Through Flow Technology – Enabling Highly Reliable Inkjet Manufacturing of Flat Panel Displays

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Abstract

Through Flow Technology offers unparalleled advantages for the manufacturing of flat panel displays using inkjet technology, including: outstanding reliability, self-maintenance, self-priming and simple set up. The Xaar 1001 GS6 is the first product incorporating this technology. The concept and test results will be presented.

1. Introduction

Inkjet printing has long had the potential to be a key process step in the manufacturing of flat panel displays. After a long incubation period, where inkjet printing has been confined to R&D laboratories and prototyping-scale facilities, a number of display makers are now investing in scale manufacturing facilities incorporating inkjet printers. The market entry of alternative integrators, OEMs and inkjet print head manufacturers implies that inkjet printing is gaining industry acceptance as a commercially viable deposition step in display manufacturing. However, despite all the current activity and commercial interest in inkjet printing, no print system exists that meets the consistency, reliability, lifetime and volume and placement accuracy specifications for display manufacturing.

Poor print head performance and nozzle failure has profound implications for manufacturing yield. The downtime to replace and then align a replacement print head, or more especially an array of print heads, can be substantial and costly. Minimising the need to replace a print head and ensuring that any replacement results in minimal downtime is a necessary requirement for future print head technology. Xaar's 1001 GS6 print head (Fig. 1.) is the first to fulfil this critical requirement.

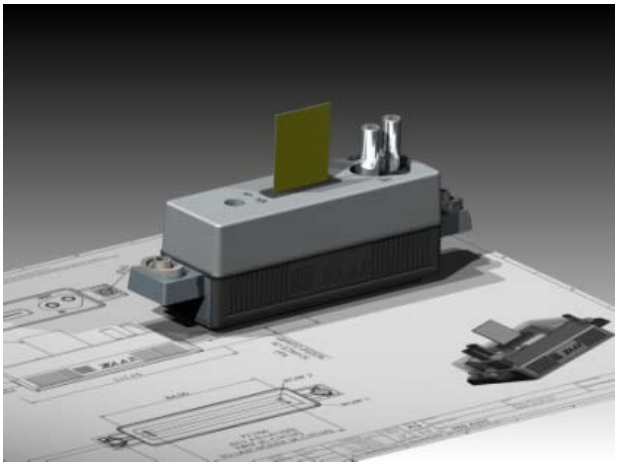

Fig. 1. The Xaar 1001 GS6 print head with Through Flow Technology

2. Experimental

Through Flow Technology is the direct result of a completely novel print head design known as the Hybrid Side Shooter. Traditionally, piezo-electric inkjet print head design is of the end-shooter variety, whereby nozzles are placed at the end of the long channels. The Hybrid Side-Shooter (Fig. 2.) nozzles are placed on the side of the channels. Fluid can now continuously circulate at high speed (>10X printing rate) through the manifold and channels, actually brushing against the back of the nozzles. Any nozzle-blocking air bubbles or particulates present in the fluid or print head are swept past the nozzles and effectively removed from the print head and in to an external trap. Extensive fluid dynamics modelling has gone in to ensuring that no "dead spaces" exist in, and all filtration is external to,

the print head. This makes the print head not only more reliable, but also self-recoverable.

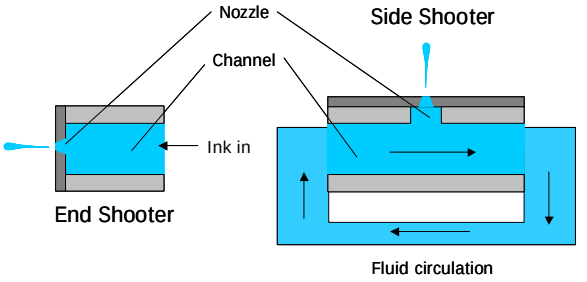

Fig. 2. Schematic of the Hybrid Side Shooter principle

If any blockage does take place, recirculation will clear the blockage and allow the nozzle to return to full functionality, within the order of a few milliseconds. In addition, continuous fluid circulation has other, considerable benefits: pressure and temperature (to better than 1°C) can be set at the print head and unstable fluids remain in suspension.

The current print head specification is given below.

Table 1. Xaar 1001 GS6 print head specification

Description	Value	Unit
Active nozzles	1000	-
Print swath width	70.5	mm
Ink inlets / outlets	1 / 1	-
Nozzle pitch	141	µm
Nozzle density (nozzles / inch)	360	npi
Drop velocity*	6	m/s
Printhead weight (dry)	122	G
Dimensions (W x D x H)	130 x 30 x 50	mm
Binary Mode		
Drop volume*	6	pL
Typical firing frequency*	42	kHz
Greyscale Mode		
Number of grey levels	Up to 16*	-
Sub drop volume *	6	pL
Drop volume at 8 levels*	42**	pL
Typical firing frequency	6**	kHz

*Dependent on ink used and system integration
**Linear printing speed of 0.42m/s

The nozzles are arranged in two rows of 500 nozzles each, offset by half a nozzle pitch giving the print head a resolution of 360npi. The two rows are separated by a distance of approximately 4mm.

At FESPA'07, a world first display of high-speed, high quality and reliable printing was demonstrated live with a four-head CMYK configuration jetting Sun Chemical UVjet inks and supported by Xaar drive electronics. In a non-stop operation over 5 days, Xaar's 'proof of concept' system printed outstanding quality at the rate of 24m/minute. By the end of the event the rig had produced a flawless label strip 21.5km in length, with the only maintenance being a single nozzle wipe at the commencement of printing each day. The performance achieved at the show was deemed to be of similar quality to flexo-printing.

