Validating A Model-Based Ink Key Presetting System

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ABSTRACT: A model-based ink key presetting system for offset presses was reported at TAGA 97. The system was centered on a steady-state inking system model which comprised the effects of the roller train, vibrators, overall system gain, and density-inkfilm thickness relationship. A number of press tests with specific plate designs were performed for determining the critical parameters of the model. The system was then implemented for ink key presetting based on the plate coverages for various printing jobs. This paper includes a review of the model, determination of the model parameters, results of presetting, and a discussion of issues for further enhancement of the presetting system.

Introduction

As the technology is changing rapidly in the graphic arts industry, it has become possible to create a digital bridge between electronic prepress and pressroom with an ink key presetting system which can analytically preset ink keys and shorten make-ready time. In the ink key presetting process, the plate coverage is estimated from a digital plate file or by using a plate scanner. Via an inking system model, optimal ink key openings are further estimated and ink keys and fountain roller speed are set automatically through an electronic interface.

During our literature search, we found many industry vendors (such as Creo, Scitex, Ultimate Technographics, Screen, and Heidelberg) are pursuing digital ink key preset solutions. Most of the vendors, automatically (with built in software) generate ink key profiles (usually CIP3 compliant) during the prepress stage and route the information to press through an interface. The ink key profiles are usually low-resolution continuous-tone image representing ink

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coverage of each plate. This process eliminates the need for plate scanners, generating better ink profiles and coverage information from first generation digital data, resulting in faster make-ready and better workflow. However, we were not able to find any technical details about their respective products. Also there has been no TAGA paper discussing the benefits of make-ready due to implementing ink key presetting, which tempted us to pursue this project.

In the ink key presetting process, a file containing all ink keying information is created during the prepress stage. The file automatically sets the ink keys on the press for perfect ink key presetting and fountain roller speed. All the ink presettings are calculated directly from the imaging data and are stored on the computer in the network. The resulting ink management file can be transferred to the press, before or after exposing the film or plate. When the job is ready to go to the press, all the ink key data is ready and waiting. By using the first generation digital file for calculating ink key presetting values, we no longer need expensive plate scanners to produce "ink profiles" for presses. The calculations are based on raw data from the same RIP used for rastering the PostScript files.

Brief review of the model:

The ink key presetting system was based on the inking system model developed by us (Chu and Seymour, 1997). In the model, the roller train was modeled by nip equations with 50-50 split ratio; vibrators were modeled as a series of convolutors and were represented with a square matrix; the relationship between density and ink film thickness on paper was modeled as an exponential function; and all other parts were modeled with a linear relationship.

Based on this model, the ink film thickness is described by Eq. 1, and density-thickness relationship by Eq. 2. All model parameters can be determined by a specially designed press test via these equations. Ink key presetting can then be determined following Eq. 3.

$$f_i \propto \frac{r - r_0}{(a_0 + (1 - a_0)c_i)} V_i (I - B) \qquad (1)$$

$$d_i = d_s(1 - e^{-hf_i}) \qquad (2)$$

$$(r - r_0)(I - B) = -\frac{1}{h} V^{-1} \begin{bmatrix} (a_0 + (1 - a_0)c_1)\ln(1 - \frac{d_1}{d_s}) \\ \dots \\ (a_0 + (1 - a_0)c_n)\ln(1 - \frac{d_n}{d_s}) \end{bmatrix} \qquad (3)$$

with,

i	zonal index, from 1 to n,
a_0	minimum relative inking level, depending on roller configuration, from 0 to 1,
$I - B$	zonal key opening minus its offset, a vector for all keys.
$r - r_0$	fountain roller speed setting minus its offset,
c_i	zonal coverage,
f_i	zonal ink film thickness,
V_i	zonal vibrator vector (row vector),
V^{-1}	inverse of the vibrator matrix,
h	gain factor,
$d_1 ... d_n$	zonal densities,
d_s	saturation density,

Eq. 1 states that the zonal ink film thickness is a function of coverage, fountain roller speed, key opening, and vibrator setting. In other words, the higher the coverage, the thinner the ink film thickness, and vice versa. A minimum relative inking level, a_0, is necessary to supply the ink stored on rollers. Ink film thickness is proportional to both fountain roller speed setting and key opening, minus their corresponding offsets. The zonal ink film thickness is further complicated by the ink spread caused by the vibrators. The vibrator matrix consists of rows of ink spread curves which is a function of the corresponding zonal coverage. The proportional sign instead of equal sign is used in Eq. 1 for there are other gain factors such as the effects of ductor roller and press speed (presumably to be a linear relationship), affecting the ink film thickness on paper.

