Spatial Uniformity of Offset Printing

Franz Sigg*

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Abstract: Unevenness within a single offset printed press sheet is the topic of this report. For offset printing, evenness across the cylinder is adjustable using the ink fountain keys. Affecting evenness around the cylinder is more difficult and in practice often ignored.

The question is whether the tolerances specified by standards can truly be met when solid densities and dot gain are not only measured on the single location of a color control bar, but when looking at the whole press sheet. A special test pattern was designed that samples the area of the whole press sheet at every ink key. The following parameters were evaluated for each of the CMYK colors: solid density, dot gain, doubling and the uniformity of the paper and measurement instrument itself.

Preliminary tests showed unevenness of up to ± .15 density units (with high inking), however, a much better controlled experiment showed deviations around the cylinder of about 0.08 density units.

Introduction

As part of a thesis project, a test form was printed at RIT on a Heidelberg Speedmaster 74 sheet fed press. Part of the test form contained 100 steps wedges with 1% increments for 7 colors, C, M, Y, K, C+M, C+Y, and M+Y which were assembled in a randomized fashion on a letter size test target.

The purpose of the experiment was to investigate performance of various halftoning methods. A total of 6 halftones were tested on two similar test forms. Each of these test forms was printed first at normal ink levels and then at a higher inking level but only for magenta and black. Figure 1 shows the non-randomized version of the test target, and Figure 2 shows one of the test forms.

*Rochester Institute of Technology

Figure 1, Non-randomized version of RIT 100 Steps Chart

The 100 steps randomized step wedges were measured using a GretagMacbeth SpectroScan instrument. When the plate-press curves were plotted, very noisy curves were obtained as shown in Figure 3. This was a surprise.

The curves in Figure 3 indicate that there can be more than 0.15 density difference between two patches that are only 1% different in dot area in the RIT 100 Randomized Steps Chart file. How is this possible? We did not see such differences in the gradient targets or the gray uniform frame around the RIT 100 Randomized Steps Chart.

At this point it was clear that sooner or later we would want to verify what we came to call 'the wiggles' with another press run, but before committing to this, it was important to evaluate all possible causes that could quickly be verified.

Figure 2, One of the two test forms containing the randomized RIT 100 Steps Charts

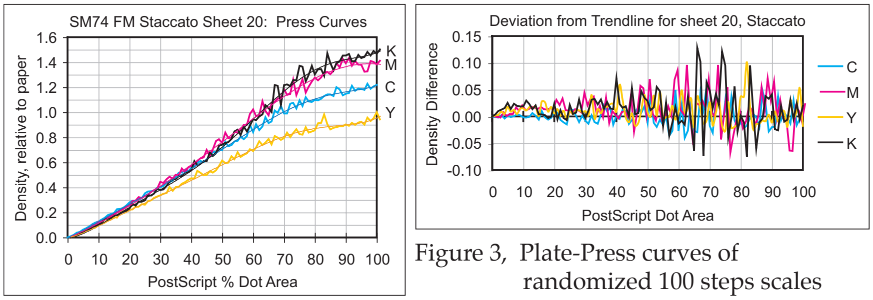

Figure 3, Plate-Press curves of randomized 100 steps scales

Testing of hypotheses for possible causes of 'wiggles'

• Question: What if the measurements were not carefully centered on the patches? This would cause random errors because of the randomized layout of the patches. Answer: The measurements were repeated with careful placement and essentially identical results were obtained.

• Question: Would an Approval proof of the test page show the same problems? Answer: No it did not, Figure 4 shows very low noise.

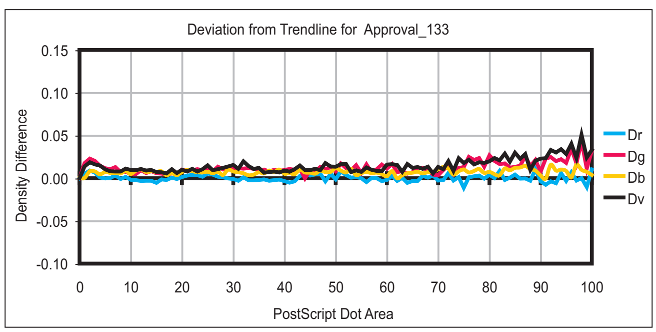

Figure 4, 'Wiggles' from Approval proof

• Question: Are those 'wiggles' really random? Answer: No they are not, the 'wiggles' position pattern is very similar for a given ink, independent of screening method or inking level, see Figure 5. The amplitude of the 'wiggles' however do seem to be random.

• Question: Are the 'wiggles' already on the plates? Answer: No, plates were linear, matching the requested PostScript dot areas within ± 1% dot area. This is normal for these plates.

