AN INVESTIGATION OF PRESS RESPONSE TIME DUE TO INKING CHANGE ON A WEB OFFSET PRESS

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Abstract: The implementation of SPC for process color printing requires that the inclusion of color control bars, a sampling and measurement procedures, data collection, analysis, and interpretation in real-time, and appropriate corrective actions and feedback to ensure that the process is capable and is in control. In order to achieve statistical control of a printing process, the differentiation between special-caused variation and common-caused variation is a prerequisite. Further, sampling of press sheets, when inking changes have been made, must be appropriate to avoid over control, thus, process tempering. This paper describes an innovative method of using x-bar and R charts to investigate the response time of a web offset press when inking changes are made. Initially, a test form with two identical halves was printed uniformly across the width of the web. Then two levels of inking changes were made on either side of the test form. Density measurements on solid ink patches were collected and analyzed for the transient phase, i.e., from before the inking change was introduced to after another inking equilibrium was shown on sampled press sheets. Additionally, colorimetric measurements on three-color overprint tints were collected and analyzed from sample press sheets in a similar fashion. It was concluded that the press response time is inverse proportional to the amount of inking change made, i.e., a small inking change takes longer to reach to its equilibrium than a larger inking change would. From process control and optimization viewpoint, measurement of solid patches is preferred over measuring tint patches. Such findings help optimize the SPC implementation in pressroom and ensure that the risk of over sampling is avoided.

INTRODUCTION

Color measurement and the use of statistical process control or SPC techniques have provided pressroom personnel with tools for better understanding process variations. Having the ability to use SPC to differentiate between special-caused variation and common-caused variation, this provides us with the ability to control a press run with the use of control charts.

Normal uses of control charts is to attain a state of statistical control. This requires sufficient subgroups with subgroup size varying when sampling. The use of control charting helps monitor a process and determine process

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capability. As pointed already, control chart provides a basis for detecting assignable-caused variation and corrective action. In this paper, the control chart of x-bar and range will be used in an unorthodox manner to investigate the press response time when an inking change is made.

Before we discuss the research question, a few terminology need to be explained. the term, *steady state*, refers to the state of a printing press when control settings have been left undisturbed for a long period of time. A *step-change* refers to the change in press control settings from a reference settings to different settings. *Response time* is the time required for the printing press to stabilize between step-changes. This is often estimated in the number of impressions between the initial and final steady state of a press. *Induction period* is the time delay which occurs before the press starts to respond to a step-change. The length of the time delay is influenced by the ink train design. Typically the inking system consists of twenty or so rollers arranged in a train for transporting ink from the ink reservoir to the lithographic plate. Finally, *ink coverage* is the image area of a plate expressed as a percentage of the total plate area.

PRESS RESPONSE DUE TO INKING CHANGES

Review of literature

A close loop system is characterized by the fact that controlling variables are accomplished by measuring it, and comparing it to a reference, then act on the difference that is deemed assignable-caused so as to reduce the error to an acceptable level. Today, most printing presses are not being controlled as a close loop system. If we agree that the printing operation can be controlled as a close loop system, then the need to develop a systematic procedure for close loop color control on press is paramount.

Understanding and modelling press responses due to statistical fluctuations and special-caused variations are essential steps in developing close-loop color control system. Studies of dynamic press responses of a lithographic offset press were reported by C. C. Mills[1] and, later, by Neuman and Almendinger[2]. In Neuman and Almendinger's studies, two classes of models are sought: static models to describe the steady state operation of the process, and dynamic models to characterize the process response following step-changes in the press control settings. In both cases, solid ink densities are used as response variables. When studied effects of step-changes in water feed, press speed, and impression cylinder pressure, overall response time for each condition was short, i.e., 15 to 20 impressions. This is not the case for a step-change of ink feed. Neuman and Almendinger reported a slow response time of 226 to 1855 impressions. Mill's experimental results were similar to those of Neuman and Almendinger's in that less time was needed for ink feed increase than for ink feed decrease between the initial and final steady state of a press.

John MacPhee took a different approach to study press response time. He developed a model for calculating mean ink residence time as a function of press speed, ink coverage of the signature, and the number of rollers in the inking system[3]. MacPhee's model assumes a steady state printing conditions and it does not take step-changes into considerations. Consequently, discrepancies exist between his calculations of the press response time and experimental findings of Neuman and Almendinger's. Specifically, a sheetfed press run with an ink coverage of 25% was studied by Neuman and Almendinger. They reported that the press response time of 80 -102 impressions for a step increase in ink feed, and 160 -190 impressions for a step decrease. Based on the ink train and ink coverage factors, MacPhee's calculation showed 158 impressions as the press response time. Further, no explanations were given as to why the response time was different for ink feed increase and ink feed decrease in Neuman and Almendinger's experiment.

