High Speed Xerox Inkjet Technology

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Abstract

A modular print head strategy gives the capability to move Xerox's inkjet technology from the desktop and office area to the higher speeds required for the production market. An array of 3 inch print heads can be used to print images at speeds faster than 300 feet per minute. The heads use a non-aqueous, phase change ink which is solid at room temperature. When jetted, the solid ink sits on the surface of the paper, which decreases image bleeding and show through and would eliminate the need of a drier and media preconditioning. An image on web array (IOWA) sensor can continually monitor test patterns during printing. This IOWA sensor can enable color to color registration, image uniformity, and jetting efficiency to be continually monitored and adjusted during printing.

Introduction

The role of inkjet in digital printing is growing. A number of new product offerings in the high speed short run market and been recently announced. This paper describes new technologies that Xerox has developed that could enable a production inkjet printer with unique capabilities. These include a solid ink that prints well on a wide variety of uncoated papers, and an image on web array (IOWA) sensor that senses image uniformity, registration between colors, and the presence of missing jets. The innovations also include a scheme to obviate the presence of missing jets, color to color registration improvements by accounting for the elasticity of the web, and various options to control the final image appearance through heat and pressure

A diagram of the technologies described here is shown in figure 1. The paper web leaves the unwinder and enters the printer. Because the solid ink adheres well to uncoated paper, there is no need for any paper preconditioning such as the application of a binding layer. Neither is there a need for any specially pretreated papers. The paper then passes by a pre-heater which brings the web to the desired temperature for ink adhesion and imaging quality in the print zone.

After passing the preheater the paper enters the print zone. The paper passes along a series of print heads that eject ink horizontally on one side of the paper. Each station can be populated with heads that jet ink of a different color. Although the figure shows one group of heads for each color and illustrates 4-color printing, this architecture has the flexibility in populating the stations. One option is to populate more than one station with black only to give higher resolution printing. The print zone can also be populated with more than 4 stations to provide an opportunity to print with additional colors to give a larger color gamut. Another option is to populate the stations with lighter inks as a way to decrease the graininess of the prints.

After leaving the print zone, the paper passes under an image on web array (IOWA) sensor. The IOWA is a full width contact image sensor. The IOWA captures images printed on the web at a resolution of 600 spi in the cross process direction and at a resolution in the process direction that depends on the speed of the web. The high speed sensor has sufficient resolution in the process direction to sense any misalignment of the print heads with an accuracy of less than 10 microns. More details on the use of the IOWA in maintaining print quality is discussed later in this paper.

The paper then passes by another heater. The temperature of the heater is set so that the compact drops are melted and flow to provide good coverage over the paper. Following the heater, the web passes through a glosser-spreader. The two rolls of the glosser-spreader are under high pressure to give good adhesion of the ink to the paper. The material of the front surface of the glosser-spreader is chosen to set the gloss of the image to the desired level. After exiting the spreader, the web can be rewound or can continue to a variety of finishing equipment such as a cutter-stacker.

