FURTHER COMPARISON OF CONVENTIONAL VS. WATERLESS LITHOGRAPHY

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Abstract

A series of designed experiments involving four press runs were conducted at RIT using a four-color sheet-fed lithographic press. The press was retrofitted with temperature control system and is suitable for conventional and waterless printing. The objective was to learn more about press performance differences, quantitatively and statistically, between conventional and waterless lithography. Specifically, we want to find out (1) whether waterless printing is more consistent (over time) in solid ink density, and (2) whether waterless printing produces less dot gain than its conventional counterpart. This research concludes that waterless printing is only as good as conventional lithography in achieving solid ink density consistency over time, but not better. Furthermore, the average of dot gain of waterless printing is the same as conventional lithography, but not less. Further research and testing in the area of temperature monitoring and regulation for improving the press performance are discussed.

Introduction

Conventional lithography is a mature and the most used printing process for high quality printing in the graphic arts industry today. It has been serving as a benchmark point for many innovative printing processes, e.g., inkjet, electrophotographic, thermo dye transfer, etc. By means of benchmarking, some processes learn where its technology must be improved before it can be accepted by the market; some processes are pleased to show that it can produce the same level of quality as the "best in class" printing technology. Ultimately, all processes wish to show that they have exceeded their benchmark points.

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Comparing to many non-impact printing processes, waterless printing is a close derivative of the conventional lithography. In conventional lithography, the use of water is necessary to keep the non-image area of the plate desensitized during printing. In waterless printing, silicon-coated waterless plates, special formulated inks, and temperature regulation system in the lithographic press are necessary.

By eliminating the use of water and fountain solution additives, the industry perception of the waterless printing is that it's an environmentally friendly process; it offers a shorter press makeready cycle; it also produces more consistent printing. Although perception is a reality, there is not a lot of quantitative data to elaborate and support such perception as benchmarking findings. This has been a motivational factor behind our research interests.

Research Questions

Our TAGA 94 paper indicates no quantitative evidence that waterless printing is more consistent than conventional printing [1]. This being a continuation of the waterless research project, the objective was to learn more about press performance differences, quantitatively and statistically, between conventional and waterless lithography. Specifically, we want to find out (1) whether waterless printing is more consistent (over time) in solid ink density, and (2) whether waterless printing produces less dot gain than its conventional counterpart.

Notice that we focus our attentions on process consistency and its capability as a measure of press performance. A consistent printing process is important for device characterization and is critical to the success of any color management systems [2]. Process capability is something that statistics can help determine based on designed experiments. One limitation in this research is that we are not trying to address if there is significant difference in productivity between conventional and waterless lithography.

Methodology

This being a continuation of the waterless research project at RIT, special attentions were given to the selection of press, paper, test form, plate, ink, etc. The following offers further explanations of the experimental conditions:

(a) Same press: A Heidelberg Speedmaster 4-color sheetfed press was used. The press was retrofitted with a temperature control system for each printing unit with must be turned on during presswork. Thus, the temperature regulation was set at 75° F for both waterless and conventional printing. The makeready speed and running speed were both at 8,000 impressions per hour. The color sequence was in the order of KCMY.

(b) Same paper: Uncoated No. 1 premium opaque paper, 17.5" x 22.5", 60 lbs. basis weight.
(c) Same test form: The GATF digital test form consists of a collection of synthetic test patterns and pictorial images.
(d) Different plate and ink combinations: For waterless printing, Toray negative-working plate and Dainippon dri-o-color ink were used. For conventional printing, 3M Viking negative-working plate and G.P.I. ink were used.
(e) Same printing specifications: Both conventional and waterless printing are to conform to the same solid ink density (SID) specifications (also see the next section). The tolerance is ±10% of the SID for each of the process inks.

Special attentions were also given to plate exposure and press run procedures. The following offers further explanations:

(a) Same press operator for color control: One of the authors of this paper who teaches presswork was the press operator. Press adjustments were allowed only by him during press runs. Press adjustments were based on experiences of the operator and the use of a Heidelberg's CPC2 color control system. We believe this best simulates typical printing conditions. Assistants were available for ink fountain change over, paper handling, press makeready, press sheet sampling, clean up, etc.
(b) Plate exposure: Both conventional and waterless plates were exposed to the same degree as determined by the Ugra plate exposure wedge, i.e., solid step #4.
(c) Four press runs in two days: The first day was for the press operator to become familiar with printing the test form. It also helped determine the printing specifications in terms of solid ink density. The second day was the printing experiments where press sheets were sampled. The run sequence was determined by flipping of a coin. The press run began with the waterless run on the second day. It was followed by the conventional run.
(d) Press sheet sampling: Samples were pulled every 80 impressions. The press run lasted for 60 minutes. Consequently, a total of 100 samples were collected for each press run.
(e) Data collection: Solid ink density and dot gain are measured from one section of the color control bar (page 2 of the GATF digital test form) by a X-Rite's X-Scan scanning densitometer.
(f) Press temperature monitoring: With the assistance of Dr. Shem-Mong Chou of Rockwell International, an infra-red thermometer was used to measure ink form roller temperature during the press run.