1st. Conclusion: The problem is not pre-press or measurement related, it must be a press problem.

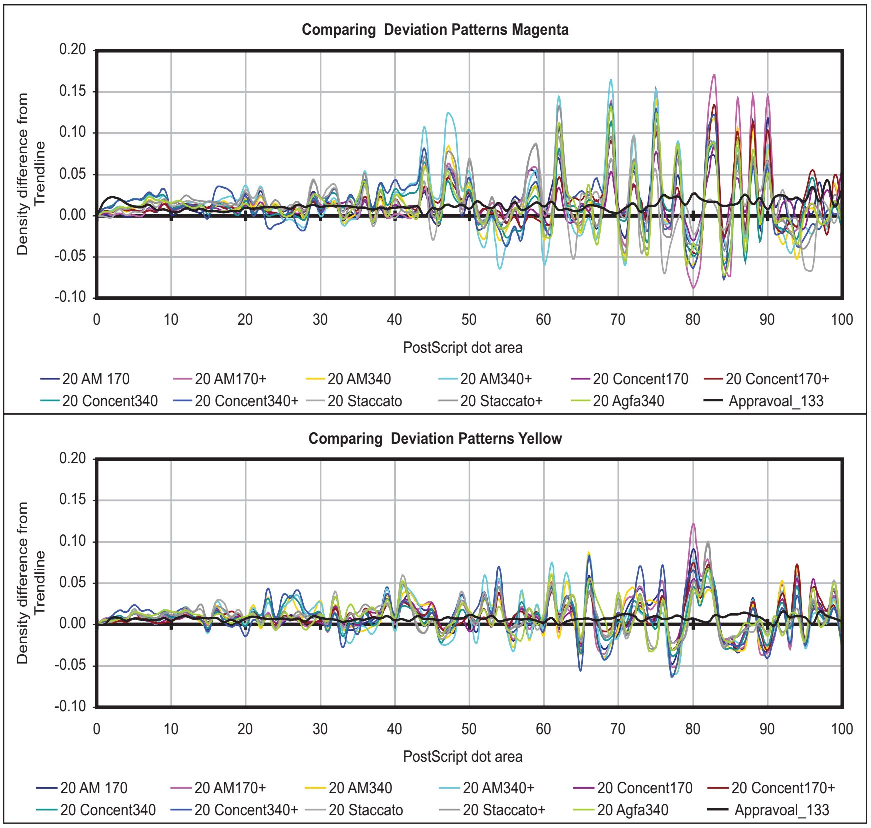

Figure 5, 'Wiggles" pattern for various screening methods. Yellow with normal inking, magenta also includes samples with high inking.

• Question: Could it be ink starvation ghosting? Answer: Yes, but actually, any unevenness in inking would cause the random 'wiggles' pattern due to the random positions of the patches within the target over a larger, uneven area. Non-randomized scales would therefore not show 'wiggles' because they cover a smaller area with less unevenness.

• Question: Where are the high and low excursions of the 'wiggles' within the test page? Answer: Figure 6. Because the RIT 100 Randomized Steps Chart is handwritten PostScript code, it was possible to reprogram the chart for display purposes in such a way that, for each color separation, a circle is placed over each patch, and the color of the circle is an indication of the magnitude of the wiggle. Red means a positive wiggle, green means a negative wiggle, the stronger the color, the larger the excursion. Figure 6 shows the result.

