Improved Reliability in Industrial Inkjet Printing

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Abstract

Industrial printing applications benefit from the increased performance and flexibility of the latest inkjet printheads with throughflow TF Technology™ (ink recirculation through the ink channels). Reduced maintenance requirements and improved reliability specifically address the needs of high duty print operations such as 'single pass' web or sheet fed printing.

Introduction

Inkjet technology has seen a remarkable development in the recent past, and inkjet printheads are today accepted as 'manufacturing tools' in the industry. While inkjet applications like 'wide/grand format' printing are impressive indeed, they, however, still suffer from disadvantages, the major one being the need for multi-pass printing.

'Single pass' printing is therefore the magic word and it is inkjet's true entry into large scale commercial and industrial printing. To make single pass printers work with high quality, high productivity and high reliability there are a couple of key requirements to be met, which needs close cooperation within a partnership of ink, printhead and substrate manufacturers and the printer manufacturer. Figure 1 gives a feeling of the complexity of the task to build a single pass inkjet printer, and we indeed can state that 'single pass inkjet printing' is one frontier of digital imaging.

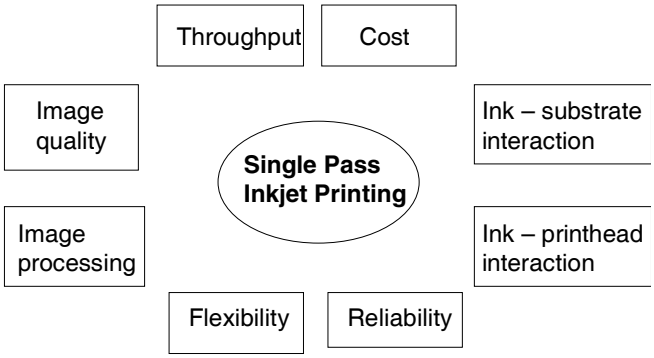

Figure 1. *The development of single pass inkjet printers requires to meet a complex list of demands.*

A considerable number of the requirements listed in figure 1 are on the task list of the inkjet printhead manufacturer. In summary the inkjet printheads are required to enable high quality printing with high productivity and high reliability. A further requirement is low cost operation, which demands a printer design without redundant nozzles thus imposing an even higher demand on the reliability of the inkjet printhead. The main tasks for the inkjet printhead manufacturer are compiled in figure 2 and they will be dealt with in this publication.

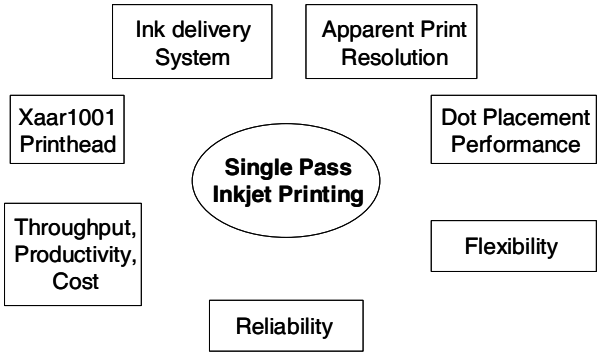

Figure 2. *The task list of the inkjet printhead manufacturer*

1. The Xaar1001 Printhead

Xaar inkjet printheads contain piezo-electric actuators with closely spaced ink channels at a high linear density or native resolution of 180 dpi. Their 'shared wall and shear mode' actuation principle is based on controlled motion of the channel walls. Each such motion of the channel walls creates an acoustic wave within the ink channel, and by appropriate 'voltage waveforms', i.e. temporal voltage profiles, the superposition of the individual acoustic waves at the nozzle results in the formation of an ink drop of specified drop volume and drop velocity.

The shear mode actuation operates with wall shear motions, which are in amplitude a mere ten thousands of the height of the wall, and thus exert only minimal mechanical stress on the channel wall. This is the reason for the extremely high printhead lifetime of typically more than 1-year operation when printing with certified inks.

Xaar's traditional inkjet printheads, as are those of all other printhead manufacturers, are termed 'end-shooters'. This name describes the fact that the nozzle in such end-shooter printheads is located at the end of the ink channel, and that there is no other exit for the ink but through the nozzle. Though high quality printing is often achieved with end-shooter printheads there are certain disadvantages. The most prominent issue are failing ink channels due to air bubbles in the ink channel, which requires a maintenance operation and thus a stop of the print operation to recover those ink channels.