Eq. 2 states that the optical density of the printing is basically linear-proportional to ink film thickness and gradually becomes saturated at high film thickness. The exponential coefficient, h, reflects the rate toward saturation, the higher the faster.

Eq. 3 states that the ink feed rate (the product of key openings and fountain roller speed) can be determined by following the formula. Both the key openings and roller speed affect the total ink feed rate. It is important that an appropriate roller speed is chosen such that an optimal resolution for key openings can be obtained. If all key openings are low, a lower roller speed should be set to allow keys to be opened more for better control. On the other hand, if all key openings are high, a higher roller speed should be set. This simple scaling issue is further illustrated in Fig. 1.

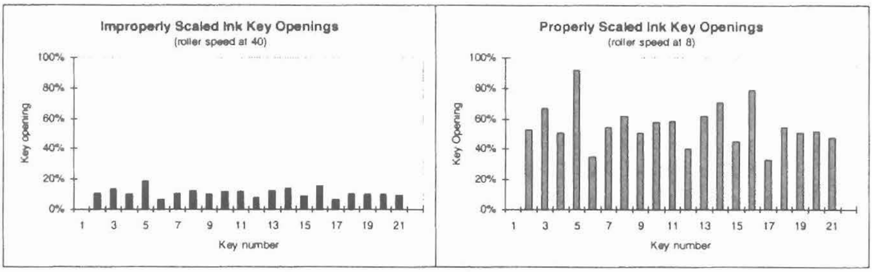

Figure 1. Selecting a proper key open range. (Left) The roller speed was set too high resulting very low overall key openings which provides very coarse key adjustment. (Right) After reducing the roller speed setting, the overall key openings are then scaled properly and provide the optimal resolution for fine adjustments.

The parameters that needed to be determined from press tests included the gain factor (h), vibrator matrix (V), saturation densities (d_s), key open offsets (B) and fountain roller speed offset (r_0). As for a_0, it has been determined from the roller train model to be around 0.46 depending on roller configurations. All other parameters can be read from instruments during the test or measured with a densitometer during or after the test.

Press test for parameters

A number of press tests were conducted with specially designed CTP plates for determining the press parameters. The test included tests for various levels of ink key openings, fountain roller speed settings, and ink spread by vibrators.

The plate design was very simple. It consisted of a number of solid horizontal (lateral) bars in non-overprinting process inks with various zonal coverages for each of the K, C, M, and Y inks, uniformly across the lateral direction. There are two benefits to use a uniform coverage design. First, the effects of vibrators can be ignored because the coverages are the same for all key zones, provided the key openings are all the same. In order words, the effects of vibrators will be nullified if the ink feed rate and ink throughput rate of all key zones are the same. Second, direct measurement of density with only one key open can provide ink spread information due to the vibrators' action, without further derivations.

The plates were designed with PostScript language, and then converted in a CTP system to generate the plates and preview files. From the preview files, the exact plate coverages were calculated to check against that of the original design.

A Harris M-1000B short cut-off web-offset press was used for the tests. All ink fountains were cleaned and calibrated prior to the test.

During the press run, make-ready was first achieved at low speed (500 fpm). Then the speed was increased to a nominal running speed (about 1500 fpm) for the test.

For each sub-test, a move was made, then a deck of signatures was pulled after a three minute stabilizing time. After the test, a densitometer was used to measure densities at designated spots of the signatures. The data were then further analyzed to obtain the parameter values we were looking for.

<u>Key Opening offset.</u>

The purpose of this sub-test is to find the key open offsets (B). As shown in Fig. 2 as an example, the relationship between density and key opening is basically linear until the density is increased to the saturation range. However, at the low opening range, the relationship deviates from linear. This is mainly caused by crooked ink keys (See Fig. 11 in Discussion for detail). The contacting surface to the ink roller forms a wedge when key opening becomes small and creates the non-linearity. The offset, B, can be calculated simply by extrapolating the linear curve to the abscissa.