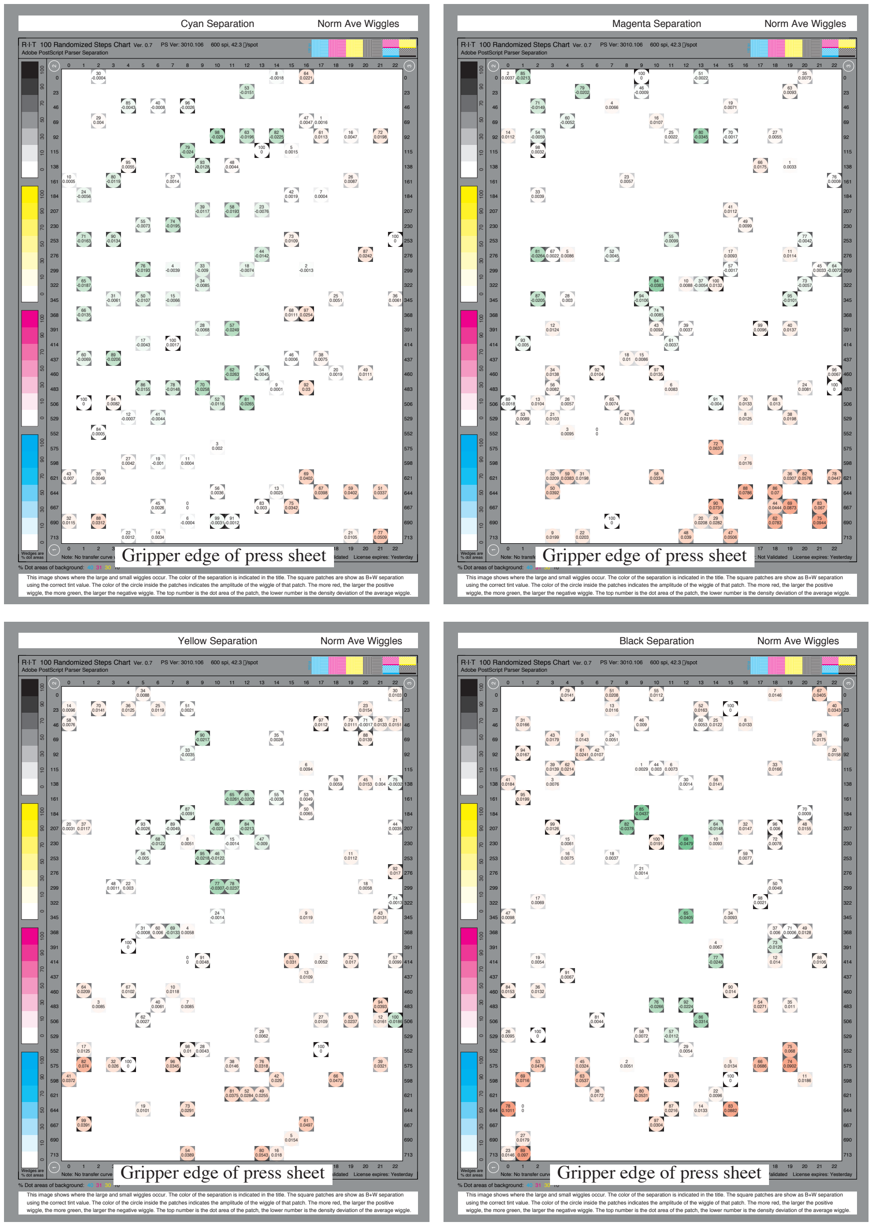

Figure 6. Location of wiggles. Red = positive, Green = negative. Average of all screenings with normal inking, for cyan, magenta, yellow and black

High and low ‘wiggles’ are not randomly occurring on the sheet. For all colors, the high ‘wiggles’ tend to be near the gripper edge, the lower ‘wiggles’ are farther back. This points to gradual, uneven inking around the cylinder. (Only the average of the data is shown in Fig. 6, but figures for individual screenings show similar patterns.) These results were confirmed by also reading press sheets from previous press runs.

Conclusion: Because of the pattern of high and low excursions of the ‘wiggles’ for all colors, it is concluded that there must be a pattern of non uniform inking around the cylinder. (Across the sheet variation is adjusted with ink keys.)

Insight: Dot gain, or better in this case, tone value increase can be caused by either a change in dot size, or by a change in ink film thickness on the dots. This explains why patches with only one percent dot area difference on the plate can have relatively large density differences.

Therefore the question now becomes: how even is the inking over the whole area of a press sheet.

Measuring spatial uniformity

A new test form was designed where, for each ink key, there is a column of blocks, each with 16 patches. Each block contains, for each CMYK color, 4 patches with a 70% tint, a solid, and two patches with 170 lpi parallel line tints that permit determination of directional dot gain. For yellow, the parallel tints were left out to make room for a white paper patch and a position ID patch. For each column, the colors in each block are staggered to make sure that ink consumption is as even as possible across the whole press sheet. Figure 7 shows a section of the lower left corner of the test form which contained 19 ink keys and 14 rows for a 6 color Heidelberg Speedmaster 74 press.

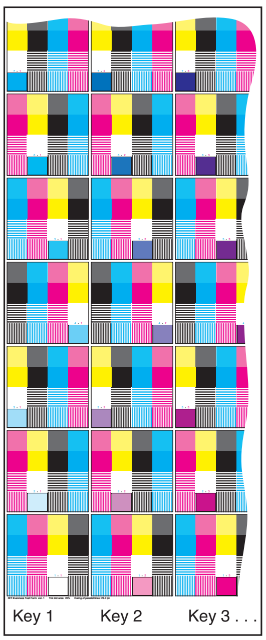

Figure 7, Lower left corner of evenness test form

Printing was done on a coated cover stock. Inkkeys were adjusted to result in even densities. Ink roller stripes were checked and the blankets were properly torqued. Ink sequence was KCMY using printing units 2 to 5.