Determining Process Stability and Consistency

Statistical data analysis procedures were scrutinized to assure valid comparison. An important consideration is that process stability must be evident before calculating the process consistency. In this experiment, data suggesting special caused variations were excluded with the use of the statistical analysis software called JMP [3]. By doing so, process stability can be determined and the comparison of process consistency can then be carried forward.

To determine process stability, we used statistics such as histogram, individual and moving range charts, and the Shapiro-Wilk test for normal distribution as means of "leveling the playing field" in our previous research effort [1]. We had difficulties in making clear distinctions because multiple criteria for process stability were utilized. In this research, we used the R chart, as in x-bar and R charts, with a subgroup size of four as the sole criterion to eliminate data points suggesting special-caused variation [4]. The assumptions are that (1) short-term variations of a stable process are random, and (2) a stable process can exhibit data trend in its x-bar chart. As an example, Figure 1 illustrates the x-bar and R chart of the waterless press run. Notice that data points within a subgroup with its range greater than the control limits (two points circled) are excluded. However, data shown at the beginning of the x-bar chart, suggesting trending, are left alone.

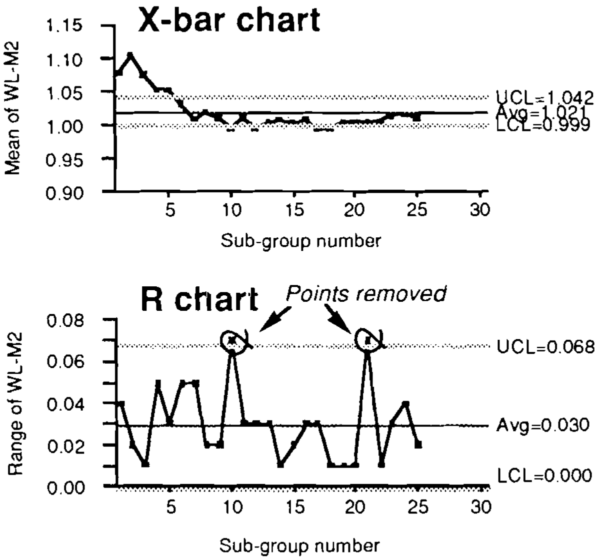

Figure 1. X-bar and R chart.

Process consistency is how repeatable the process is with only random variations present. The magnitude of process consistency is expressed as 6σ where σ (pronounced *sigma*) is the standard deviation of the data with special caused data excluded. Process capability, or CP, is equal to tolerance divided by 6σ [5]. The higher the CP is, the more consistent the process is. Since both waterless and conventional processes are subject to the same printing specifications (tolerances), the magnitude difference of σ determines which printing process is more stable or capable.

Results and Discussion

Table 1 and 2 summarize solid ink density consistency comparison between waterless and conventional printing. Both processes were screened for special cuased variations. Up to 8% of the data were excluded to reach to process stability. Whether by comparing CP or 6 sigma of the process, it becomes evident that waterless is only as consistent as the conventional process, but not more consistent.

Table 1. Process performance summary—Waterless SID

	Waterless solid ink density			
Ink Color	K	C	M	Y
Sample size	100	96	92	100
# of data points removed	0	4	8	0
Subgroup size	4	4	4	4
x-bar-bar	1.126	0.882	1.022	0.769
UCL (x bar+ 3sigma hat)	1.150	0.897	1.041	0.783
LCL (x bar- 3sigma hat)	1.101	0.867	1.003	0.755
sigma hat	0.017	0.010	0.013	0.010
6 sigma hat	0.099	0.061	0.076	0.058
R-bar	0.034	0.021	0.026	0.020
Special caused variations	No	No	No	No
Aim point	1.10	0.89	1.10	0.79
USL (+10% of aim point)	1.210	0.979	1.210	0.869
LSL (-10% of aim point)	0.990	0.801	0.990	0.711
Tolerance	0.220	0.178	0.220	0.158
CP	2.22	2.91	2.90	2.71
Process capable (1.33)?	Yes	Yes	Yes	Yes

Table 2. Process performance summary—Conventional SID

	Conventional solid ink density			
Ink Color	K	C	M	Y
Sample size	100	96	100	100
# of data points removed	0	4	0	0
Subgroup size	4	4	4	4
x-bar-bar	1.134	0.835	0.825	0.739
UCL (x-bar + 3sigma hat)	1.160	0.852	0.840	0.729
LCL (x-bar - 3sigma hat)	1.109	0.818	0.809	0.718
sigma hat	0.017	0.011	0.011	0.007
6 sigma hat	0.105	0.067	0.064	0.041
R-bar	0.036	0.023	0.022	0.014
Special caused variations	No	No	No	No
Aim point	1.10	0.89	1.10	0.79
USL (+10% of aim point)	1.210	0.979	1.210	0.869
LSL (-10% of aim point)	0.990	0.801	0.990	0.711
Tolerance	0.220	0.178	0.220	0.158
CP	2.10	2.66	3.43	3.87
Process capable (1.33)?	Yes	Yes	Yes	Yes

Table 3 summarizes the magnitude of dot gain between waterless and conventional printing. Dot gain is computed in accordance with CGATS.4 with the use of Murray-Davies equation [6]. Contrary to industry perception, when plates are exposed to the same degree, as indicated by the Ugra plate exposure wedge, there is no significant dot gain difference between them.