The Xaar 1001 GS6 exhibits extremely fine control of volume and velocity, both inter- and intra-head, crucial when a print bar or modular approach is taken to obtain single-pass coverage of large-area substrate. This control is achieved without the need for Drive-Per-Nozzle (DPN). The results for volume control are exhibited in Fig. 3. The 3-sigma data, in histogram form, is of single printed dots from each of the 1,000 nozzles of ten print heads (i.e. 10,000 nozzles) selected at random. These results were generated by printing using Sun Chemical UVjet ink on a microporous substrate. The data shows maximum variability of approximately ±3µm.

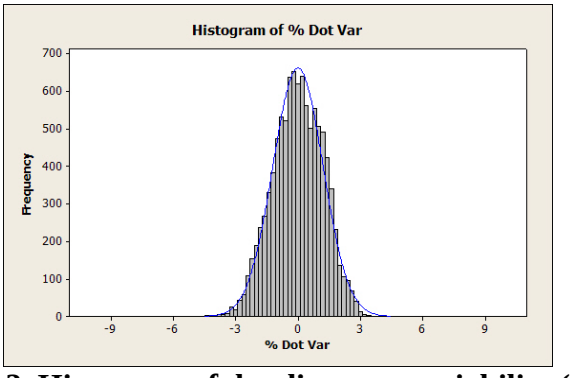

Fig. 3. Histogram of dot diameter variability (no DPN)

This control, combined with Xaar's patented greyscale technology, consistently generates extremely accurate sub-droplets (6pL or multiples thereof), jetted at high

frequency (>120 kHz) and which coalesce in-flight to ensure an extremely accurate final drop size, with no satellite formation.

Drop placement accuracy is dependent on individual nozzle trajectory errors (jetting straightness) and errors in each nozzle's position on the print head. Xaar's state-of-the-art manufacturing processes have enabled exceptional print head drop placement accuracy, Figs. 4 & 5.

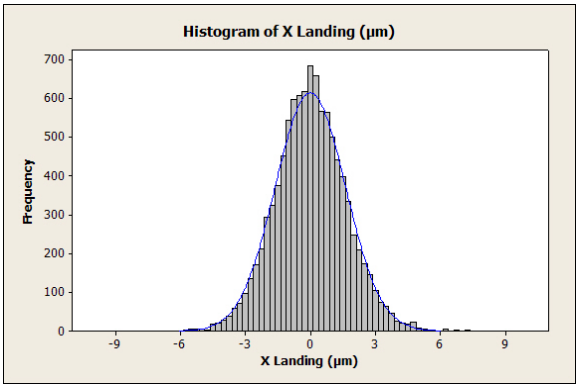

Fig. 4. Histogram of drop placement accuracy across the head (no DPN)

Drop placement accuracy across the head (X-landing, 3-sigma, 10,000 nozzles represented, static mode printing) is of order ±6µm.

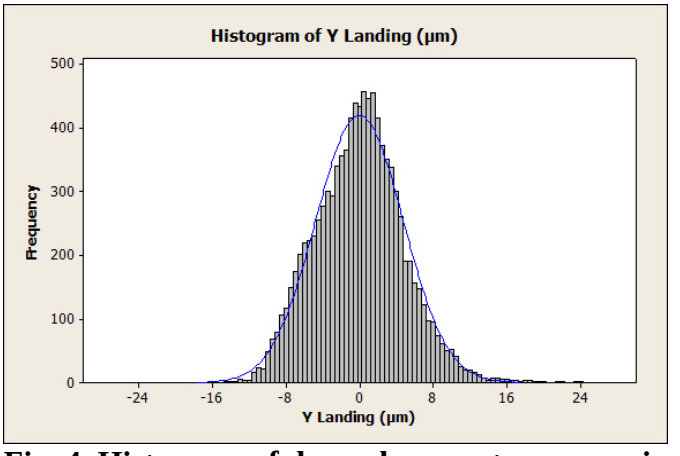

Fig. 4. Histogram of drop placement accuracy in print direction (no DPN)

Drop placement accuracy in the print direction (Y-landing, 3-sigma, 10,000 nozzles represented, static mode printing) is of order ±16µm.

The Xaar 1001 GS6 print head is fully internally coated with parylene prior to nozzle ablation ensuring that all internal surfaces are fully protected from aggressive fluids. The print head is compatible with solvents and other materials traditionally used in display manufacturing and printed electronics. It is fully EMC compliant.

The lightweight compact print head is designed to be truly 'plug and play'. Micro-precision accuracy of nozzle plate ablation in manufacturing means that all print heads have identical nozzle placement positioning. With multiple print heads mounted on a print bar the precision designed mechanical interface ensures fast and accurate relocation of a new replacement print head with micron accuracy, eliminating the need for alignment or calibration procedures. Multiple heads, precision mounted on a print bar create an unlimited printing width. Designed originally for high-speed single pass applications, the Xaar 1001 GS6 forms the core of a production printing solution for the manufacturing of flat panel displays.

Finally, the print head is able to jet fluids with a viscosity range (to date) between 10 and at least 100cps. This in itself offers significant advantages over other piezo-electric print heads in that less modification of fluids is required in order to achieve best possible jetting conditions.

3. Summary

Xaar has developed a unique print head technology based on Through Flow. This technology delivers unparalleled print head reliability, crucial for manufacturing of flat panel displays using inkjet.