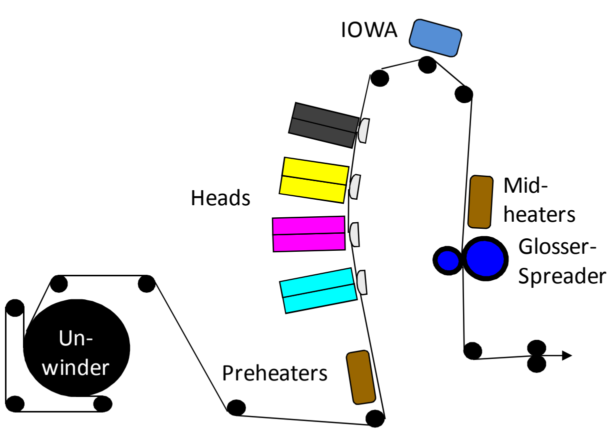

Figure 1 – Diagram of high speed inkjet technologies

Figure 2 *– Modular Solid Ink Print head*

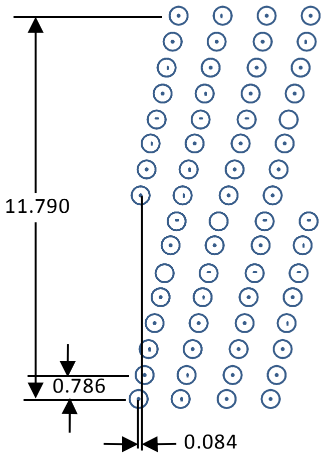

Figure 3 – Nozzle arrangement on print head

Print Heads

The high throughput long life stainless steel piezo inkjet print heads are an enhancement to those used in Xerox's office products and a head is shown in figure 2. The width of the jetting area is approximately 3 inches. The design of the print head was optimized to achieve high jetting frequencies and high reliability[1]. The face plate of each head contains 880 nozzles arranged in a staggered pattern to provide printing of a single color with a resolution of 300 spots per inch. Specifically, the jets are arranged in a staggered grid of 16 rows at 55 columns, a section of which is shown in figure 3.

One possible arrangement of the print heads is shown in figure 4. The print heads cannot be butted together, so the print heads must be interlaced to eliminate gaps when transitioning from one print head to the other. A print head row consists of 7 print heads and provide printing at a resolution of 300 spi in the cross process direction. A second pair of print box units can be interlaced with the first to increase the printing resolution to 600 spi. Additional pairs could be added to increase the print resolution beyond 600 spi.

The print heads use a granulated, resin-based ink that is solid at room temperature but melted in the heads. The jetstack can be operated at a temperature as high as 140 degrees C, with the actual operating temperature chosen based on the ink properties. The print heads operate up to a maximum jetting frequency of 43 kHz. Because the ink undergoes a temperature phase change when the drops are jetted to the relatively colder paper they immediately increase in viscosity and remain on the top of the paper rather than being absorbed by the paper fibers. Therefore, the printer is well suited to printing on inexpensive uncoated papers which don't require any pretreatment prior to printing. Because there is no water or solvent there is no need for any drying after printing.

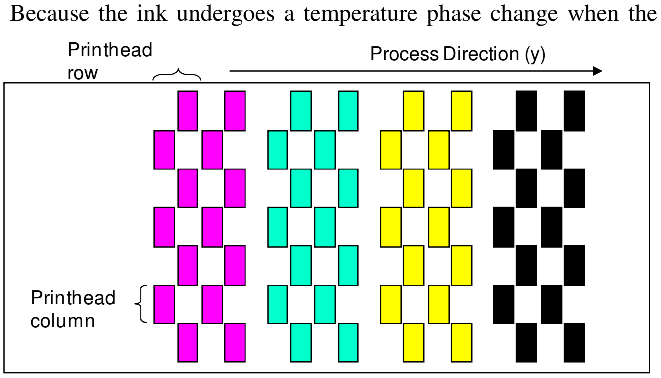

Figure 4 – Arrangement of print heads for 4-color printing.

Aqueous based inks are often difficult to remove from the paper during the recycling process and require a change in the deinking chemistry from the standard deinking process [2]. Because solid ink sits primarily on the surface of the paper as toner does, recycled prints may be deinked using the standard techniques used in the deinking industry [3].

Image on Web Array Sensor

The IOWA sensor is a linear array contact image sensor (CIS) that is spaced about a millimeter from the paper and monitors diffuse light reflection from the web as the paper and image passes underneath. In-line contact image sensors have been used previously to automate the measurement of image registration [4] and uniformity [5]. The width of the IOWA sensor is greater than the width of the web. It is operated as a monochrome sensor to provide the highest resolution in the process direction. CIS sensors need each pixel calibrated with an offset and a gain. The illuminant is turned off to provide the dark level, and the moving web itself is used to provide the white level. If ink passes under the IOWA, it decreases the light reflectance and this decrease is