One press sheet was cut into smaller sections so that it could be read on a Gretag Spectroscan

Spectrophotometer. Status E density values were copied to a special Excel workbook for analysis.

Results

The paper measurements were uniform, only 9 out of 266 values were .01 density units higher than the rest which were all the same. Most of the higher values were at the lead edge.

Figures 8 and 9 show 3D plots of absolute and relative unevenness of solid magenta density. Unevenness across a press sheet can be adjusted

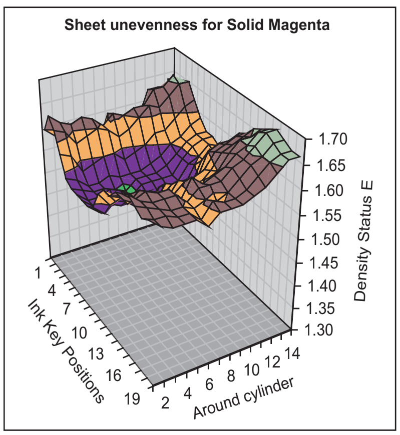

Figure 8, Magenta solid unevenness

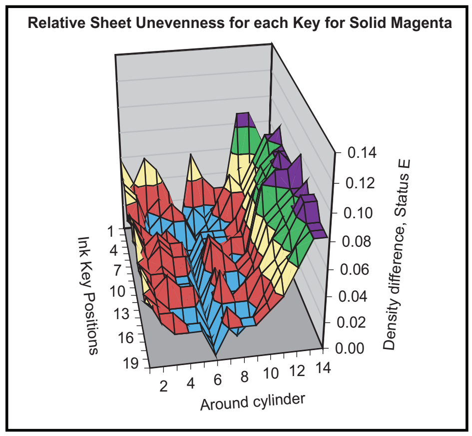

Figure 9, Relative magenta unevenness

using the ink keys. Therefore, this is not something to be concerned with, we know how to adjust it. However, unevenness around the cylinder is not easily adjustable, and very often not measured because there is only one color control bar across the sheet. Therefore, Figure 9 shows deviations from the lowest reading for each key. This cancels out unevenness across the sheet, which is corrigible by ink key settings.