Table 3. Dot gain comparison

	Waterless (ave +/- 3s)	Conventional (ave +/- 3s)
Black	25.3 +/- 3.09	23.91 +/- 3.22
Cyan	19.05 +/- 2.74	19.67 +/- 3.38
Magenta	20.75 +/- 1.63	20.46 +/- 1.32
Yellow	19.05 +/- 2.62	20.31 +/- 2.45

Figure 2 shows plate/press curves of waterless and conventional press run. The press sheet selected for measurement was from the middle of the press run. These graphs confirm the similarity in dot gain at the 50% dot area level between the two printing processes.

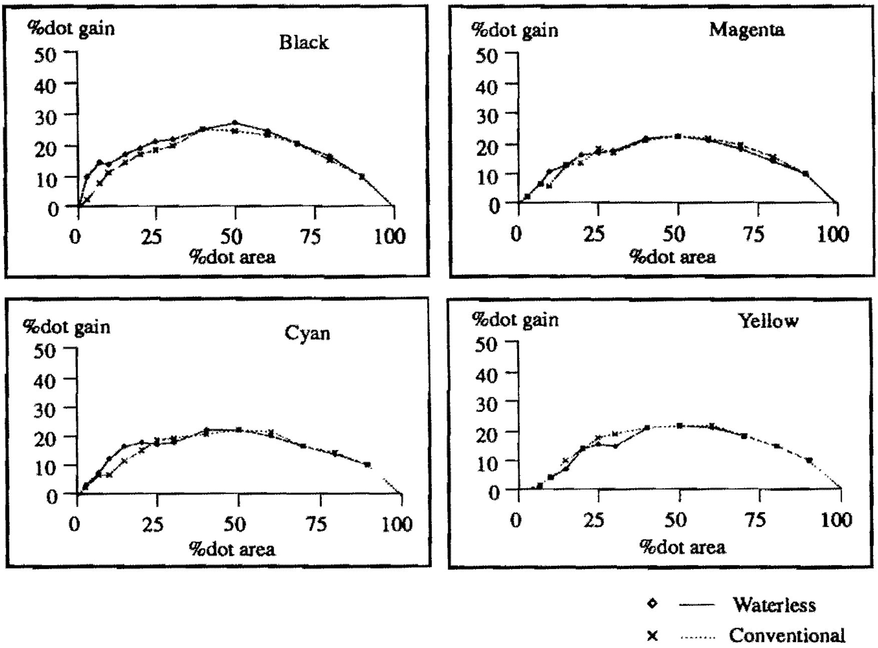

Figure 2. Plate/press curves of waterless and conventional printing.

Table 3 summarizes average press temperature and its variations between the two processes. A total of 20 temperature measurements were taken at ink form rollers for each press run. Even the temperature was regulated at 75° F, we were surprised by the higher average temperature and larger temperature variation found in the waterless press run. We suspect that the presence of water in conventional lithography helps dissipate heat from the plate into the room atmosphere. Thus, it provides consistency in maintaining solid ink densities and press temperature.

Table 3. Press temperature comparison

	Waterless temp. (°F)				Conventional temp (°F)			
Ink color	K	C	M	Y	K	C	M	Y
Sample size	20	20	20	20	20	20	20	20
x-bar	81.42	76.51	79.96	84.96	75.91	75.91	76.37	80.83
6 sigma	7.02	2.7	2.76	7.56	4.68	1.68	2.94	3

Summary

We see the merit of using x-bar and R chart as an effective means of weeding out special caused variations from the data. Up to 8% of the data were excluded prior to process capability calculation. This adds validity to claiming process stability and the calculation of process capability.

Knowing that conventional lithography is the "best in class" printing technology, we find it difficult to prove that waterless printing is more consistent than its benchmark point. We could not find significant differences in dot gain between the two processes either. Visually, we cannot distinguish the printed images apart. We conclude that waterless is only as good as conventional litho, but not better.

Consistencies of solid ink density and dot gain are functions of inking conditions. Inking conditions are temperature dependent. We believe that press temperature control and regulation are critical to consistent press performance. Temperature control cannot be just a feature in waterless printing, but all printing presses. This is an area that warrants further research.

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