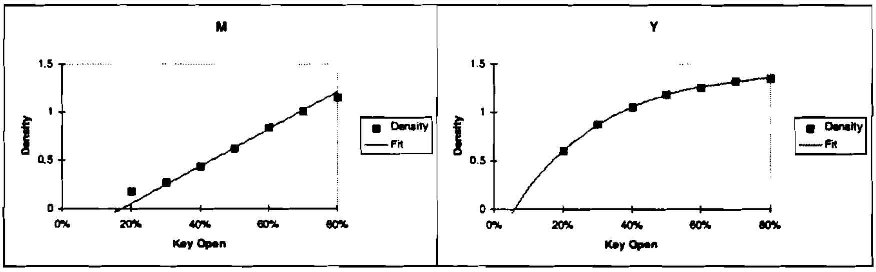

Figure 2. Density vs. Key opening. With 42% coverage, the M ink density depicts a linear relationship with key opening in all range except at 20% as shown in the left part of the graph. With 5% coverage, the Y ink density approaches the saturation density at higher key openings.

Fountain roller speed offset

The purpose of this sub-test is to find the fountain roller speed offsets. As shown in Fig. 3 as an example, the relationship between density and fountain roller speed setting is also basically linear until the density is increased to the saturation range, except at the lower end. The offset is negative rather than positive as in the case of key opening offset, and can be calculated simply by extrapolating the linear curve to the abscissa.

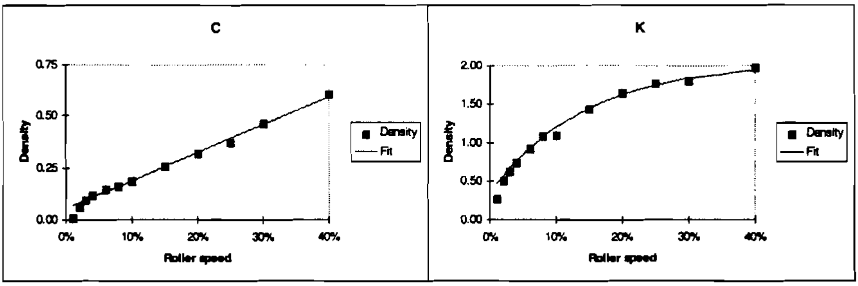

Figure 3. With 42% coverage, the C ink densities depict a linear relationship with fountain roller speed setting in all range except at 1% as shown in the left part of the graph. With 5% coverage, the K ink density approaches the saturation density at higher roller speed.

Saturation densities and Gain factors

With the key openings and fountain roller speed data corrected for offsets, ink film thickness can be derived following Eq. 1. The effect of the vibrators can be ignored due to the uniform coverage design of the test plates. The experimental data were then plotted in density vs. ink film thickness as shown in Fig. 4. Fitting the data to Eq. 2, the saturation densities and gain factors for each of the K, C, M, and Y inks were then determined.

