are tack sequenced. An advantage for tack-decreased ink sequence is that it yields a larger CMYK color gamut. The role of ink tack in spot color printing is unknown. From a previous ink trapping study using spot color inks (RIT, 2008), we learned that ink trapping is a function of ink tack. But, there is no clear understanding what tack value is suitable for spot color printing. Thus, ink tack represents a degree of freedom in spot color printing.

The number of two-color overprints in CMYK printing is limited. These colors are measured as a part of the color characterization process. There is no need to predict two-color overprints. If Pantone colors are used in spot color printing, more than a thousand of these colors, via specially formulated inks, can be printed along or in combination with other spot colors. There are too many possible combinations of two-color overprints. No one measures these overprint colors and no one knows the color of the overprint until printed.

The key question in this research is, “Does weight-based ink trapping converge to a constant when tack values of the two inks are the same?” If the answer to the research question is “Yes,” we will be in a good position to predict the overprint color based on a variation of the Preucil ink trapping formula. This is because ink trapping becomes a constant, and the only unknown is the overprint.

This research will limit its scope regarding the effect of ink tack on weight-based ink trapping. The goal is to see if ink trapping of uni-tack inks will converge to a constant. Predicting overprint colors using uni-tack inks will be explored in as a follow-up study.

Methodology

To estimate weight-based ink trapping, this research started by generating ink samples using spot color inks (Pantone 1788C and Pantone 7466C) of known ink tacks (8, 11, and 14). There are three stages in ink sample preparation: (A) producing single ink sample, (B) producing wet-on-dry overprint sample, and (C) producing wet-on-wet overprint sample.

A. Single ink sample preparation

A1) Deposit known quantity of ink to the IGT High Speed Inker (Figure 1). In a preliminary test, 0.08 cc of the ink yields an ink film thickness of around 1 μm on the ink sample.

Figure 1. *IGT High Speed Inker.*

A2) Mount a removable cylinder to the Inker and transfer the ink from the Inker to the cylinder.
A3) Weigh the inked cylinder by a precision scale.
A4) Mount the inked cylinder to the IGT Printability tester (Figure 2).

Figure 2. *IGT Printability tester.*

A5) Transfer the ink from the inked cylinder to a piece of paper in the IGT Printability tester.

A6) Weigh the inked cylinder to determine the ink weight on unprinted paper, W_{WP}.

B. Wet-on-dry overprint sample preparation

B1) Step 5 of the above procedure is altered to produce wet-on-dry overprint samples by transferring the ink from the inked cylinder to a piece of paper already printed with the first ink.

B2) Weigh the inked cylinder to determine the weight of the second ink, W_{WD}.

C. Wet-on-wet overprint sample preparation

C1) Wet-on-wet overprint samples are prepared by mounting two removable cylinders on the IGT Printability tester so that the second ink is transferred on top of the first ink in a single pass.

C2) Weigh the second inked cylinder to determine the weight of the second ink, W_{WW}.

Different ink trap values, i.e., $t_{Density}$, $t_{ISO,}$ and t_{ITR}, of ink samples with the same and different ink tacks, and different ink sequences were generated. Spectrophotometric curves of paper, first ink solid, second ink solid, and their overprint solid were also measured as a part of the data collection.

Two sheetfed press runs were conducted to print uni-tack inks on the 100# SAPPI McCoy Gloss text using a 6-color Heidelberg Speedmaster 74 offset press. The first press run produced prints in two ink sequences using tack 11 inks. The second press run produced prints also in two ink sequences using tack 14 inks. The test form is identical in both press runs (Figure 3).

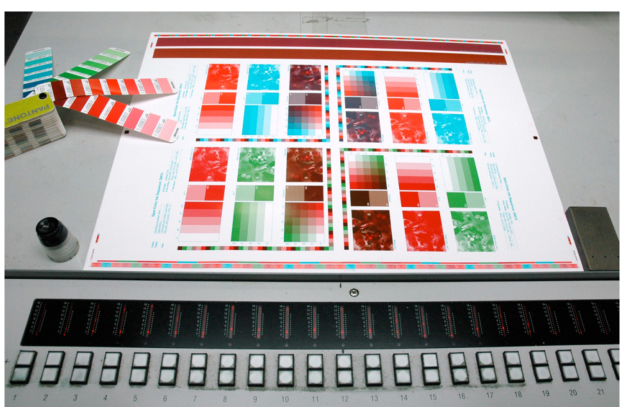

Figure 3. *Spot color overprint test form.*

Results and Discussion

The results of this research can be discussed in the following aspects: (A) effect of ink sequence on overprint color, (B) ink trapping as a function of ink tack, (C) gravimetric ink trapping convergence of uni-tack inks, and (D) comparison of overprint colors by printing and by ink drawdown.

