Uniformity in Solid Areas with the TonerJet® Printing Technology

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Abstract

TonerJet® is a novel print technology developed by Array Printers AB in Sweden. It is a direct printing method with the possibility to be a challenge to the electrophotographic technologies in the area of color office printers and multifunction machines.

During the last year significant progress has been made in print quality, horizontal banding has been removed, dot positioning and uniformity in solid areas have been greatly improved.

Historically there have been problems with toner supply, giving vertical stripes in solid areas. Since the TonerJet® print head usually uses two rows of apertures, the amount of toner used by the first row affects the available amount of toner for the next row. Array Printers has studied the problem and in this paper hardware, software and process solutions will be presented. Advantages, disadvantages and implementation will be discussed.

Keywords: TonerJet®,Dot Deflection Control, Software Density Control, Print Uniformity.

Introduction

TonerJet® is a direct print process[1] where the image is formed directly on to the print media, e.g. paper or belt. The print media passes at single pass[2] four print heads, one for each color, mounted in fix positions. Each print head covers the full width of the print media.

The resolution is usually 600 dpi and the print head prints dots in a print sequence that is repeated in correlation to the print media movement. This gives a horizontal resolution (parallel to the print head) that depends on the print head. The vertical resolution depends on the print media movement and the interval between the print sequences. The print media is paper or an intermediate image transfer belt. Figure 1 shows a printer model with four print heads, one for each color, using a transfer belt as print media.

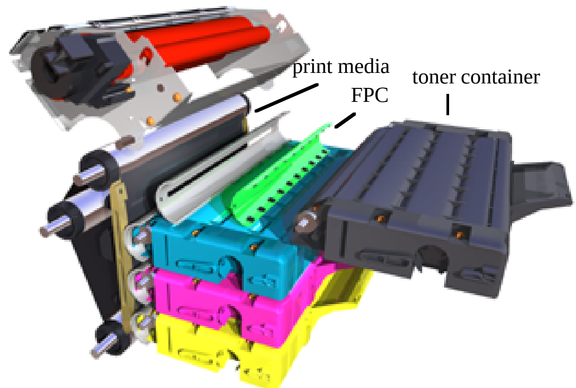

Figure 1. TonerJet® printer with four print heads, CMYK, using a transfer belt as print media.

How does the TonerJet® print head address toner to the print media? The toner particles (negative charge) are attracted to the print media by electrostatic forces created by a potential difference between a toner supply roller and a back electrode. The back electrode is located behind the print media and has a higher potential than the toner supply roller. The potential difference creates an E-field that transfers the toner particles from the toner sleeve to the print media. The FPC (Flexible Printed Circuit) is mounted in this E-field.

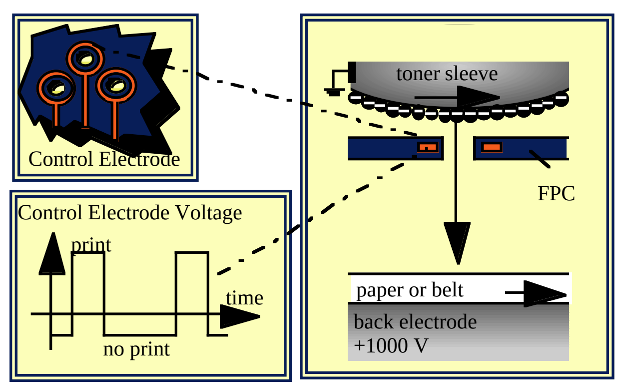

Figure 2. The control electrode in the Flexible Printed Circuit, FPC, controls the toner transfer through the aperture.

The FPC has an array of small apertures through which the toner can pass and form dots on the print media. The apertures are surrounded, or partly surrounded, by control electrodes. The toner transfer to the print media is then controlled by the potential of the control electrodes. Thus, the control electrode potential decides if the toner particle will remain on the sleeve, or pass through the aperture and form a dot. Figure 3 shows the array of control electrodes in the FPC, and figure 2 shows how the control electrode potential is pulsed to a print voltage, that allows toner transport to the print media.