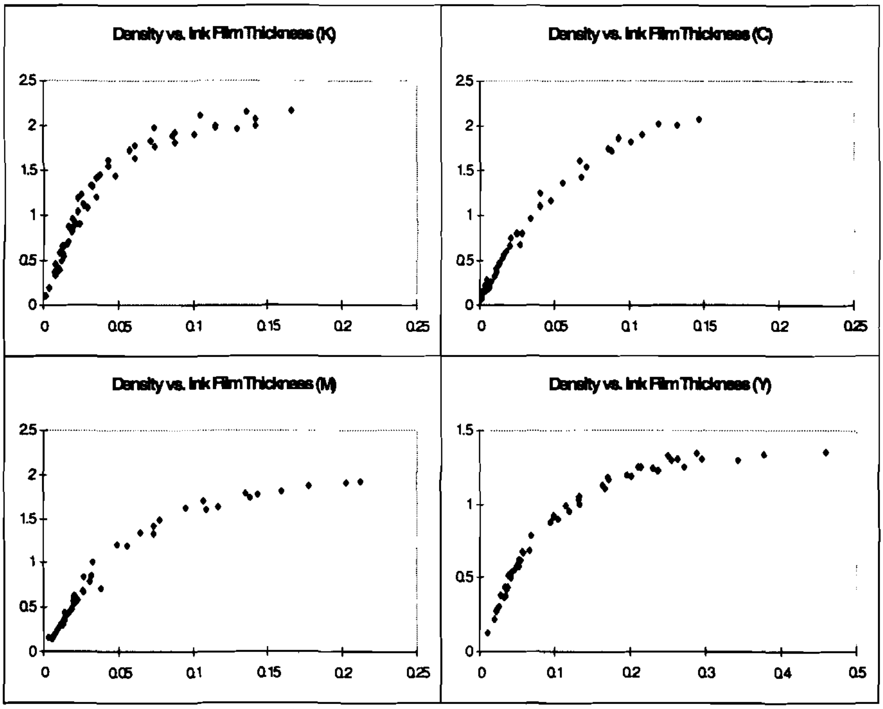

Figure 4. Combined density (ordinate) vs. Ink film thickness (abscissa). Data from all four printing surfaces, all four process inks, after converting key openings and fountain roller speed settings to the corresponding ink film thickness following Eq. 1. From this data, the saturation densities and gain factors can be determined for each ink.

Ink spread

The purpose of this sub-test is to find the extent of ink spread (V) due to vibrators' action. It was done by opening one center key and closing all other keys. A baseline run with all key closed was also done to remove the bias due to the incomplete key closure. After measuring the densities, the density data were converted to ink film thickness with the relationship in Fig. 5. Referring to the example shown in Fig. 4, there are two groups of ink spreads. Ink spreads farther with low coverage (5% for C and M), and closer with higher coverage (42% for K and Y). This confirms earlier simulation results reported (S.M. Chou, 1997). In addition, the extent of spread does not seem to depend on the properties of the inks, because both K and Y with the same coverage have the same spread, and likewise for C and M.

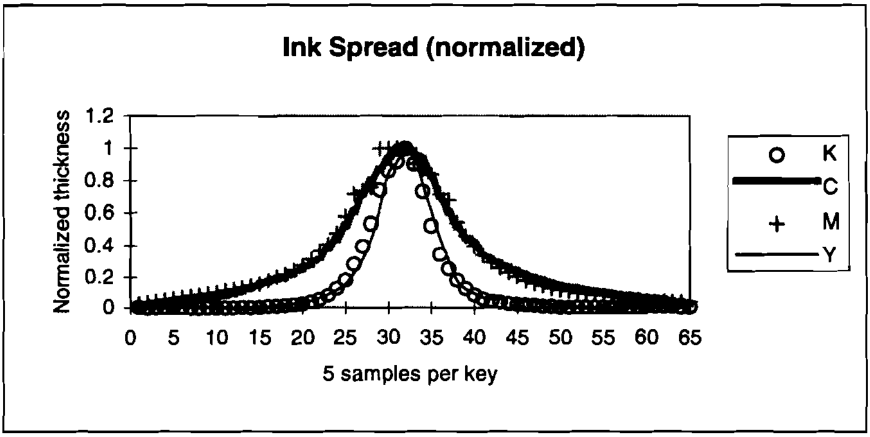

Figure 5. Ink spread for K, C, M, and Y inks at 42%, 5%, 5%, and 42% coverages respectively. It clearly shows that the extent of ink spread is wider for lower coverage, and vise versa.

Due to the nature of the curves being bell-shaped curves, they are fitted with Gaussian curves with different width (standard deviation of a normal distribution). In a series of tests, we gathered similar curves for various coverages and then derived an equation for the relationship of the width vs. coverage as shown in Figure 6. The ink spread matrix, V, can then be constructed with rows of ink spreads corresponding to the zonal coverages.

Test results

From the press test results, the gain factors and saturation densities can be determined for each of the K, C, M, and Y inks, while fountain roller speed offsets and ink key opening offsets can be determined for each fountain. The vibrator matrix can then be formed dynamically with the ink spread curve for each zonal coverage.

Ink presetting involves first calculating the ink feed rate (the product of key openings and fountain roller speed settings) following Eq. 3, and then selecting proper ranges for ink key openings, such that the overall ranges of the key openings is not too low nor too high; fountain roller speed settings are then determined accordingly. However, settings below minimum fountain roller speed should be avoided for non-linearity errors.