A. Effect of ink sequence on overprint color

It is appropriate to first demonstrate the problem in predicting spot color overprints using current premedia software. As shown in Figure 4, we use two spot colors of the same tack (Pantone 1788 and Pantone 7466) to print two color blocks by a 6-color Heidelberg sheetfed offset press. The top row is a 50% overprint tint and the bottom row is an overprint solid. The left side was printed with the Pantone 1788 ink first; the middle section was printed with the Pantone 7466 ink first; and the right side is the PDF as displayed in Acrobat with the "Overprint Preview" turned on.

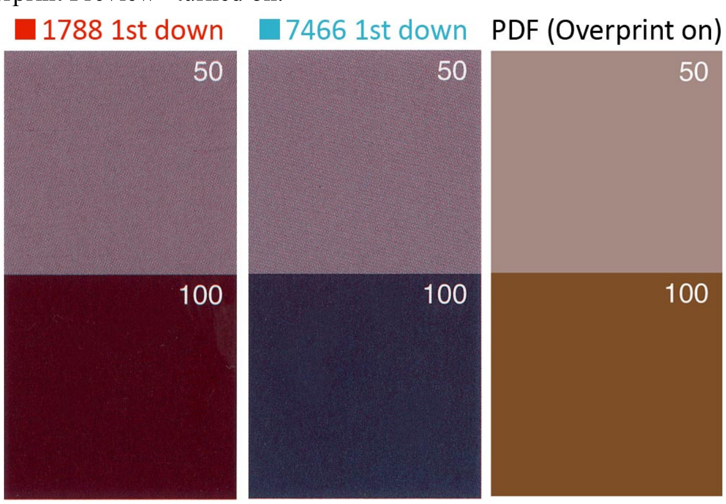

Figure 4. *Overprint solids in two ink sequences and the PDF display.*

While the color of the two 50% overprint-tints look similar to each other, the overprint solids look very different. In fact, the color difference between the two overprint-solids, due to ink sequence change, is more than 20 ΔE (Table 1).

Table 1. *Overprint color differences due to ink sequence change.*

	7466 (Tack 11) on 1788 (Tack 11)			1788 (Tack 11) on 7466 (Tack 11)			ΔE
	L*	a*	b*	L*	a*	b*	
Paper White	95.47	1.91	-7.40	95.66	1.82	-7.52	0.2
Pantone 1788	54.45	71.82	40.75	54.65	70.51	37.99	3.1
Pantone 7466	64.14	-51.68	-23.74	64.80	-51.04	-23.58	0.9
Overprint	27.02	28.83	0.23	32.16	10.49	-12.21	22.8

In terms of premedia display, the PDF in Acrobat Professional fails to predict either overprint solid correctly. Figure 4 points out that printing characteristics must be taken into color management consideration before spot color predictability can be improved in premedia software.

B. Ink trapping as a function of ink tack

Sun Chemical's sheetfed ink division, Kohl and Madden, provided spot color inks at three ink tack levels in this project. Ink tacks were measured and verified per ASTM D4361 procedures (ASTM, 2002). Six cases of ink samples were generated using the prescribed "ink sample preparation" procedure, on 100# SAPPI McCoy Gloss text. Table 2 summarizes ink tack (input) values and ink trapping (response) values in terms of $t_{Density}$, t_{ISO}, and t_{ITR}.

Table 2. *Ink tack and ink trapping values of two spot color inks.*

Overprint solid	Tack_1st	Tack_2nd	ΔTack (1st - 2nd)	$t_{Density}$	t_{ISO}	t_{ITR}
1788_T11 on 7466_T11	10.2	10.4	-0.2	0.49	0.81	0.81
7466_T11 on 1788_T11	10.4	10.2	0.2	0.62	0.64	0.60
1788_T14 on 7466_T14	13.8	13.6	0.2	0.50	0.79	0.79
7466_T14 on 1788_T14	13.6	13.8	-0.2	0.47	0.69	0.57
1788_T8 on 7466_T14	13.8	7.7	6.1	0.83	0.81	0.93
7466_T14 on 1788_T8	7.7	13.8	-6.1	0.04	0.31	0.36

Figure 5 shows the relationship between ink tack difference (ΔT or $Tack_{1st}$–$Tack_{2nd}$) and ink trapping responses. All three ink trapping values, i.e., $t_{Density}$, $t_{ISO,}$ and t_{ITR}, increase as ΔTack increases.