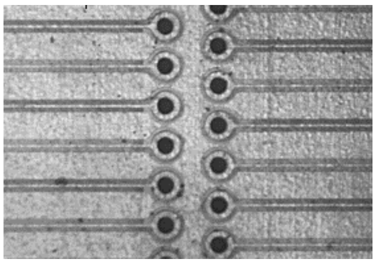

Figure 3. Top view of the FPC and its two rows of apertures. Control electrodes surround each aperture.

Gray Levels

Grey levels are created by controlling the amount of toner in each dot. One dot is made by a print sequence, where the control electrode is pulsed to a print voltage during a short time, the print pulse time, see figure 4.

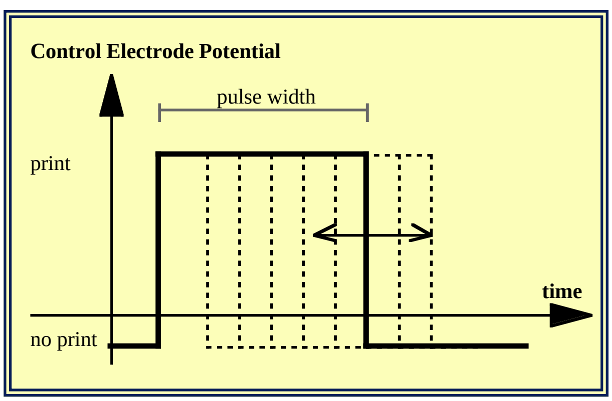

Figure 4. A print pulse and its pulse width.

The software controls the pulse width for each dot. A short pulse releases few particles from the toner supply roller and gives a light gray dot. A long pulse releases all toner above the aperture and gives a solid black dot. The software can therefore create true gray scale printing down to a few particles per dot.

Uniformity in Solid Black Areas

Historically the TonerJet® technology has been using six rows of apertures with 100 holes per inch in each to achieve 600 dpi resolution. This mainly generated two problems, the first was too many driver circuits which is costly and the second was bad uniformity in solid black areas because, of hole overlap in the toner feed direction. The ring electrode diameter has to be larger than the desired dot and consequently the ring electrode, defining the toner pick area, is overlapping subsequent apertures intended for the adjacent dots. This causes all apertures situated downstream relative to the toner feed direction to suffer from toner deficiency, thus printing weaker dots and giving bad uniformity.

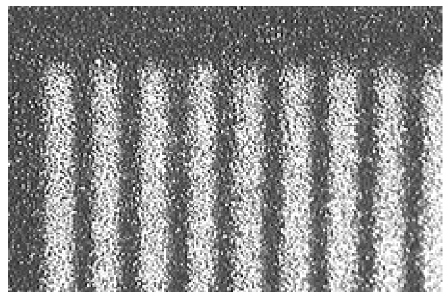

Figure 5. Toner pick area from a two row FPC only printing with the first row, not leaving enough of toner for the second row.

Sufficient improvement of uniformity has been reached by implementing three innovations.

First and most important is the Dot Deflection Control that divides the number of apertures by three. The second is a reduction of aperture width to reduce the overlap, while still maintaining the same area. The third is a software controlled method to supervise the toner consumption by each row of apertures.

Dot Deflection Control

With the dot deflection control (DDC) technology[3], one aperture can address more than one horizontal dot position. Two deflection electrodes partly surround the aperture and create an asymmetry in the E-field. The trajectory of the toner particles is then easily controlled by the applied voltage difference between the two DDC electrodes, see figure 6:

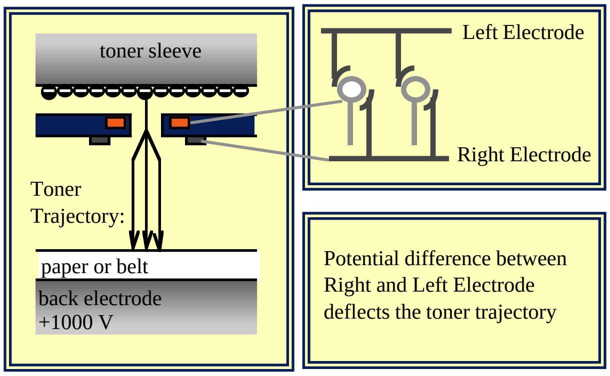

Figure 6. Dot Deflection Control (DDC) increases the resolution and reduces the overlap.