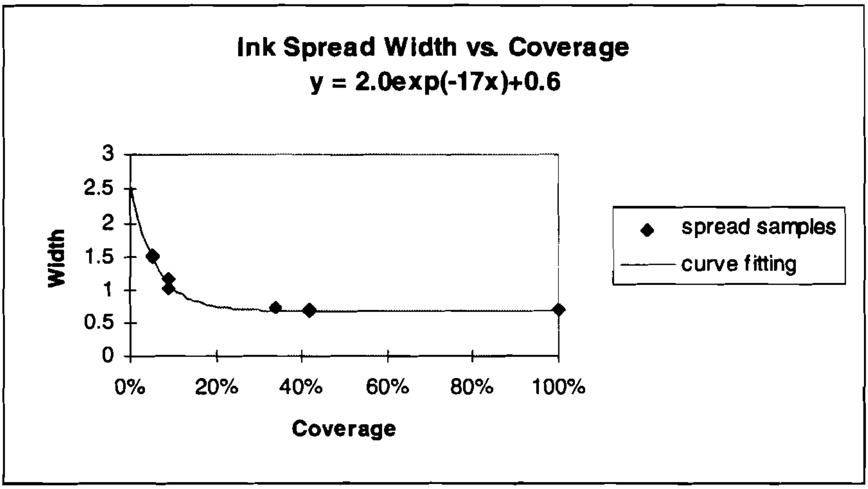

Figure 6. The widths of ink spread are plotted against coverage and fitted with an exponential decay.

For validation, we first recorded the pressman's key and fountain roller speed settings at the end of a printing job and then compared them against the presettings which we would have done. When comparing, fountain roller speed settings of the two were adjusted to be the same and key openings were scaled accordingly to make a fair comparison.

We also did some actual ink presettings by presetting our numbers before make-ready. Pressmen then proceeded for make-ready and printing job. At the end, the ink key and fountain roller speed settings were recorded and compared against the presettings. Signatures were also collected in various stages such as before the first key movement, after SAVE, and after color OK for visual comparisons.

In general, the comparisons were favorable and encouraging, although some noise sources have made the comparisons difficult.

<u>Favorable results</u>

There are quite a few examples that the presetting results match the pressman's setting quite well as shown in Figure 7. Although the detailed key openings does not match perfectly, the general profiles are very similar and meet the presetting goal. The differences of the printing results of the two key settings may be negligible with the ink spread effect of the vibrators.

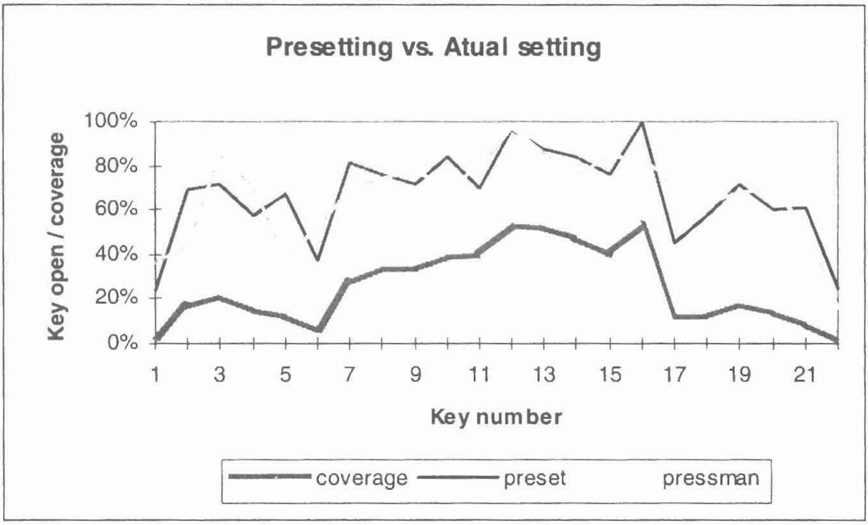

Figure 7. Typical pressman's setting vs. presetting. The two settings match quite well in general, but not in detail.

We have actually used some presetting data to preset keys for a couple of printing jobs and had very encouraging results as shown in Figure 8. Note that not only the general profiles are similar, but the detailed key-to-key up-and-down's are also very similar.

Also note in Fig. 8 between Key 7~11, the coverages except for K are extremely low, but both presettings and pressman's settings match. This confirms that a significant key opening should be maintained even in minimal coverage zones to achieve the desired color/density, as suggested by the model.