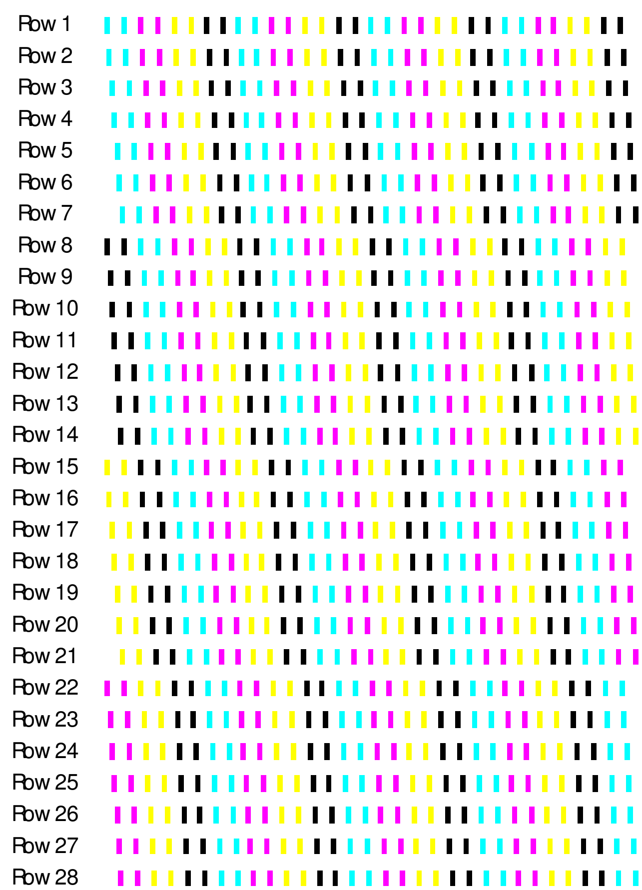

Figure 5 – Registration test pattern

used to sense the presence and location of ink on the web.

Registration between the print heads is sensed by printing and sensing a test pattern. One test pattern consists of an interlaced pattern of single pixel wide lines on the web. A section of the registration test pattern is shown in figure 5. The pattern consists of a series of rows of dashes oriented in the process direction. Each dash is printed from a known nozzle of one of the print heads. Each row samples different nozzles from the group of print heads. The pattern is designed so that the dashes are equally spaced within a row if the print heads are aligned.

The position of each nozzle in both the process direction and cross process direction can be determined at a resolution higher than the IOWA resolution by using not only the location of the IOWA pixels under which a particular dash passes but the gray level of the response [6]. From the position of every nozzle on the print head, both the color to color alignment between print heads along different positions along the web and the spacing between print heads in each print head row can be measured.

Registration

To maintain good image quality, it is important to continually monitor and adjust the registration between the print heads across the print zone. Both the initial alignment of the print head array and the maintenance of alignment are automated with the use of the IOWA sensor. If an analysis of the captured registration image shows the print heads are not registered, an adjustment is performed. Each head may be potentially mis-registered in the cross process (x) direction, the process (y) direction, or rotated with respect to the process direction (roll).

Figure 6 shows a cartoon of these registration errors between a subset of the heads. Figure 7 shows the actuators that can be adjusted to maintain registration. Motors physically move the heads in the cross process direction and rotate the heads, while registration in the process direction can be adjusted by changing the delays in the firing of the jets.

If the print head is not oriented perpendicular to the path of the web travel, the staggering of the nozzle array would lead to streaks due to an unequal spacing of the nozzles in the perpendicular direction. The unequal nozzle spacing can be detected from the registration or similar test patterns. A motor attached to each head can rotate the head relative to the web in order to recover an equal nozzle to nozzle spacing.

There are three types of cross process registration errors. If two heads of different colors are offset from their intended positions in the cross process direction, a color to color registration error occurs (x-series error). If two heads of the same color from different print box unit pairs are offset, then an interlace error will occur between the two 300 spi heads (x-interlace error). If adjacent heads in a print box unit pair exists, then the nozzle spacing will not be equal as it transitions from one print head to another print head (x-stitch error).