Objectives of the study

The above literatures are indeed pertinent to our studies of the effect of ink feed change and the transient response of a press. Without such knowledge, we run the risk of either under or over sampling when controlling a lithographic press. Specifically, we wish to address the following issues with the use of x-bar and range charts and two different color measurement techniques: (1) to devise a method to characterize the steady state of a press, (2) to devise a method to determine the press response time when ink feed is changed, (3) to find out if the response time is independent of the amount of ink feed change, (4) to find out if using colorimetry will generate the same findings as using densitometry.

EXPERIMENTAL

Test form

A test form, consists of two identical halves, was designed for the RIT's Harris M1000B web offset press. This helps accomplish the ink feed changes at two levels simultaneously. Only the yellow printer was varied while cyan, magenta, and black printers were left unchanged. The amount of inking change is denoted by the number of LEDs displayed on the remote inking console. A large ink feed increase resulted in a blue filter density increase of 0.25 for the solid yellow patch. A small ink feed increase resulted in a blue filter density increase of 0.15 for the solid yellow patch.

Sampling and Measurement

The press speed of 400 fpm was used for the press makeready. It then ran at the printing speed of 1,200 fpm. By ways of pilot studies, we learned that (1) it is not possible to perform any real-time press sheet sampling, (2) the total of the induction and the transient time is less than three minutes. Thus, we collected all the press sheets for a duration of three minutes which is from the time of ink feed change to three minutes after the inking change is made. In a post facto analysis, press sheets are sampled at 1 every 10 impressions in order to reduce the number of press sheets measured. At the 1,200 fpm press speed, each sample is about one second apart in real time.

Measurement were made at one location per sampled press sheets. Both densitometric and colorimetric measurement were performed. We chose to measure a solid yellow patch densitometrically, and a three-color (near neutral) tints colorimetrically.

Interpretation of x-bar and R charts

Data collection and plotting of x-bar and R charts were done with the use of the Excel spread sheet and a statistical package called, Process Control Chart Tool Kit, running on a Macintosh computer. Before we discuss an innovative use of the x-bar and R charts, we should first review normal uses of the charts. Charts for X-bar and R should be placed one above the other so the average and range for any one subgroup are on the same vertical line (figure 1). When one or more data points are outside the X-bar's control limits, this is an indication that a general change has affected all pieces after the first subgroup is out of limits. When one or more data points are outside the R's control limits, they are evidence that the uniformity of the process has changed. In this case, ink feed was the only intentional variable conducted in the experiment.

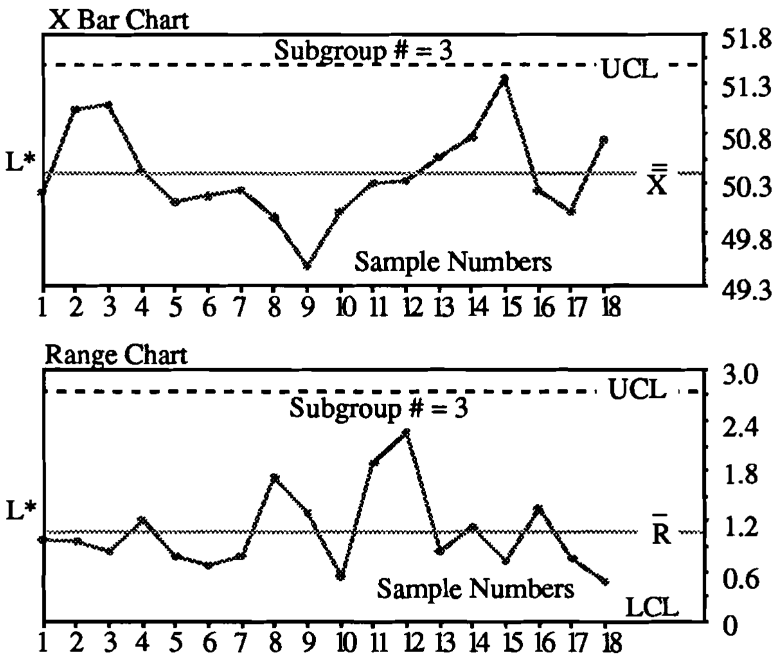

Figure 1. An example of x-bar and R control charts

During the data analyses, we noticed that the choice of the sub-group size has a profound effect on the resulting x-bar and R charts. Figure 2 shows the x-bar and R charts of the press response profile due to the large inking change in density. Here, the subgroup size is 2.

