Quantifying Fringing in Digital Silver Halide Writing

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Abstract

In the process of producing a hard copy print of a digital file using digital writing technology, whether the marking engine makes an exposure (light or thermal) or a physical mark (dye/pigment transfer, mechanical energy), the printed image may not be a perfect rendering of the original digital file. For example, the target file may include a straight line; however, the printed line may show extraneous features, artifacts, in addition to the intended line. The underlying mechanism responsible for extraneous features in digitally written images are different for the various output technologies used to make the hard copy print. In some thermal systems, the symptom is "thermal smear"; in some inkjet systems, the symptom is "bleeding" or "feathering"; in electrophotography, the symptom may be "toner sprays"; and, in digital AgX, one such symptom is "fringing." All of these symptoms have one characteristic in common: the edges migrate relative to the original digital image. We will examine factors that may affect line broadening in different imaging systems and show ISO 13660 line blur as a metric to quantify this phenomenon.

Line Broadening in Output Technologies

There are many technology choices for printing a digital file. Application, convenience, cost, and quality are the factors that drive choice. Line or edge quality is fundamental to the perception of sharpness. It may be expected that the edge qualities may vary quite a bit. Figure 1 shows the images of a "plus (+) sign," demonstrating horizontal and vertical lines, from four different output technologies.

Inkjet technology shows bleeding from capillary action as the ink is absorbed into the ink-receiving layer and paper support. The ink/receiver interaction is an ongoing area of opportunity for both ink and media manufacturers. A macroscopic problem, such as smearing a printed edge when it is not sufficiently dried, is another concern with line broadening in inkjet outputs. Other potential concerns can be related to the printhead design or dot placement because the line comprises dots. Similar to the mechanics of inkjet dots, electrophotography uses toner particles to make an edge. Electrostatic charges are the mechanism for satellites or extraneous toners near the intended edge. Thermal technologies are concerned with accurate modulation of heat. In going from high densities to low densities, the decay of the thermal energy may not be controlled and may cause unintended energies in low densities. This mechanism applies to thermal exposures, as well as thermal energies to impact colorants onto a receiving media.

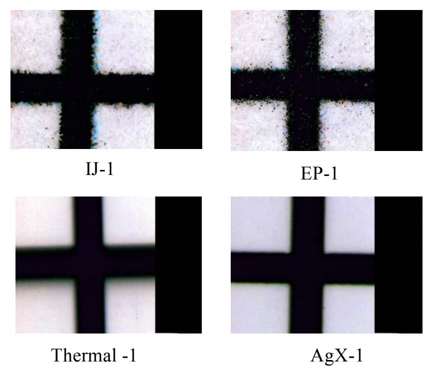

Figure 1. Photomicrograph of lines

A common factor to line broadening in all output technologies is color registration. Offsets in alignment of the separation colors would make a line more broad, and any studies involving line broadening should address color registration. A second common factor is the effect of page motion, which may be an added dimension to line broadening. A reasonable approximation to indicate line broadening is the use of ISO 13660 line blur, which measures the distance between the 10% and 90% thresholds, based on line reflectance and background reflectance. Figure 2 shows the measured blur of the same target in several output systems. One can see that higher blur in Figure 2 is also seen as a blurrier line image in Figure 1.

Fringing Mechanism

Of the output systems in Figure 2, AgX shows low blur numbers, indicating that the technology is capable of sharp edges. Although the edges shown are good; historically, AgX media design has managed a phenomenon known as fringing.[1] Fringing is unintended exposure adjacent to an area of high exposure. It is most easily seen as white text on a dark background, where the white text becomes "filled in" as a result of fringing. The cause of fringing is related to the sensitometric response of the media at the exposure time of the digital writer. We have chosen six media to study to see if levels of fringing can be related to sensitometric differences. The digital writer is the laser-based Fuji Frontier 350 Digital Minilab. The six media received the same separation exposures in a laser sensitometer to approximate the characterization of a response to a digital writer. The results are shown in Figures 3–5. There is a wide range of curve shapes, especially in the red-sensitive and blue-sensitive records.

