ToneRJet® Color Printing

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Introduction

TonerJet®[1] is a direct printing process where charged toner particles are deposited directly onto plain paper. An array of ring electrodes creates dot-sized electrostatic fields to draw charged toner particles through openings in an electrode array, depositing them in an image pattern on a plain paper surface. Early TonerJet printing technology used monocomponent magnetic toner to produce black images on plain paper. Recent work has shown that the TonerJet process is also capable of operating with nonmagnetic toner, enabling the use of process colors for full color printing. This paper describes experimental use of single color nonmagnetic toner in the TonerJet printing process. The results of those experiments have been incorporated in a four-color experimental printer capable of single-pass full color printing at 300 dots per inch and 10-15 pages per minute.

Printing Process

A simplified TonerJet print zone for monochrome color printing shown in Figure 1 uses a monocomponent nonmagnetic toner charged by contact with the fibrous supply brush. The charged particles are placed in contact with the developer sleeve where they adhere by electrostatic forces. An elastic metering blade is used to form a uniform thin toner layer on the surface of the developer sleeve. A uniform electric field is created between a high potential on the back electrode and a low (zero volt) potential on the developer sleeve. That uniform field pattern is modified by control potentials on individual ring electrodes in a two dimensional control electrode array placed in the print zone. Those individual dot-sized electrostatic fields interact with the uniformly charged toner particles; drawing them from the developer sleeve, through the apertures in the ring electrodes, and depositing them on the paper surface in the desired visible image pattern. That toner particle image is then made permanent by heat and pressure fusing the toner particles to the paper surface. Control of the particle motion through the apertures by the electrostatic fields was described in a previous paper (Reference 2).

Single Color Printer

Early TonerJet printing process development was devoted to single color black printing using monocomponent magnetic toner.[2,3] Recent work has been devoted to replacing the opaque black magnetic toner with a toner material that is suited to superimposed color images. The first step in that investigation was an experimental single color printer with independent control of paper speed, developer sleeve speed, print zone potentials, and control electrode timing. Replaceable toner containers enable operation with any one of several colors and permit color superposition experiments by repeat printing with a new color.

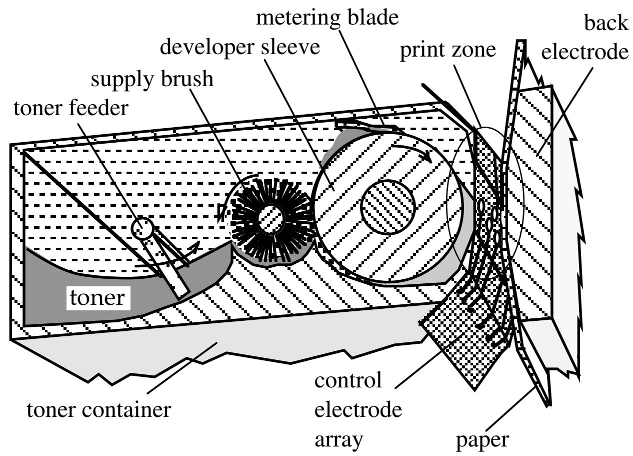

Figure 1. Simplified TonerJet print zone for monochrome color printing.

Color toner sets from commercial color photocopiers or laser printers were used for all experimental color printing. The selected color toner set requires use of a lubricated fusing roller to give good toner release characteristics. A fusing station from a commercial photocopier has been adapted for use in the single color printer.

A cleaning station removes stray toner particles from the control electrode array after printing each page. A combination of electrostatic and vacuum forces is applied in an automated sequence between pages during continuous printing operation.

A few typical operating parameter values of the experimental single color printer are:

- Paper speed: 50 mm/s
- Back electrode potential: +1500 V
- Control electrode potential (print): +275 V
- (nonprint): -50 V
- Print time: 400 µs
- Dot Spacing: 300 × 300 dpi

The single color laboratory printer produces much more uniform dots of smaller average diameter than previous magnetic toner printers. The size uniformity, circularty, edge sharpness, reflection density, and position accuracy are all improved in the single color printer as shown in Figure 2. A sample of the same print pattern from a Canon LBP4 300 dpi printer is also shown in Figure 2c for reference.

The average TonerJet dot diameters are 160 µm using the magnetic toner and 135 µm using the new color toner.

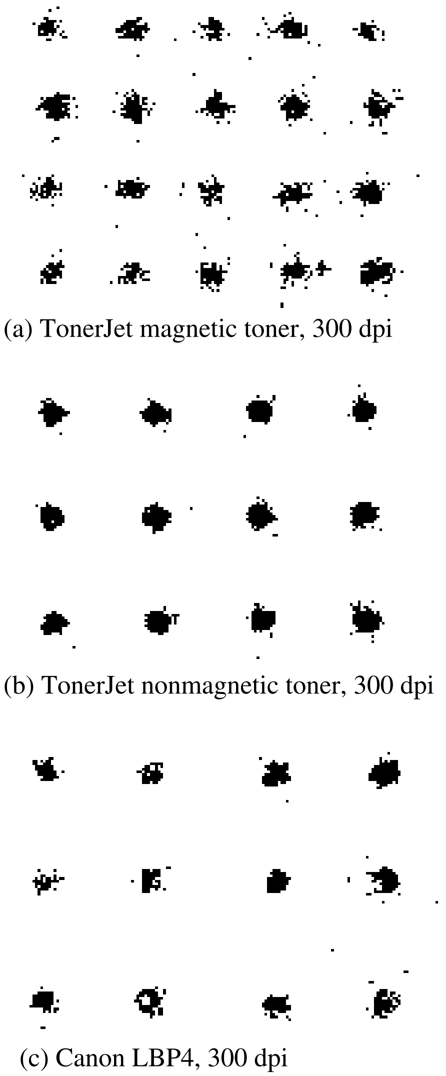

Figure 2. TonerJet 300 dpi printed dots.