During the test, we collected some signatures for visual comparisons. We visually compared the first signature, which was gathered after registration but before any key movement, against the first "SAVE" signature and the final "OK" signature and found some pages were very close.

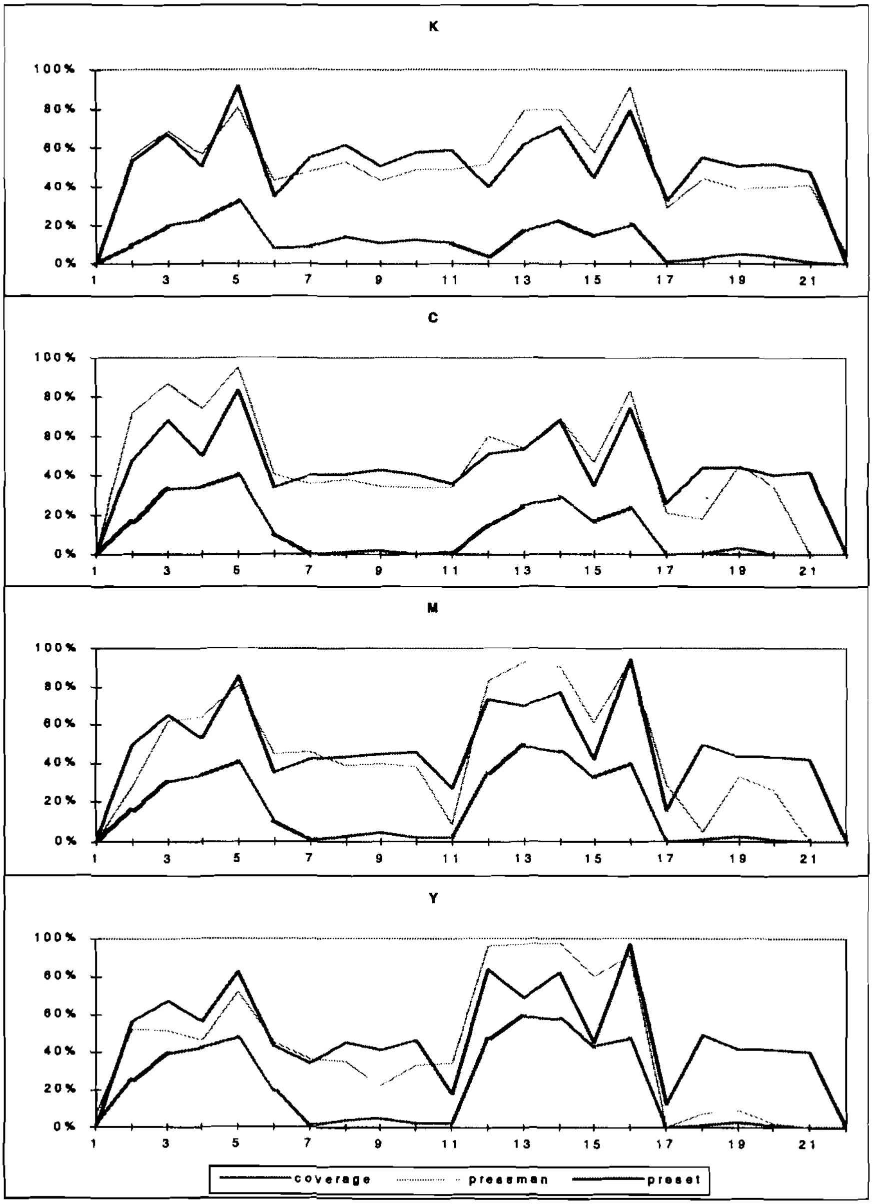

Figure 8. Detailed match of presetting and pressman's setting (Key opening/coverage "ordinate" vs. key number "abscissa"). This is an excellent example of good match. Following presetting, the pressman proceeded to adjust key opening to achieve color matching. Note the detailed matches for most of the keys, even for Key 7~11 where coverages are extremely low for C, M, and Y inks.

Discussion

From the results shown above, the model-based ink key presetting system seems to have the potential to provide reasonably close presetting. For example, it demonstrated close general match, key to key match and minimum key opening (Figs. 7~8). However, the presetting has not always been very close. Fountain calibration, for example, is the most obvious problem. In addition, several factors haven't been addressed in this model, such as no coverage zones, dot gain, wet trapping, edge keys and target density vs. color matching, which may all affect the accuracy of the presetting. In order to become a viable system, the model-based ink key presetting system must be enhanced by addressing these issues.