The Xaar1001 printhead is the first inkjet printhead using ink throughflow technology, a Xaar patented technology. While the actuation principle by acoustic waves remains the same as with Xaar's end-shooter printheads the design of the actuator is modified such that the ink can flow through the ink channels while drop formation takes place at the nozzle, which is located at the side of the ink channel; therefore the term 'side shooter' for Xaar1001 printheads. Air bubbles or particles, which would stop operation of end-shooter printheads, are removed by the ink flow

so that that particular channel resumes drop formation once the air bubble or particle has left the active channel area. As will be described in detail below the side-shooter principle provides inkjet printing with high reliability and thus fulfils one of the key requirements of 'single pass inkjet printing'.

The two interleaved actuator rows of the Xaar1001 printhead provide a total of 1000 active channels with 360 dpi print resolution, as shown in figure 3. Subdrops of 6 pl are fired with 42 kHz subdrop frequency, allowing a 7 dpd greyscale operation with 6 kHz. The nozzles are positioned in a staggered fashion to compensate for the 3 cycle firing mode and to provide printing of straight lines across the printing direction when working in 360 dpi resolution.

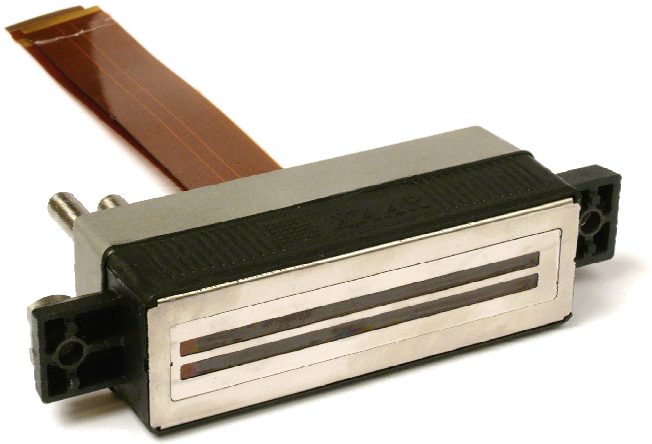

Figure 3. *The Xaar1001 printhead with two rows of actuators provides 1000 active nozzles at 360 dpi effective nozzle pitch.*

2. The Ink Delivery System

To maintain both the continuous ink throughflow and to provide the necessary underpressure at the nozzle the Xaar1001 printheads need a special ink delivery system. Ink is circulated from an ink input container through the printhead into the ink output container and from there pumped back into the ink input container. Specific vacuum levels at the ink input and ink output containers, respectively, control the ink flow rate and at the same time set and control the meniscus vacuum at the nozzle. The ink volume being printed during operation is replenished from an ink reservoir into the ink input tank. During recirculation between the output and input containers the ink is heated or cooled to maintain the specified printhead temperature, to filter the ink from air bubbles or particles, and if necessary to stir the ink in order to prevent agglomeration of particle based functional fluids.

Ease of operation of the Xaar1001 printhead is based on the ink throughflow technology, which enables easy filling and start-up, as well as it avoids maintenance operations after loss of channels when ingestion of air bubbles or particles has occurred.

3. Apparent Print Resolution

The Xaar1001 printhead contains two actuator rows, each with 141µm nozzle pitch. Both rows are offset half a nozzle pitch so that the printhead works at 70.5µm effective nozzle pitch or 360 dpi print resolution.

A 360 dpi print resolution would surely result in limited print quality when printing in binary mode. Greyscale printing, however, increases the apparent print resolution drastically. A 360 dpi print resolution combined with 8 level greyscale operation results in a 1000 dpi apparent print resolution and is thus sufficient for high quality print jobs.

The Xaar1001 is a greyscale printhead delivering subdrops of 6 pl volume at a rate of 42 kHz. Waveforms specifically designed for the individual fluid enable greyscale drop formation such that the train of subdrops produced combine at the nozzle and a single drop hits the substrate. The different total volumes of greyscale drops are described by the term dpd or 'drops per dot'. An 8 level greyscale waveform for example can produce 0 to 7 dpd, i.e. total volumes between 0 and 42 pl. Figure 4 shows the formation of a 7 dpd drop at the nozzle plate.