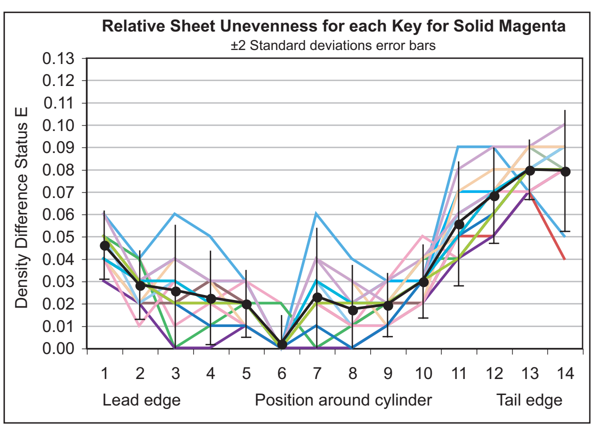

Figure 10, Relative unevenness for solid magenta

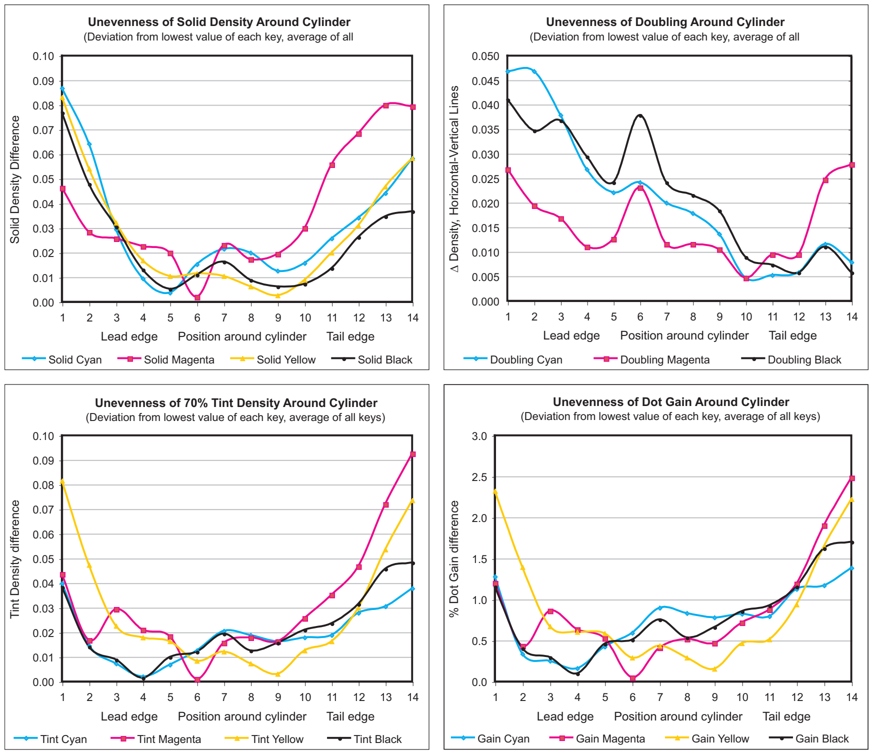

Figure 10, Unevenness around cylinder for solids, doubling, tints and dot gain

Evenness of dampening

Dampening also affects evenness of offset printing. This is tested by gradually reducing water supply until scumming takes place, see Figure 11.

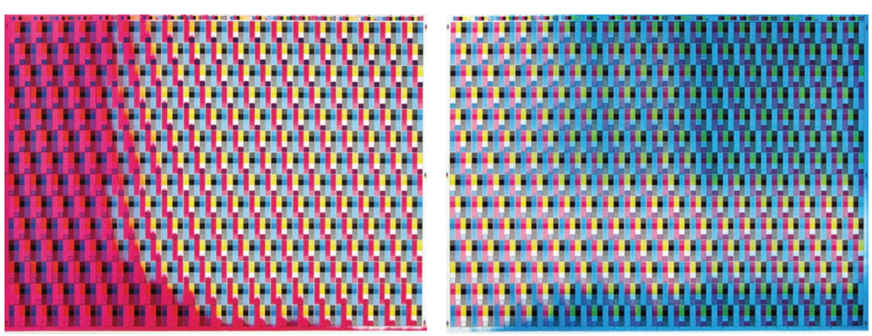

Figure 11, Press sheets showing scumming due to uneven dampening

Unfortunately, for this test, there was not enough time to also adjust the water fountain rollers before printing. Therefore these results come from a not optimally adjusted press.

Summary and a few things to consider

On the press that was used for this report, there is a consistent pattern of higher density and dot gain values at the lead and tail end of the sheet. Unevenness of inking around the cylinder is around 0.08 density. Dot gain varies less than 2.5% at 70% dot area and 170 lpi. Since doubling has a different cause, it shows a different unevenness pattern than solid density or dot gain.

If unevenness around the cylinder consumes 0.08 density units, and if we choose a tolerance of ± 0.10 density units for solids, then only 0.12 density units are left for variability due to across the sheet variability *plus* sheet to sheet variability *plus* run to run variability. This may not be enough to cover the natural variability of the press and leave some safety margin.

Using randomized profiling targets and averaging at least two targets at different positions on a press sheet and rotating those targets seems well justified to reduce the effect of spatial unevenness.

This report attempted to shed some light on one aspect of the fundamental question of: What is the basic variability of the offset printing process that cannot be reduced? Knowing the irreducible variability of a process is essential in order to set meaningful specification tolerances.

In this particular case, we were looking at the spatial variability around the cylinder, which is one source of variability. It is not a source of random noise, there is a systematic pattern, but there is not much we can do about it. Other researchers are also looking at this question, some of which are listed in the Related Sources section.

Acknowledgments

Special thanks to Eugenio Carvajal for his careful experimental thesis work, the students of the Test Targets class for the brainstorming sessions, Steve Suffoletto for his reviews and comments about offset press setup, David McDowell and Ken Elsman for their participation and helpful suggestions. Much appreciation goes to the Printing Applications Laboratory at RIT and its leaders for the support they give to students and faculty research efforts.

Related Sources

The following are some publications that relate to the topic of printing variability.

Breede, Manfred
2007 "The Effect of Ink Film Thickness Variations on Color Control in the Circumferential Printing Cylinder Direction of Offset Presses", Paper presented at 2007 TAGA Conference, Pittsburgh PA.

CGATS
2003 "CGATS Recommended Industry Practice: Color characterization data set development — Press run guidelines", http://www.npes.org/standards/Tools/PRG-V1AUG03.pdf

MacPhee, John
2007 "The Effect of Certain Process Parameters on Inherent Color Variations on Press", Paper presented at 2007 TAGA Conference, Pittsburgh PA.

Siljander, Roger, and Fisch, Richard
2001 "Accuracy and Precision in Color Characterization.", TAGA Proceedings. pp. 57 – 79