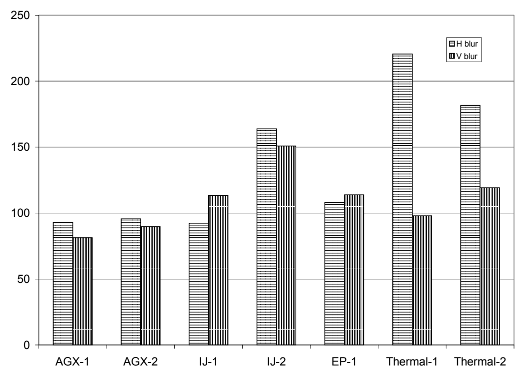

Figure 2. ISO 13660 Blur Measurements

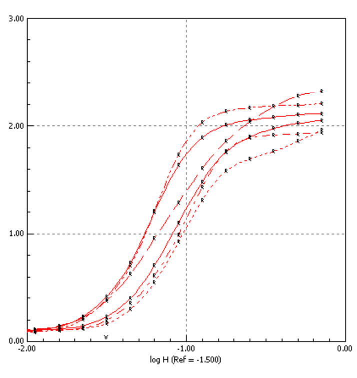

Figure 3. Red Laser Sensitometry

Separation sensitometry was used because the Fuji Frontier 350 writer is calibrated on separation scales. We mapped the calibrated separation D-max from the Fuji Frontier 350 writer to the laser sensitometer and calculated the relative log exposure needed to achieve the calibrated D-max. The concept of modulating laser power to calibrate media sensitometry to a set of aim-printed densities is found in Reference 2. Table 1 shows the individual channels and combined relative Log exposure that the writer outputs to achieve D-max. There are significant differences in exposure range. Higher exposures translate to higher required laser power, accounting for excessive fringing. The rank ordering is consistent with log exposure to achieve printing D-max. Rather than making a descriptive statement, we will quantify the level of fringing in these samples.

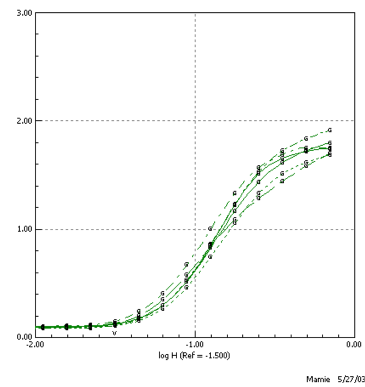

Figure 4. Green Laser Sensitometry

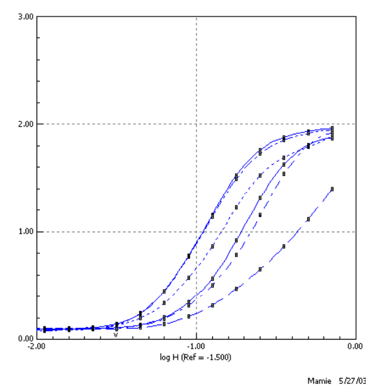

Figure 5. Blue Laser Sensitometry

Table 1. Relative Log Exposure to achieve Printer D-max.

Sample	R	G	B	Total Log E	Fringing
A	1.08	1.57	1.41	4.06	best
B	1.40	1.52	1.66	4.58	good
C	1.23	1.44	1.70	4.37	good
D	1.62	1.68	1.78	5.08	poor
E	1.34	2.00	2.06	6.40	very poor
F	1.11	1.41	1.65	4.17	good

Target and Metric

The target chosen for this study is a font-size series from 4 pt to 14 pt, in positive text, as well as reverse text. Text was chosen because it is visual and the dimensions of the lines are standardized, regardless of addressability. We intended to evaluate the horizontal line from the hyphen and the vertical line from the letter "I." The expected width of the letter "I" is a series of different widths from 6 pt to 14 pt. The width of the hyphen is also a series of widths but because 12 pt and 14 pt are the same width, and 6 pt and 8 pt are the same width, they allow for replicate measurements.

To obtain prints of the target file, we made prints on the Fuji Frontier 350 minilab. Prior to the start of printing, we verified that the lasers were aligned to give the best color registration in a procedure much like those in inkjet printers after a cartridge or printhead replacement. The photoprocess was verified to be in control and free from dirt or streaks. Each paper was calibrated to the same code value-to-density relationship. Next, the target was printed.

The ISO 13660 line blur metric fits the symptoms of fringing and was chosen to test as a metric. The instrument used to do the measurement is the Quality Engineer Associate's Personal Image Analysis System. This instrument was studied for accuracy in measuring line dimensions.[3] Positive and reverse texts were measured to compare the metric to the visual judgments.

Measurement Results

Figures 6–9 showed the line blur measurements. For positive text and media that did not fringe excessively, blur is independent of font size. For media exhibiting noticeable fringing, blur is higher for larger fonts in positive text. If we account for line width and compare a 14 pt/12 pt hyphen to a 10 pt "I," we see that the numbers are not similar, indicating that the mechanisms for the resultant blur are different for the two line directions. For samples A, B, C, and F, blur is higher in the "I" (page direction) than in the hyphen (line direction). For the two high-fringing samples, D and E, the line direction showed higher blur than the page direction.