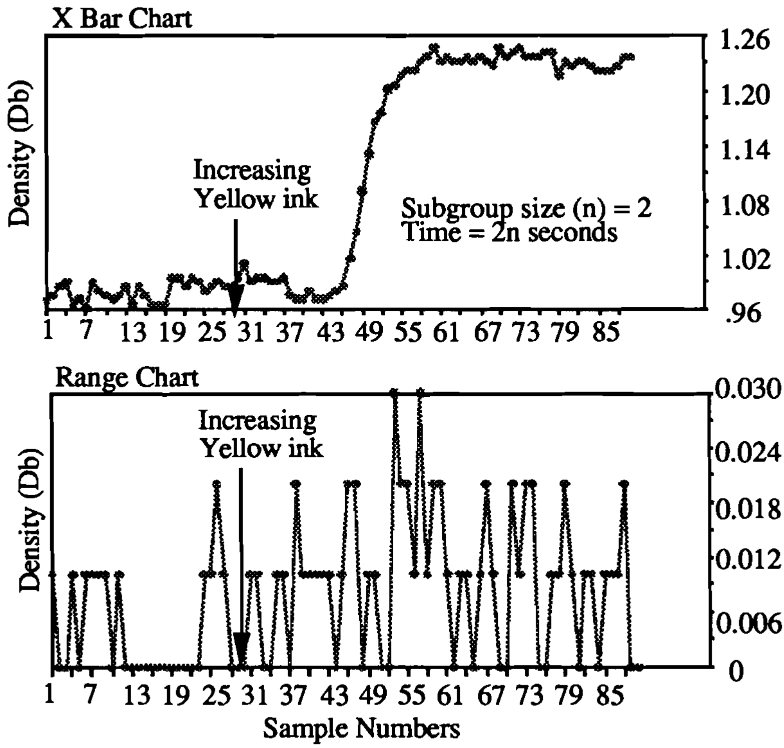

Figure 2. The press response profile in x-bar and R charts with subgroup size of 2.

Figure 3 shows the same set of data with the subgroup size of 10. As one can see, the larger the subgroup size, the less noise is in the plots and the easier it is to spot trends. On the other hand, the larger the subgroup size, the less precise the response time can be determined. It was decided that two subgroup sizes of 7 and 15 be used for data analyses (private communication with Professor Hubert Wood). Thus, the range of the press response time is plus or minus one-half of the subgroup size. This range can also be expressed in terms of seconds since the press was running at a constant speed and the sampling was done in equal intervals, i.e., one sample every ten press sheets or one sample every second at the printing speed of 1,200 feet per minute (fpm).

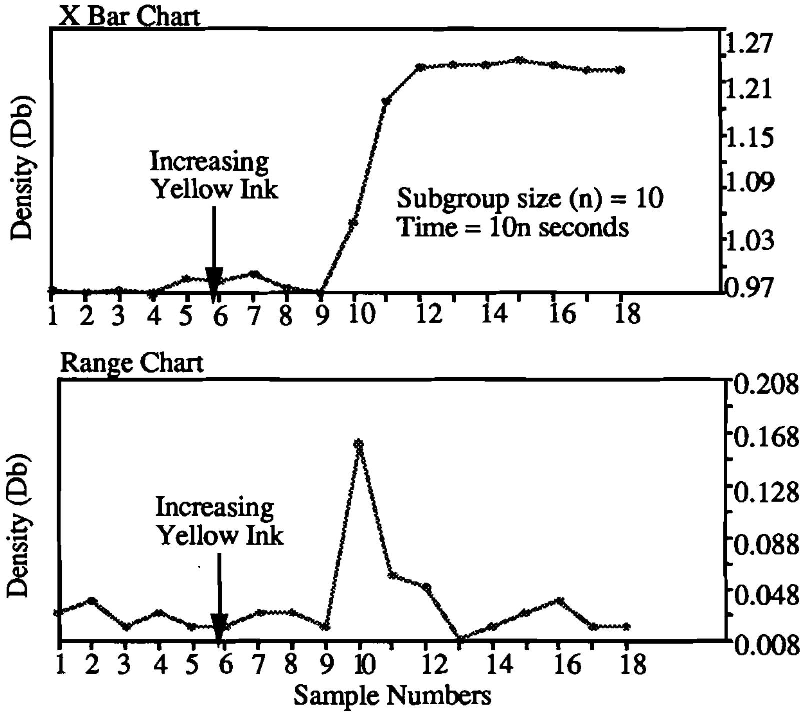

Figure 3. The press response profile in x-bar and R charts with subgroup size of 10.