No coverage zones

Although the key settings for low coverage zones follows in general the presetting values. For no coverage zones, however, it is a totally different story. In order to prevent printing defects over a long run, the keys are normally fully closed which violates the minimal key law suggested by the model, as shown in Figure 9. This factor can drastically upset the presetting results, but should be relatively easier to be resolved (Set to zero, if there is no coverage) compared to other factors.

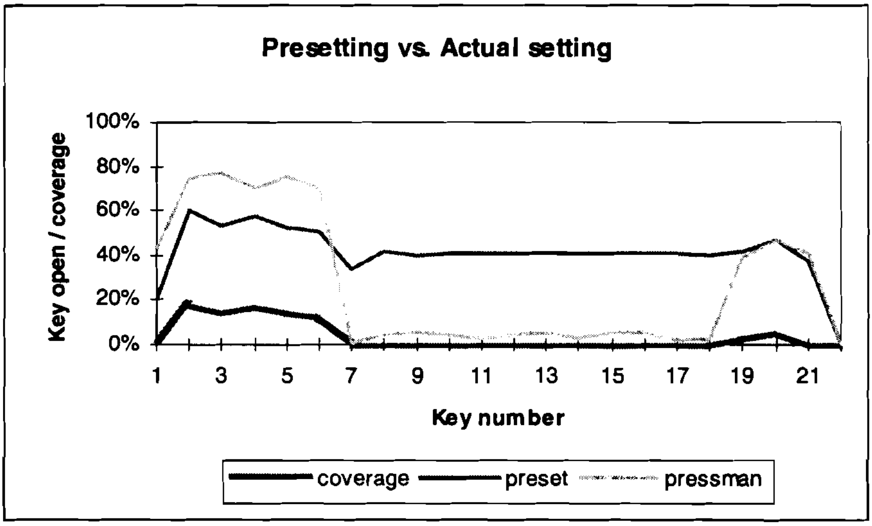

Figure 9. No coverage job. When there is no coverage in certain key zones, pressman would tend to close the corresponding keys fully, as in this case from Key 7 through Key 18.

Fountain calibration

There are situations when "more" or "less" ink key opening is needed but cannot be achieved from the ink desk. For a quick fix, a screwdriver is used to move keys in question to the desired openings. Although the problem is fixed temporarily, the fountain is no longer calibrated for later jobs. Figure 10 illustrates a drastic example of the "screwdriver syndrome," where the zonal coverages are the highest but the pressman's key openings are extremely low. It is quite obvious that a screwdriver intervention had been applied before the current job, such that with very low key open display, the actual ink feedrate was sufficient enough for the relative high coverage.

We found that presetting was usually quite close for jobs of different forms but with the same title (magazine). It is close even for different titles in a span of a month or so, as long as there were no very low coverage jobs in between.

To resolve this issue, either the fountains should be kept calibrated or zero-checked all the time, or the presetting system should keep track of the changes and adapt to it.

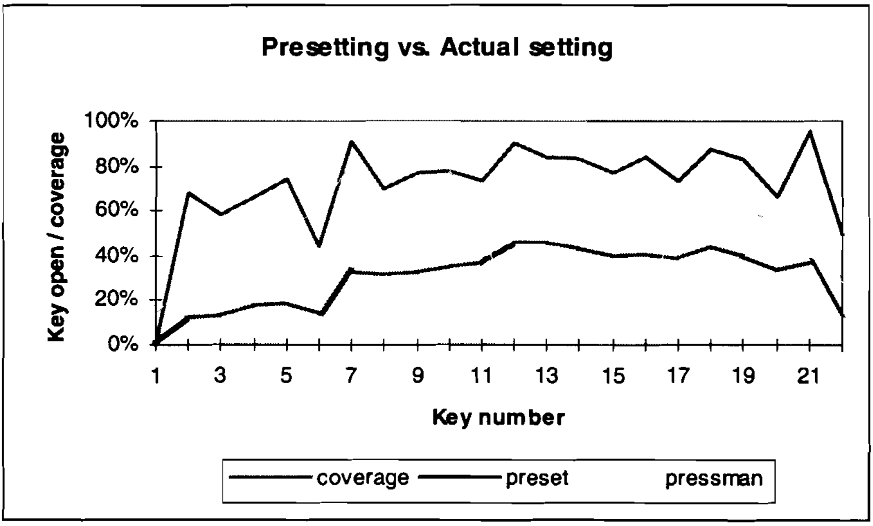

Figure 10. Ink key out of calibration. Ink key openings for keys 12 through 16 were absurdly low which were obviously due to bad calibration.