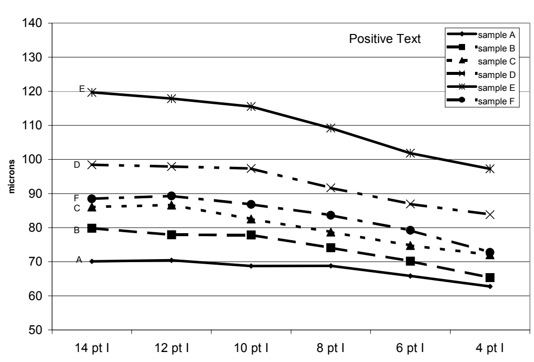

Figure 6. Blur of Positive Text in Page Direction

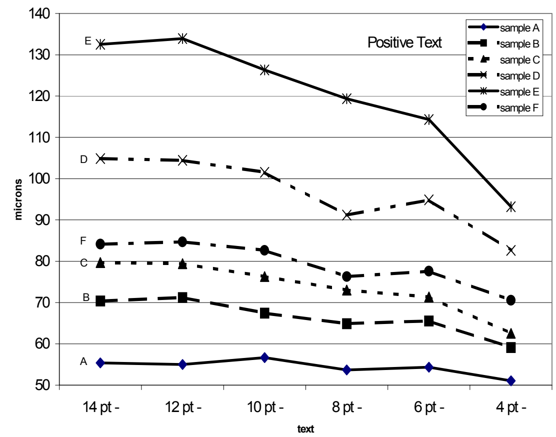

Figure 7. Blur of Positive Text in Line Direction

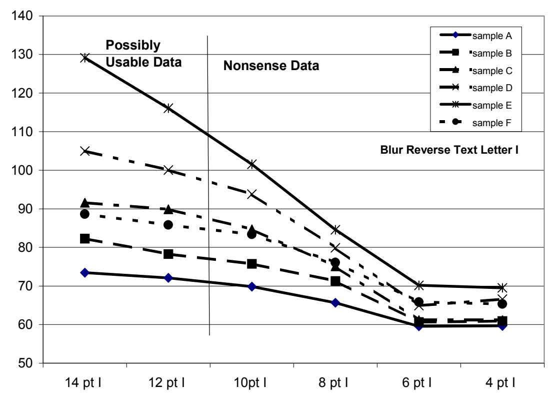

Figure 8. Blur of Reverse Text in Page Direction

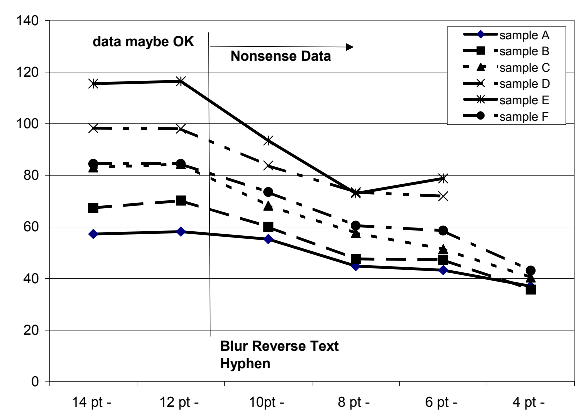

Figure 9. Blur of Reverse Text in Line Direction

In reverse text, we expected some instrument confusion where there is no white point in the area of the text. This happens in small fonts and in media with extensive fringing. In fact, the instrument recognized that measuring the 4 pt and 6 pt hyphen is not possible. The use of blur in reverse text is limited to low fringing media and 12–14 pt fonts. There is a region of reasonable correlation with positive text: for example, blur is similar for a 12 pt hyphen between positive and reverse text for the 4 samples which exhibit good fringing.

Conclusion

Many hard copy output technologies must manage possible line broadening to achieve good edge qualities. With proper media design, digital AgX can achieve sharp edges relative to other output technologies. Sensitometric characteristics explain most of the variations in fringing but not the subtle differences, such as those seen when comparing blur in the line direction to blur in the page direction for the same line size. Positive text is easier to characterize but not very visual. Characterization of fringing or any line broadening in negative text is limited to large fonts and relatively low fringing (or narrow line broadening) media, even if an external white point (external to the text but still part of the same media) calibration is available. ISO 13660 Blur can illustrate relative rank ordering in line broadening with positive text. Other methodologies are needed for a satisfactory analysis of reverse text.

References

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Biographies

Mamie Kam-Ng is Senior Principal Engineer in Systems Technology Platform of Eastman Kodak Company. Her current interests are in the areas of media formulations, digital AgX writing technologies, and cross-technology benchmarking. Mamie holds 11 US patents and a BSChE from Pennsylvania State University. She serves on the council of the Rochester Chapter of IS&T.

Patrick Reed and **Frank Byrne** are members of the technical staff in Systems Technology Platform and both are active in characterizing output media. Patrick holds a BS in Imaging Systems Management from Rochester Institute of Technology and was issued one US patent. Frank holds an AAS in Mathematics from Monroe County Community College.