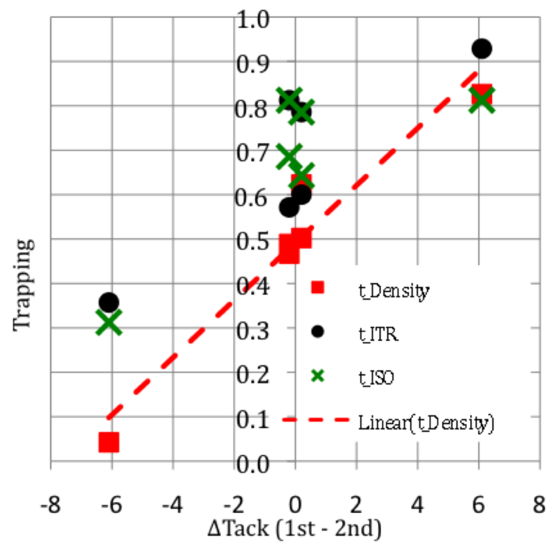

Figure 5. *Wet-on-wet ink trapping as a function of ink tack.*

When ink trapping increases, more of the second-down ink is transferred which causes the overprint color bearing more colorimetric influence of the second ink. The opposite is also true. When printing with uni-tack inks, ink trap converges as tack differences reduce. The density-based ink trapping, $t_{Density}$, converges at the value of 0.5 when two inks with the same ink tacks (11 and 14) are overprinted.

C. Gravimetric ink trapping convergence of uni-tack inks

With regard to gravimetric ink trapping, there is little difference between the t_{ISO} and t_{ITR}. This is due to the fact that the weight of the second ink transferred to an unprinted coated paper is the same as that transferred to a dry first ink sample. If uncoated paper is used as the substrate, t_{ISO} will be less than t_{ITR}. This is due to ink weight on uncoated paper is like greater than on coated paper. While gravimetric ink trappings of uni-tack inks also converge, the converging ink trapping value is 0.7 +/- 0.1 and is higher than density-based ink trapping of 0.5.

D. Overprint colors by printing and by ink sample

The gravimetric method is intended to find out the ink trapping value, not the overprint color. But we were curious how overprint colors by printing and by ink sample preparation compare to each other. Figure 6 shows colorimetric comparison between the offset print and ink drawdown using tack 11 inks.

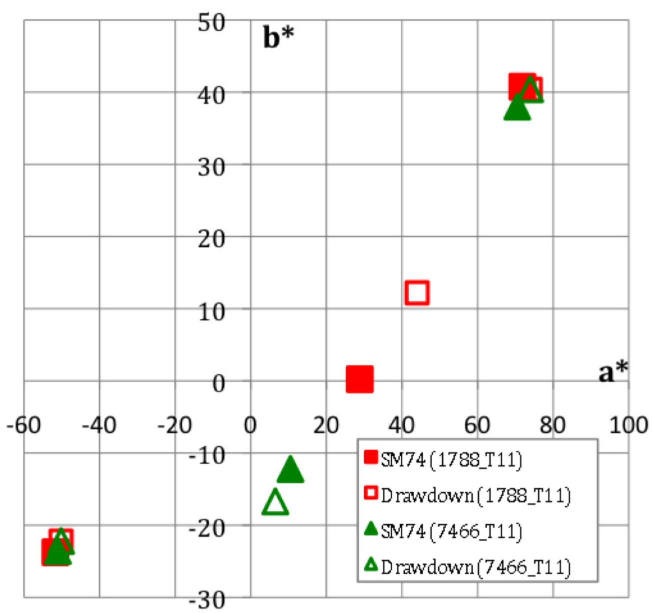

Figure 6. *Colorimetric comparison between ink sample and print.*

Notice that colors of solid inks in Figure 6 are similar between the print and the ink sample. This is due to the fact that the same ink, ink film thickness, and same paper are used for ink sample preparation and printing. Figure 6 also shows that colors of the overprint solids are different between the prints (solid marks) and ink samples (outline marks) under the same ink sequence. Similar differences were seen between prints and ink samples using tack 14 inks.

A possible cause of color difference in overprint color by printing and by ink sample is the difference between the "effective" tack of the ink as opposed to its "apparent" tack. To explain, apparent tack is defined as the force required to split a thin ink film between two rapidly separating surfaces; it is a rheological parameter indicative of internal cohesion of the ink (ASTM, 2002). While ink tack is measured at a specific temperature and at a specific time delay, the tack of the first ink is changing as printed sheet travels from the first printing nip to the second printing nip. For a sheetfed offset press running at 8,000 impressions per hour, the paper will take 2–3 seconds to travel between any two adjacent printing nips. This suggests that the effective tack of the first ink film will be higher than its apparent tack by the time it is overprinted with the second ink film. Thus, higher ink trapping will render the overprint color with more influence of the second-down ink.

Conclusions and Further Research

The motivation to study weight-based ink trapping is to be able to predict overprint colors in wet-on-wet printing. The Preucil ink trapping formula requires optical measurement of printed samples. In addition, there are two unknowns in one equation. Gravimetric or weight-based ink trapping presents a possible solution because ink trapping can be determined independent of printed sheets.

A series of ink transfer experiments using inks of known tacks were carried out in this project. We learned that gravimetric ink trapping is proportional to the tack difference between the first-down ink (high) and the second-down ink (low). For uni-tack inks, gravimetric ink trapping converges at 0.7 with a +/- 0.1 spread.

Further research includes (1) testing more uni-tack ink sets for ink trapping convergence, and (2) development of a spectral-based overprint model to predict the color of the overprint solid by treating ink trapping value as a constant.

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