Defective keys

Conventionally, fountain calibration involves zero-checking. However, just zero-checking probably is not sufficient for the crooked key illustrated in Fig. 11. The causes for the crooked key may be either from wearing by touching the fountain roller or skewed by the pressure of neighboring keys. When a key like this touchs the roller, it forms a wedge and allows some ink to feed to the inking train. Ink won't stop until the wedge is totally close by pressing hard on keys. Note the relationship between key opening and the ink feedrate will be non-linear in this range. Therefore, a mere zero-check cannot guarantee the calibration. A redesign of fountain keys or even the complete ink fountain may be necessary for a more consistent and controllable behavior (Nikkanen, 1997).

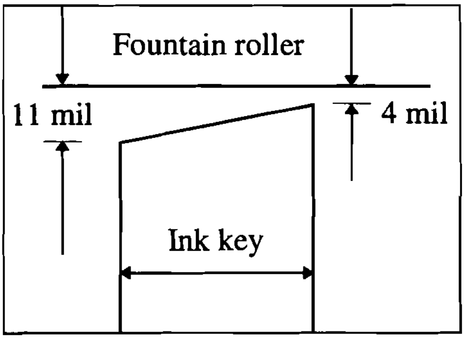

Figure 11. A crooked ink key forms a wedge allowing ink to pass to the inking train when one side of the key touches the fountain roller while the other side is still open.

Dot gain & Wet trap

Dot gain is introduced at plate making and during printing process in CTP printing. The maximum overall dot gain can be as high as 20% (SWOP, 1997). The images we used for coverage calculation were from plate files which were dot gain compensated. This means that lower ink presetting will result. The error in zonal ink consumption may be up to 20% of the zonal coverage for CTP (The error in ink presetting will be less according to Eq.3). This error of dot gain may be very significant depending on the images and needs to be addressed.

When over-printing wet inks, the second-down ink always has less trap than the first-down ink which is printed directly on the paper. Typical wet trapping for web-offset printing is about 70% (SWOP, 1997). Again, the images we used for coverage calculation were from plate files which were wet trap compensated. This means that higher ink presetting will result. The error in zonal ink consumption may be as high as 30% of the zonal coverage for CTP (The error in ink presetting will be less according to Eq.3). This is another important factor which needs to be considered.

Incidentally, the net error may be lessened by partial canceling of the above two factors depending on the image content, since the effects are opposite to each other.

Edge keys

In general, pressman tend to fully close the edge keys (the first and the last) since there is often no coverage there and in most cases there is no paper there at all to take any ink. However, in some other cases, when high coverage bleeds to the edges, the edge keys may be opened to achieve the desired density. Also, the rollers at the edge tend to act as an additional source of ink, so the keys need not be opened as wide.

Density vs. color appearance

We have assumed a set of universal target densities for each of the K, C, M and Y inks for ink presetting. This assumption may contribute to some error in the results. First, the general target densities may be different depending on the paper, ink and printing jobs. Second, the zonal target densities of the different pages of the same side of the signature may be different depending on the image content. In other words, color appearance and color matching is often more important than keeping a universal density set for printing.

Due to the above error sources, an exact ink presetting does not seem to be possible. The goal for ink presetting is then to preset ink to be close enough such that paper can be saved and make-ready time can be shortened. A return on investment (ROI) study needs to be done to determine the figures.

Conclusions

In this paper, we have reviewed the ink key presetting system developed by us previously, and have described how we obtained the model parameters with press tests. Furthermore, we have presented some examples of ink key presetting results for the validation of the presetting system. The results indicate that reasonable ink key presetting can be achieved, as long as ink fountains are kept calibrated. To further improve the performance, other factors such as dot gain and wet trapping should also be addressed.

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