Special Aspects of Quality Control and Color Management in an Ink Jet Minilab

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Abstract

Recently ink jet technology has begun to enter the photo finishing business. One of the biggest challenges for ink jet systems is, however, to reach the speed of a few hundred 4 × 6" pictures per hour like the conventional minilabs do.

Approaches to reach that goal are, to combine several ink jet print heads and/or to increase their speed relative to the paper.

This higher speed leads to new quality and color management problems, which are not existent or less severe under desktop printing conditions. In this paper we present our investigations on the quality of printed dots in dependence on scanning speed. The higher speed reduces dot placement accuracy and it can cause degradation of dot quality. Effects like elongated dot shapes or even separation of main drop and satellite drop have been observed. These microscopic effects cause image quality problems like increased banding or large color shift compared to the prints at normal speed.

Print parameters like speed of the print heads relative to the paper, waveforms to drive the print heads and the distance between print head and paper can not be considered independently and have to be adjusted properly to obtain best print quality.

Introduction

The last years showed a rapid progress in ink jet technology. Recently ink jet started to move into the photo finishing business yet clearly dominated by silver halide based media. Consumer will like the new possibilities in terms of choice in a wide range of media and colors. The photofinisher sees the advantages in the reduction of waste and in less maintenance. In terms of image quality ink jet technology reached a very high level which allows competition with traditional silver halide photography. But there are problems in stability of the ink jet prints. Often they are not as stable as silver halide prints in terms of light stability, resistance to humidity and water.

Currently a main problem of ink jet technology is the low speed. To compete with a silver halide minilab an output of at least a few hundred 4 × 6" prints per hour is mandatory. Performance of an ink jet device can be increased by stitching several print heads together[1] and/or by increasing firing frequency and head speed relative to the paper. In this paper we will present experiments showing some special quality aspects coming up with high scanning speed printing.

Experimental

For all our print experiments we used a piezo type drop on demand ink jet head with control electronics built in house. It gives us full control on head firing waveforms. For the presented experiments waveforms recommended by the head manufacturer were used. The maximum firing frequency is 28.8 kHz. Normal droplet size is 11 ng. Commercially available micro porous paper was used as printing media.

Speed between head and paper can be continuously varied up to a speed of 3 m/s. Distance between nozzle plate and paper is adjustable between 0.3 mm and 3 mm.
Measurements and image analysis were done with a measurement system built in house. It consists of a digital camera (Basler A113, 1.3 megapixels), suitable optics, illumination and standard image analysis software (Image-Pro® Plus, Media Cybernetics). For density and color measurements we used a GretagMacbeth SpectroScan.

Results and Discussions

Dot Positioning Accuracy Versus Speed

A 120 dpi pattern was printed, measured and compared to an ideal grid. Figure 1 shows measurements of dot positioning accuracy at constant head-paper distance. With increasing scanning speed a strong increase of positioning deviations along printing direction has been observed. The increase in positioning inaccuracy for higher scanning speeds can be explained by small variations in droplet speed and ejection timing. As long as scanning speed is small, these differences will cause only small deviations on the paper. But if scanning speed is increased by a factor of more than five, these small variations in ejection speed can cause unacceptably large deviations on the paper. One more reason for the large deviations could also be bigger aerodynamic disturbances for higher speed.

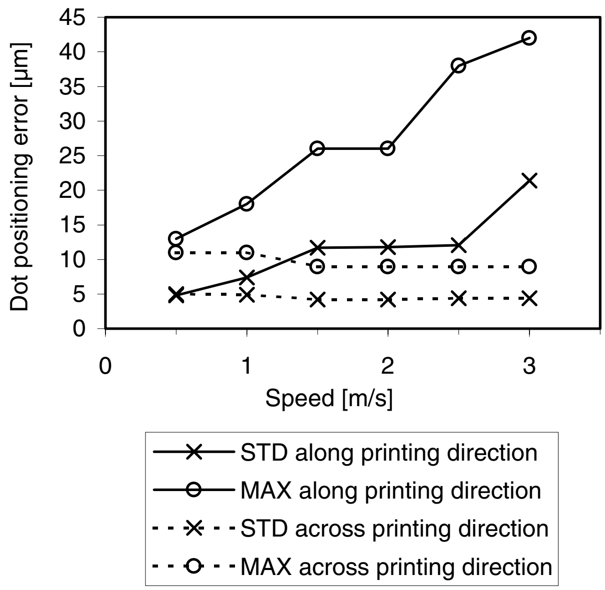

Figure 1. Dot positioning accuracy along printing direction for different speeds (STD: Standard deviation, MAX: Maximum deviation)

At high scanning speeds maximum deviations are larger than one printing pitch (18 µm at 1440 dpi, 35 µm at 720 dpi) and for a 1440 dpi print even the standard deviation at 3 m/s scanning speed is larger than one printing pitch. These deviations cause registration problems between different colors and sharpness problems within each color and will therefore decrease image quality.