The advantage of the DDC print head is that the number of apertures is less than the number of addressable horizontal dot positions. For example, if we print with 600 dpi dot resolution, and each aperture addresses three horizontal dot positions, the aperture lay-out in the FPC will be 600/3=200 holes per inch. This is an advantage for a number of reasons:

1. A print zone with only two aperture rows has much less overlap. The first row of ring electrodes overlaps the second row of ring electrodes by approximately 20 percent in a standard case, and the apertures would not overlap at all.

2. Less apertures requires fewer IC:s.

3. The FPC is easier to manufacture.

DDC also enables the software to control the horizontal dot resolution by changing the number of deflected dots printed with each aperture.

Oval Holes

It has been shown necessary to keep the aperture area above a certain value to maintain sufficient print density and to avoid toner accumulation inside the apertures that may block the hole. The area demand will normally limit the possibility to reduce the toner pick area by decreasing the hole size further, unless an oval hole could function as well as a circular. The oval holes have a reduced width while maintaining the same area, thus combining two important features. Tests have proven same good results regarding toner accumulation inside the hole for oval holes as for circular holes. The significant hole parameter is area and not shape.

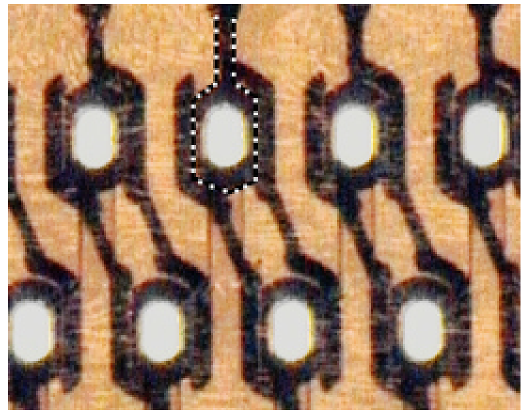

Figure 7. Back light view of a FPC showing oval apertures and the control electrode shapes. The overlap is reduced.

Software Density Control

Although the DDC and oval shaped holes almost completely takes away the overlap, it may still be that the three lines printed with each aperture in the second row are weaker in density. This is the case if the first row of apertures also prints. As for the gray scale control previously described, it is suggested that there is a time sensitive selection process when releasing toner from the supply roller. It is also shown that toner particles affected but not printed by a previous row may be amongst them that need more time to be released. Consequently, even if there is potentially enough toner available on the supply roller for the second row, it cannot be released as easily as for the first row with an untouched layer. For the second row to print with the same density as the first, it is necessary to prolong the print pulse time. The required print pulse length will be a function of what the first row has printed. A shorter time, same as for the first row, if nothing was printed and a longer time if the first row printed fully. The time ratio will be dependent on the gray level as well as the number of dots printed by the first row. Figure 8. shows a schematic graph of the relations.

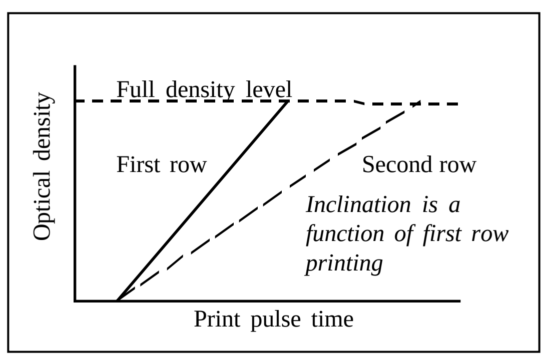

Figure 8. This graph shows that a time compensation is needed for the print pulse time of the second row if the first row also prints.

Conclusion

The conceptual problem of deficient toner supply in the earlier designs of the TonerJet® flexible printed circuits, is definitely solved by later inventions. The main contribution comes from the Dot Deflection Control that reduces the number of apertures, but also the elongated holes and especially the time compensation method improve the uniformity. The compensation method is simple and is easily implemented in the image conversion software.

References

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Biography

Anders Berg-Palmqvist and Hans-Peter Starck-Johnson have received their M.S. in Engineering Physics from Chalmers University of Technology in Göteborg, Sweden. Mr. Berg-Palmqvist and Mr. Starck-Johnson joined Array Printers 1997, working with the development of the TonerJet® print process. Both are members of the IS&T