Superimposed printing was tested by repeated printing in the same machine. First a control sample of equally spaced horizontal and vertical lines was printed in a single pass through the printer (Figure 3a). In a second sample, the vertical lines were printed in a first pass (Figure 3b) and the horizontal lines were superimposed in a second pass (Figure 3c). Comparison of the two samples (3a & 3d) indicated no disturbance to the first pass unfused image by superimposing the second image. The critical line crossing location where toner is deposited on an existing toner layer (3d) was no different from the crossing location deposited in a single pass (3a).

Multiple Color Printer

After successful demonstration of the single color nonmagnetic printer, a four color experimental printer was built for investigating known and unknown process interactions as multiple superimposed toner images are deposited directly on a single substrate. The four color machine was built as a large variable geometry machine with four individual print zones similar to that of Figure 1 mounted in a vertical frame with enough space between them to allow easy micrometer adjustment of position in all directions (Figure 4).

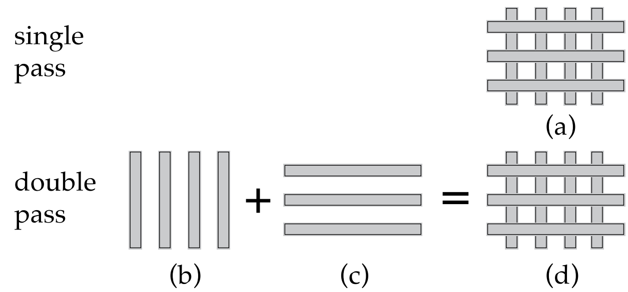

Figure 3. Superimposed printing test pattern.

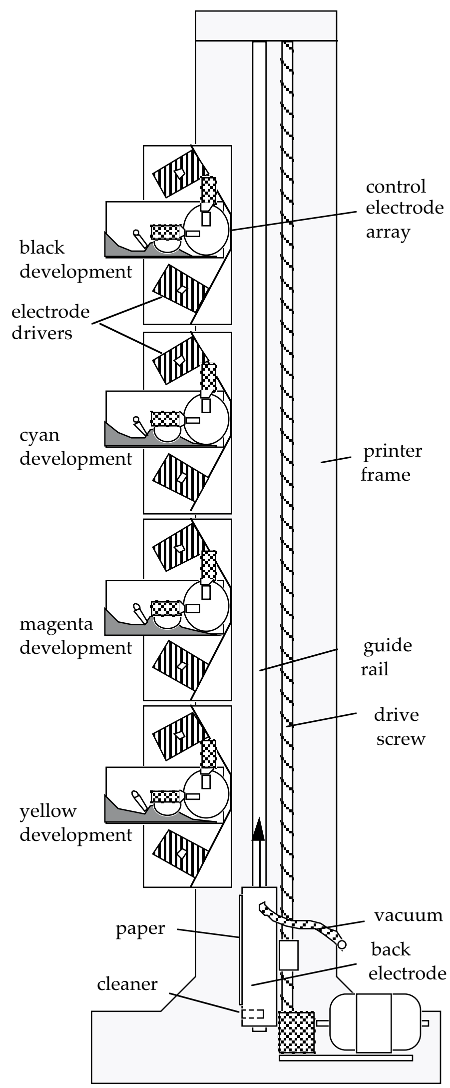

Figure 4. Experimental TonerJet four color printer.

A single movable back electrode assembly holds the paper by vacuum and transports the paper past each color print zone in sequence at a selectable speed. A cleaning vacuum slot in the back electrode assembly removes stray toner particles from each control electrode array as it passes following the print cycle.

Toner images are fixed by a lubricated hot roll fuser identical to that used in the single color printer. Vertical size limits of the multiple color printer frame require a separate fuser with manual feeding.

A new controller based on the AMD 29K RISC chip provides gray level control of the dot size and reflection density by modulation of print time. Print time modulation of the TonerJet control aperture modulates both the diameter of the printed dot and the number of toner particles in the dot. A representation of that modulation is shown in Figure 5. Initially four gray levels per color per dot were used in the multiple color printer. A custom driver is based on Apple QuickDraw.

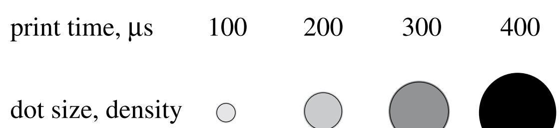

Figure 5. TonerJet dot size/reflection density modulation.

Typical printer operating parameter values are the same as those listed earlier for the single color printer.

Results

Superimposed four color experiments again show no disruption of the first layer (unfused) image and no gross contamination of other developer sleeve colors by previous toner images.

Direct single pass color printing of superimposed toner images on a substrate was successfully demonstrated. Modulation of dot size and reflection density enables more accurate representation of halftone images than those produced by multiple dot pixel techniques. TonerJet printers can thus produce continuous tone images at lower dot per inch than required by binary printing processes.

Summary

The feasibility of superimposing color toner images directly on a printing substrate has been demonstrated for the TonerJet printing process. Four color images at 300 dpi with four color levels per dot are similar to those produced using much higher resolution without individual dot color levels.

References

1. TonerJet is a registered trademark of Array Printers AB in Sweden.
2. Johnson, J. and O. Larsson, TonerJet® — A Direct Printing Process, *Proceedings of the Ninth International Congress on Advances in Non-Impact Printing Technologies*, 509 (1993).
3. Johnson, J., “An Etched Circuit Aperture Array for Toner—Jet® Printing”, *Proceedings of the Tenth International Congress on Advances in Non-Impact Printing Technologies*, 311 (1994).