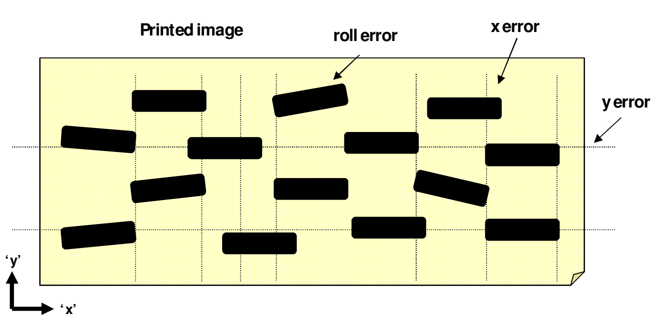

Figure 6 – Illustration of alignment errors between print heads.

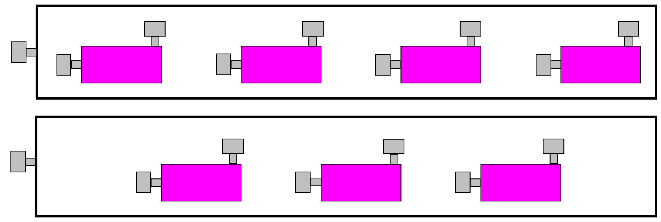

Figure 7 – Motors are used to rotate heads and translate them in the x direction. Timing delays are used to align heads in the y direction.

There is another set of motors that can be actuated in response to these registration errors. Each print head has a motor attached to it which can move the print head relative to other print heads. In addition, there is a motor attached to the print box unit which moves all the heads in the print box relative to the other heads. From an analysis of the registration test pattern, the entire set of x-series, x-interlace, and x-stitch errors between all heads are determined. From these errors, the displacement of each head from its goal position of zero registration error is determined. From the head position errors, a set of motor moves is found which will bring each head towards its goal position. The motors are all moved simultaneously. The registration is measured at regular intervals to ensure the heads remain in their goal positions. Process controls over these errors is particularly important in a continuous feed printer because the physical positioning of the web and hence the required proper head positioning varies with time.

Double Reflex Printing

The firing of the print heads must be precisely timed relative to the other print heads so that as the web passes under each head, the intended jets are adjacent to each other. The position of the web is monitored via encoders on the rollers. In the simplest implementation, the number of encoder pulses monitored is proportional to the distance between each set of print heads and can be used to set the delays as the velocity of the web varies. This approach is known as single reflex printing.

If the physical spacing between the print heads in the process direction varies slightly from the intended spacing, there will be a misregistration in the process direction. This registration error can also be determined from the test pattern shown in figure 5. For example, if a set of dashes associated with one of the heads in one of the test pattern rows is displaced in the vertical direction, this indicates the head is firing too early. This displacement is found by processing the image whereupon the timing delays between each of the heads are adjusted to maintain alignment between the heads in the process direction.

Registration errors can only be adjusted when a test pattern is printed and analyzed. However, there may be variations in the web velocity that vary on a time scale faster than the registration can reasonably be monitored. Specifically, the velocity of the web may not be the same throughout the print zone. In order to maintain a constant tension on the paper through the print zone the web control system may rotate the different rollers throughout the print zone at slightly different velocities. The paper will elastically stretch or contract in response to these velocity changes. As the paper length changes the number of encoder pulses that correspond to the distance between two print heads does not remain fixed.

In double reflex printing [7], the velocity of all the encoders on the rollers through the print zone are monitored and used to predict the local web velocity under each print head. If one roller later in the process is moving faster than an earlier roller, then the paper may be stretching between these two rollers. Double reflex printing results in a further improvement in process direction registration. In double reflex printing, the surface velocity of all the rollers is inferred from the encoder pulses and used to maintain a model of the local paper velocity throughout the print zone. This local paper velocity is used to refine the prediction of the timing delays required on a real time basis.

Missing Jet Correction

All direct marking print heads are subject to the potential of a failure of a jet nozzle due to contaminants or air ingestion. Undetected nozzle failures would lead to streaks in the image. Failed nozzles can often be recovered by forcing ink through the nozzles and cleaning the head, but this would require stopping the print job.

