Considerations in High-Speed, Commercial Quality Ink-Jet Printing

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In the commercial-quality printing market today there is often a trade-off between image quality and spatial addressability (i.e., DPI) on one hand, and speed, droplet size and printhead fabrication issues on the other. By "commercial-quality" we refer to the type of printing used for high-quality brochures, annual reports, and similar types of material.

One would like the image quality to be high in this market, but would also like printheads which may be manufactured for a reasonable price and will run fast enough.

This article is focused on commercial-quality process color printing; the requirements faced by those printing business forms and similar material will be quite different, as will the solutions which best fit those markets. We attempt to identify minimum performance levels for several of these interacting factors, so that one can know what to aim for.

Spatial Addressability Requirements

Binary electrophotographic printers, such as most desktop laser printers today, seem to perform quite satisfactorily at 600 DPI. Indeed the acceptable level of performance at this addressability had been predicted by Xerox Senior Scientist Paul Roetling.

The question may be asked, "Is this addressability sufficient for commercial-quality process color inkjet?" We offer two main reasons why we believe it is not.

First of all, desktop laser printers are aimed at a market where text quality is more important than the quality of photograph-type images. While photographic images are printed on networked monochrome laser printers with ever-increasing frequency, they still represent a relatively small amount of the total imagery typically produced on these printers. Thus, people simply tend to expect less in the way of image quality when printing photographic-type imagery on these printers. Expectations for image quality have always been high for commercial printing.

Secondly, the spots produced by most printers are typically larger in diameter than the spacing between adjacent spots. This is done, among other reasons, to produce uniform solid areas. Ink jet tends to produce spots which are even larger than those produced by electrostatic printers with the same addressabiilty. Dooley and Shaw have demonstrated that the perceived graininess of a pattern, such as those produced by frequency-modulated (FM) halftoning, is heavily dependent upon the diameter of each spot when printed.

Therefore, in order to reduce the perception of graininess, ink jet printers tend to need higher spatial addressabilities than other printers.

For a binary printer, we recommend a minimum of 1M pixels per square inch (equivalent to 1000 DPI), and suggest 1.44M/square inch (1200 DPI). If the printer has multi-level capability, as does the Xeikon, we recommend at least 360 pixels per square inch (600 DPI)

Firing-Rate Requirements

We shall base our firing-rate calculations on a process speed of one meter per second, or roughly 200 feet per minute. This is approximately one-tenth the speed of heatset web offset printing (though a small number of printers are reporting speeds approaching 15 meters per second), and is faster than current full-color digital presses. It is a convenient figure from which to scale if a different process speed is desired.

Table 1 below gives the firing rates (rounded to the closest 100 Hz) required for each orifice in order to produce a process speed of one meter per second.

Spatial Addressability α, DPI	Firing Rate f, KHz (Each Orifice)
600	23.6
720	28.3
1000	39.4
1200	47.2
1440	56.7

Droplet Volume Requirements

One of the problems particularly acute in inkjet imaging is the volume of ink applied per unit area. (This resolves into a lineal measure, the average thickness). Obviously, this will be highest in solid-fill areas. Red, Green and Blue solid fills are produced by overprinting two layers of ink. We shall compute the droplet-volume requirements based on a maximum average layer thickness for a single-color fill, with the understanding that overprinted fills may have double thickness. Further, with duplex printing, portions of the paper may receive as much as four times the single ink average thickness between the two sides.

Single ink solid fill areas must have an average layer thickness of no greater than 12 micrometers and preferably below 10 micrometers. This requirement may be put into perspective by comparing it to the thickness of a piece of paper. A typical 75 gram per square meter paper is approximately 100 micrometers thick; four layers of ink, each 12 micrometers thick, would be 48 micrometers in thickness, or just under half the thickness of the paper.

For comparison's sake, we have also included the nominal droplet diameter for each droplet volume, as well as the pixel pitch for each spatial addressability. The calculations are based on the recommended average thickness of 10 micrometers for a single-ink solid fill.

Spatial Addressability, DPI	Volume, pl	Diameter, µm	Pitch, µm
600	17.9	32.5	42.3
720	12.4	28.8	35.3
1000	6.5	23.1	25.4
1200	4.5	20.5	21.2
1440	3.1	18.1	17.6

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From the previous table, it is apparent that droplet volume must decrease dramatically as spatial frequency is increased.

Marking Technology

Continuous ink jet has demonstrated the capability to produce droplets of the required size. However, the products in which this size droplet has been produced are low-speed plotters (eg, Iris) rather than high-speed printers. Scitex Digital's high-speed continuous inkjet printers have more than requisite speed (100 KHz firing) but droplet size is apparently too large for commercial-quality printing. Scitex rolled out a four-color version of its high-speed Versamark printer at DRUPA 2000. However, it targets the utility printing market, allowing users to add full-color invoices, credit card statements, and similar material.

Calcomp and Topaz Technologies had jointly developed a Piezo-electric Drop-on-Demand (DOD) printhead (Crystaljet) with a 20 pl droplet size, and an impressive 50 KHz firing rate. This was used in their short-lived Crystaljet plotter, which printed 2 square feet per minute. If a full-width head could be fabricated, the 50 KHz firing rate ensures a process speed of over 1 meter/sec at 1200 DPI. It would be necessary to significantly reduce the droplet size for the commercial-quality printing market. Unfortunately Calcomp has disappeared, and there is a matter of patents held by Xaar which appear to address technology used in Crystaljet.

Xaar and its Swedish subsidiary, MIT, which manufactures printheads, produces piezo-electric DOD printheads. However, none of their current products have near the required speed nor resolution. They are reportedly developing a full-width printhead, in conjunction with Kyocera, for Agfa.

Conclusions

While ink jet technology is not yet ready for commercial-quality printing, it appears that this capacity will be available in the near future. We have discussed some of the factors which must first be addressed in order for this to become a reality. v

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