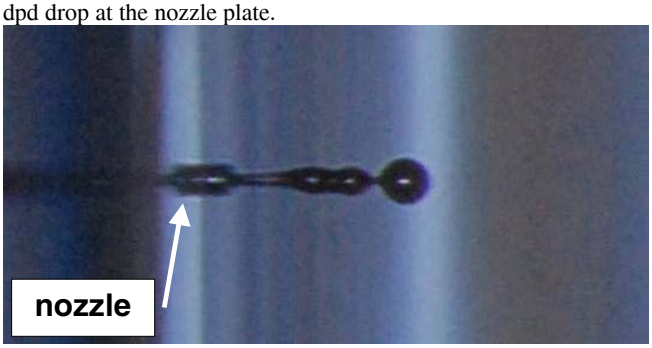

Figure 4. *The formation of a 7dpd drop at the nozzle plate. The first five subdrops have already fully merged while subdrops 6 and 7 form the bulk of the ligature. The nozzle is indicated by an arrow on the reflecting nozzle plate.*

4. Dot Placement Performance

In order to leave the printer manufacturers with as large a share as possible of the overall error budget the printhead manufacturer has to minimize the printhead related dot placement errors.

While the Xaar1001 specifications are max y-landing error <30µm (y is the printing direction), and max x-pitch error <10µm (which relates to streakiness of the printout), the typical data for the manufactured printhead base are max y-landing error <15µm and max x-pitch error < 4µm, respectively.

As is shown in figures 5 and 6 for the case of magenta UFX uv-curing ink these low dot placement errors can be maintained throughout a wide operational window defined by the temperature range 36oC to 44oC and delta offset voltage (drive voltage) from –1.0V to +1.0V. The 'sweet spot', i.e. the preferred set of print parameters as chosen from the figures 5 and 6, was 38oC ink temperature and 0V delta offset voltage, which delivered the small dot placement errors of 3s y-landing error = 7.9µm (see figure 5), and 3s x-pitch error = 3.4µm (see figure 6). It is interesting to note that a group of test persons selected precisely the printouts produced with these 'sweet spot' print parameters as best appealing, thus underlining the strength of our statistical analysis.

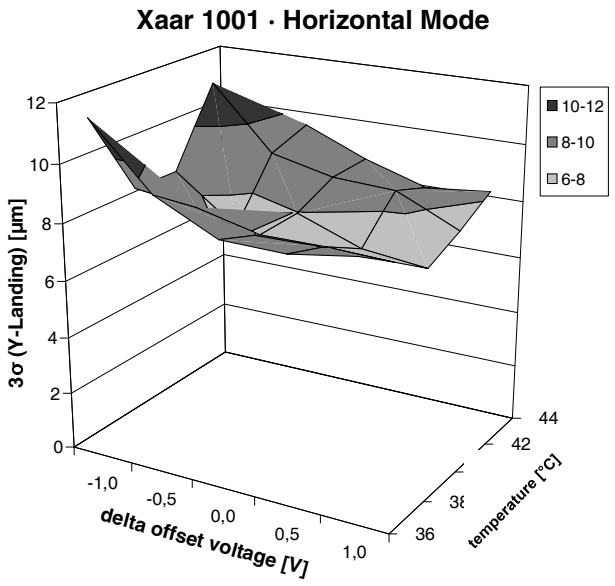

Figure 5. *The Xaar1001 printhead provides a wide operational window with small y-landing errors, and a 3s y-landing error = 7.9µm at the 'sweet spot'.*

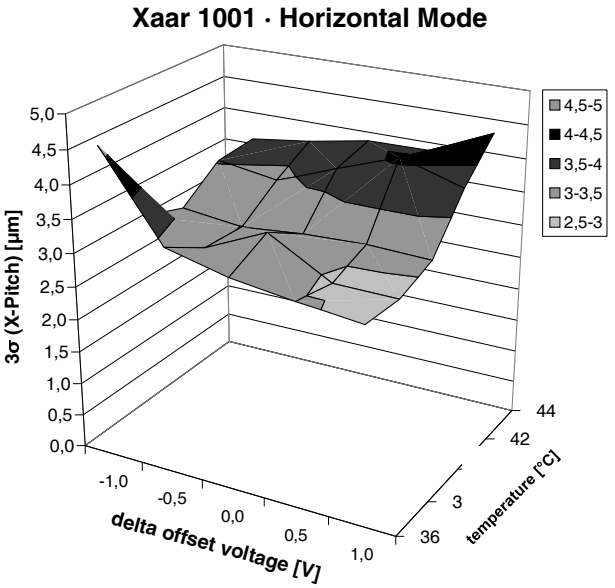

Figure 6. *The x-pitch errors are small throughout the operational window with a 3s x-pitch errors =3.4µm at the 'sweet spot'.*

5. Flexibility: Printing in Horizontal and 'Skyscraper' mode

Several applications, most prominently in packaging, require printing onto vertically oriented substrates. Apart from its wide operational range regarding temperature and driving voltage the Xaar1001 printheads operate over a wide range of meniscus vacuum. This opens the possibility to print with the Xaar1001 printheads in vertical orientation, which is termed 'skyscraper mode' in the following. Extended tests in skyscraper mode revealed very similar performance data regarding dot placement as in horizontal print mode and with the same 'sweet spot' in their operational window as were given for the horizontal mode in figures 5 and 6.