Reversing the time series to detect the new inking equilibrium

We found out that using x-bar and R charts along with statistics like mean, range, and standard deviation to analyze data from the steady state of the press run characterize the random fluctuations of the printing process. The press response time is the difference between the initial press equilibrium and the final press equilibrium. There was no problem in identifying the time before the step-change since this is under the total control of the experimenter working with the press crew. However, to identifying the timing right after the step-change was not certain. In fact, two persons could not interpret the same charts with the same results. And this is how the innovative way of using the x-bar and R charts was developed. To explain, we rely on the interpretation of x-bar and R charts by reversing the time series to relocate the first out-of-control data point. The control limits are based on the steady state of the press. Both x-bar and R charts gave us two evidences of the final equilibrium point.

RESULTS

The press response time due to inking changes based on densitometric data is summarized in Table 1. Here, the large inking change is the result of increasing the number of LEDs on the remote inking console by a factor of two. The resulting density increase, measured through the blue filter, on the yellow solid ink patch is 0.25. The small inking change is the result of increasing 50% or half of the number of LEDs on the remote inking console. This yields a density increase of 0.15. Two subgroup sizes of 7 and 15 were used to determine the press response time. Both results showed that the press response time is smaller for the large inking change. Since the findings do not overlap, we conclude that there is a significant difference in press response time due to a step-change in ink feed. The response time is greater than 50 seconds for a large inking change, and greater than 70 seconds for a small inking change. The choice of the subgroup size influences both the accuracy and precision of the response time.

Table 1. Press response time due to inking changes by densitometry

		Subgroup size	
Treatment	Δ Density	7	15
Large inking change	0.25	52.8 +/- 3.3 sec.	71.0 +/- 7.1 sec.
Small inking change	0.15	72.6 +/- 3.3 sec.	85.2 +/- 7.1 sec.

Table 2 summarizes the press response time due to inking changes based on colorimetry. Only b* values were analyzed because color variations of the 3-color neutral patch due to yellow ink increase primarily is in the yellow-blue axis of the CIELAB color space. The results showed that the press response time is smaller for the large inking change. The response time is greater than 70 seconds for a large inking change, and greater than 90 seconds for a small inking change. Based on these findings, we conclude that using colorimetry will generate similar findings as using densitometry.

Table 2. Press response time due to inking changes by colorimetry

		Subgroup size	
Treatment	Δb*	7	15
Large inking change	18	72.6 +/- 3.3 sec.	99.4 +/- 7.1 sec.
Small inking change	13	99.0 +/- 3.3 sec.	113.6 +/- 7.1 sec.

DISCUSSIONS

Using x-bar and R charts in an unconventional manner to analyze densitometric data as well as colorimetric data for the press response time due to inking changes, we are able to conclude that a small inking change takes longer to reach a new steady state. The press response time is about 60 to 85 seconds at 1,200 fpm speed for the Harris M1000B web offset press. This corresponds to 630 to 900 impressions respectively. The number of impressions is far greater than those reported by Neuman and Almendinger (80 - 102 impressions for a single-color sheetfed press).

Similar findings are concluded about press response time either determined by colorimetry or densitometry. But the response time is shorter when solid ink patches are measured. The fact that the solid yellow ink patch responded quicker in ink feed change than a 3-color neutral patch has to do with differences in % dot area of yellow printer in the image area. The effect should be similar to what was reported by MacPhee, i.e., the press response time increases when the ink coverage of the plate decreases.

We also found out that the press response time is a function of the subgroup size used in the x-bar and R charts. We do not have strong opinions regarding what subgroup size one should use. However, the preferred subgroup size should be determined by observing trends in both x-bar and R charts.

The following areas may require further studies: (1) To investigate the press response time as a function of ink feed decrease and ink coverage on the plate; (2) There is an induction period after the inking change is made on the press. The length of the induction period may be further investigated to see if it is a function of the amount of inking change introduced; (3) In terms of where to measure, it is our observation that measuring a solid ink patch is preferred over measuring a 3-color neutral tints in this experiment. This is because that tint patches are subject to color variations due to both inking changes and dot gain and doubling variation where solid ink patches only respond to inking changes. This way, there will be less noise in the solid ink data analyzed. But this takes away the simplicity that a single colorimetric measurement made at a 3-color tint can tell possible variations in cyan, magenta, and yellow printers as opposed to measuring all three solid ink patches to accomplish the same. This represents an important strategic difference in terms of process control. It definitely warrants further investigation.

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