As can be easily understood there is no increase in deviations perpendicular to the printing direction.

Dot Size and Shape Versus Speed

By analyzing dot size and shape we can also see a strong scanning speed dependence. With increasing speed the ink of the drops is distributed over a larger area (Fig. 2). When we increase scanning speed from 0.5 m/s to 3 m/s an increase of dot area of 60% can be observed.

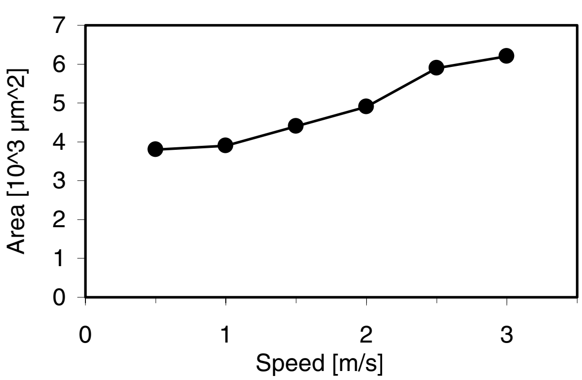

Figure 2. Increase of dot size with speed

This increase of dot area is mainly due to an elongation of the printed dots. By measuring the aspect ratio (ratio between major and minor axis of ellipse equivalent to dot) of the dots this elongation can easily be quantified (Fig. 3). At scanning speed higher than 2 m/s the aspect ratio is larger than two.

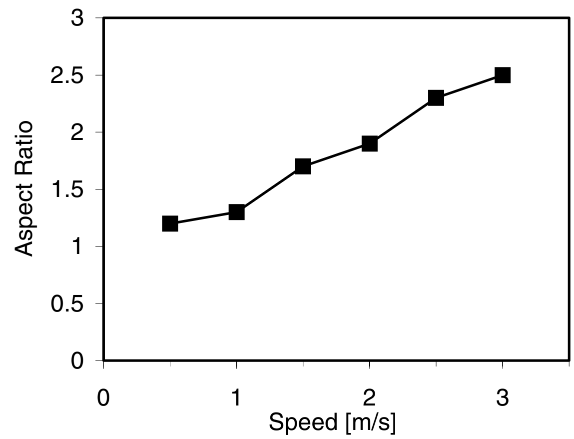

Figure 3. Increase of aspect ratio with speed

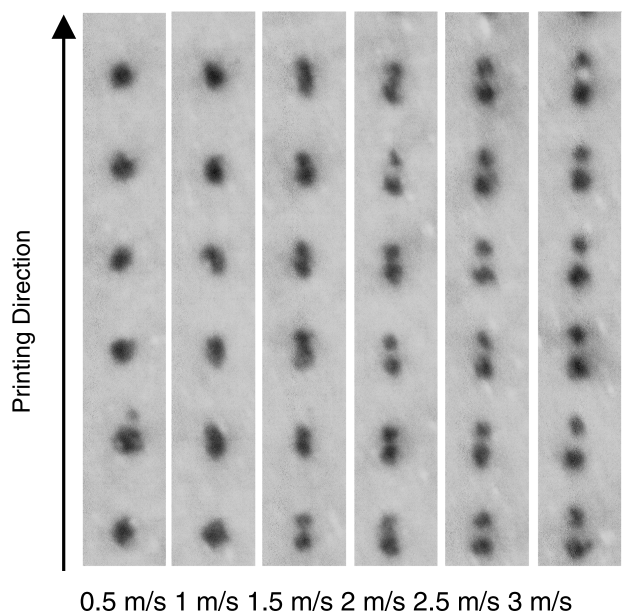

Figure 4. Dot shape in dependence of scanning speed

Dot area growth and elongated drops have been observed at high speed printing in continuous ink jet printing.[2] In the case of continuous ink jet the much less pronounced elongation and dot area growth is explained by a splashing of the drops. By looking at a microscopic picture of the dots (Fig. 4) we can estimate the reason for our strongly elongated dots at higher scanning speed. Here, the main reason is not the splashing. We observe a much larger effect due to a separation of drop and satellite. When we increase scanning speed, the satellite drop following the main drop will not be placed anymore on top of the main drop. With increasing speed it will be more and more separated from the main drop. Actually for scanning speed higher than 1.5 m/s there is not anymore one single dot on media, there is always a main drop accompanied by an almost as big satellite drop.