The IOWA sensor provides a means to detect and mitigate the presence of a missing jet. Missing jets can be detected with sensing the complete registration test pattern. If all jets are present and the heads are aligned, the dashes of the test pattern of figure 5 will be equally spaced. For each missing jet, there will be a gap in the evenly spaced test pattern dashes which can be detected through image processing.

If there is a missing jet, the drops that would be printed by this jet can be assigned to neighboring jets [8]. Figure 8a shows a 60% area coverage screen and 8b shows the white streak that would result with a missing jet. The 5 drops to be printed by the missing jet can be assigned to neighboring jets based on the available white space. The narrow white streak that would result from a missing jet becomes a white streak adjacent to two dark streaks as shown in figure 8c. The structure of this composite streak is at such a high frequency that it cannot be resolved by the eye and the resulting print appears uniform.

Conclusions

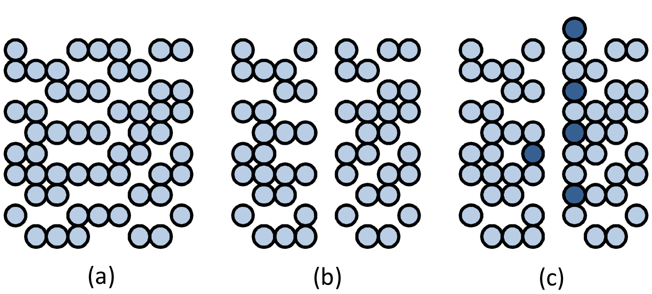

Figure 8 – Replacement of missing jet by neighboring jets

In conclusion, Xerox inkjet printing could be extended to high speeds with the innovations described in this paper. Extension of print head and solid ink technology enable printing on untreated low cost plain papers. The use of double reflex printing improves the registration over what could be achieved with single reflex printing. Missing jet substitution obviates failures that might arise with failed nozzles. The integration of an inline sensor enables automation of a number of setup and maintenance procedures. Head to head registration is automated and the IOWA sensor provides a means to detect the presence of missing jets. The IOWA sensor also further automates other image quality adjustments. The printing density both within a head and head to head can be monitored with the IOWA sensor and can be adjusted via jetting ejection waveforms if necessary. Nozzle to nozzle variations in the process direction of each drop can be detected and the image adjusted to maintain uniformity of horizontal edges.

References

[1] S. Korol, An Analysis of Recent Advances in Solid Ink Printer Performance from a Print Head Perspective, Proc. NIP24, pg. 107 (2008).

[2] H. T. Ng, M. Bhattacharyya, L. Mittelstadt, and E. Hanson, “Deinking of HP Digital Commercial Prints: Effect of Chemicals and Their Loadings on Deinkability”, Proc. NIP25, pg. 173.

[3] A. Fischer, “Environmentally Friendly Premiere at IPEX, New Inkjet Printers are Good Deinkable”, INGEDE Press Release 1/2010, www.ingede.com/ingindxe/press/pr1001.html

[4] H. Mizes, “Active Alignment of Print Heads”, Proc. NIP25, pg. 711.

[5] H. Mizes et al, “Automatic Density Control for Increased Print Uniformity and Printer Reliability with Inline Linear Array Sensing”, Proc.NIP24, pg. 206.

[6] H. Mizes and D. Viassolo, “Scanner-Based Technique to Adjust LED Printbar Uniformity”, Proc. NIP19, pg. 532.

[7] J. Folkins, “Double Reflex Printing”, US Patent 7,665,187.

[8] D. Mantell and S. Kroon, “Compensation for malfunctioning jets”, US Patent 7,422,299.

Author Biography

Howard Mizes received his BS degree in Physics from the University of California at Los Angeles in 1983, and his Ph.D. degree in Applied Physics from Stanford University in 1988. Since 1988, he has been with Research and Technology at Xerox Corporation, where he is a Principal Scientist. Dr. Mizes' research has been primarily focused on understanding and controlling the process physics of marking technologies, and quantifying and improving the resulting image quality. He has worked in the areas of charge transport and contact charging, particle adhesion measurements and modeling, and experimental probes of the xerographic development process. His image quality work has focused on improving the spatial uniformity of the printed page. e-mail: howard.mizes@xerox.com