These elongated dots with large aspect ratios will overlap much more in printing direction and therefore produce more banding in printing direction than perfect round dots.

Density Increase and Color Shift with Increasing Speed

Due to the increase of dot area also an increase of optical density with increasing scanning speed can be observed (Fig. 5). We printed black grayscale bars from 0 to 100 % coverage with 5 % steps for 0.5 m/s, 1.0 m/s, and 1.5 m/s at 720 dpi printing resolution.

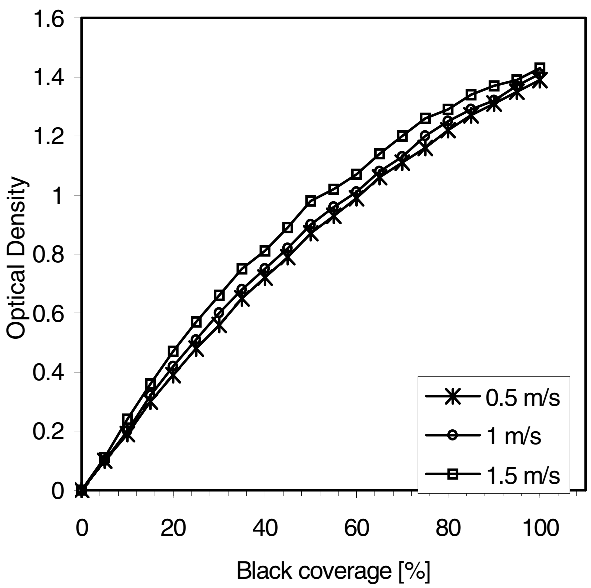

Figure 5. Optical density in dependence of speed and coverage

The measurement shows an increase of optical density of up to 20%. The difference is most pronounced at medium coverage and decreases for higher coverage when dots overlap more and more.

To quantify the color shift due to increased scanning speed we printed an ANSI IT8.7/3 test chart at 0.5 m/s and 1.5 m/s. The measurement of the color difference between the two prints results in a mean color shift of 4.4 ΔE* and a maximum color difference of 12 ΔE*. These color shifts need to be corrected by a careful calibration of the printer depending on the scanning speed.

Dot Shape Versus Distance

One way to reduce degradation of dot quality is to optimize head-paper distance. As shown in Fig. 6 dot shape and dot area is also strongly dependent on head-paper distance.

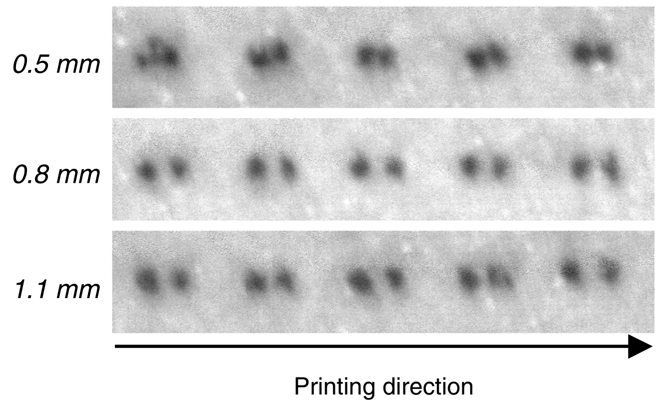

Figure 6. Dot shape in dependence of head-paper distance at constant speed (1.5 m/s)

Conclusion

Our experiments with variable scanning speed and head-paper distance showed how sensitive drop quality and positioning accuracy reacts to these parameters. By quantifying these parameters we have an effective way to optimize the system for higher printing speed with no compromise in quality.

Color shifts and increased optical density can be corrected effectively by a careful printer calibration and therefore adjustments of amount of ink put on paper. Increased banding, registration and sharpness problems due to inaccurate positioning have to be solved on the microscopic level by optimizing waveforms, shooting timing, head-paper distance, scanning speed and by avoiding too much aerodynamic disturbances.

References

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2. J. Heilmann, U. Lindqvist, *J. Imaging Sci. and Technol.,* **44**, 495 (2000)

Biography

Armin Kuendig received his MSc in physics from the Swiss Federal Institute of Technology, in Zuerich, Switzerland in 1994. From 1994 to 1998 he worked as a research scientist at the Institute of Quantum Electronics in Zuerich. He joined Gretag 1998 where he is currently R&D scientist in the ECO Basic Technology group. His main research interests are in image quality and color management. He is a member of IS&T.