6. Reliability

Print reliability is the most important advantage of the Xaar1001 printhead over Xaar's and other manufacturers' end-shooter printheads. This is based on the printhead's ability of 'self recovery' of lost channels, which allows long print runs without the need of maintenance operations.

As mentioned above the ink throughflow removes air bubbles and particles from the active channel area and results in self recovery of the channel. Such gas bubbles might be introduced into the channel by the ink itself. More often this is caused by large meniscus motions in the nozzle when printing difficult pattern or by pressure variations in the ink feed system, which both result in air ingestion into the ink channel, where the air bubbles cause acoustic mismatch and stop drop formation. The ink throughflow moves air bubbles or particles out of the short active area of the ink channel, so that those channels resume printing within a small fraction of a second. Figure 7 shows the printout from a Xaar1001 printhead, which was knocked with a wrench during operation. The impact caused a strong pressure wave in the printhead followed by extreme meniscus motions and air ingestion in all ink channels. All 1000 channels failed instantaneously, but resumed printing after a few milliseconds so that just a white stripe of some 1 to 2 mm width appeared in the printout of figure 7.

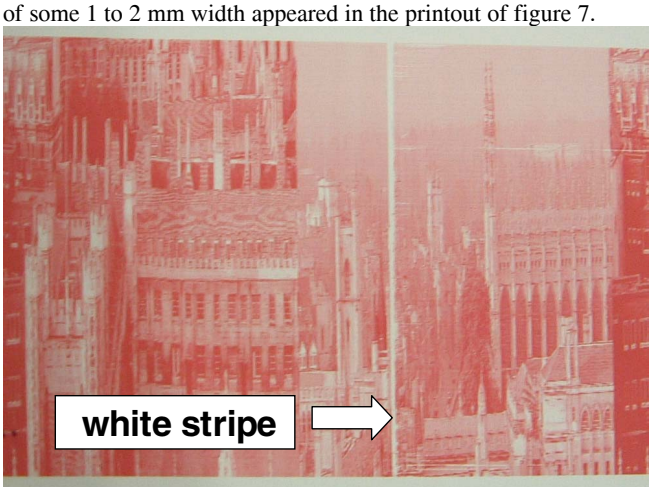

Figure 7. *When tapping a Xaar1001 printhead with a wrench the printhead lost all 1000 channels immediately, but self-recovered all nozzles within a fraction of a second so that only a white stripe of 1 to 2 mm width appeared in the printout*

The ability of self-recovery without maintenance as well as the wide operational window enables long print runs with the Xaar1001 printhead. Performance tests demonstrated print runs of 4 hours at 6 kHz and 360 dpi, i.e. an equivalent of 6 km print length, with a maximum allowed waste of one A4 page length. The Xaar1001 therefore meets the requirement to print without redundant nozzles, as was one requirement for low cost single pass printers.

Tests of print quality during long print runs in 'skyscraper' orientation were carried out with the printhead jetting continuously into an exhaust with test printouts on photo paper

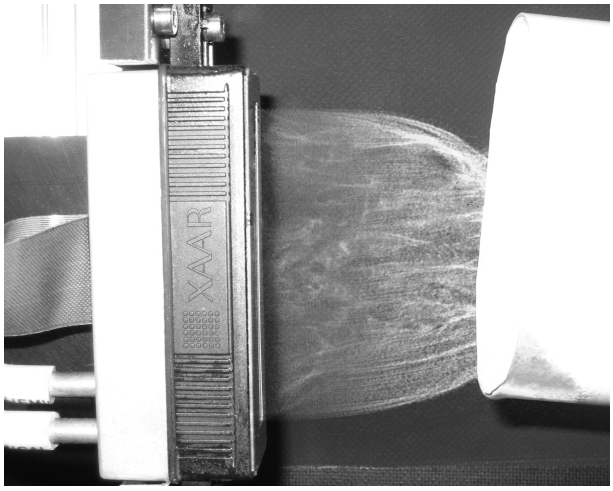

Figure 8. *A Xaar1001 printhead in 'skyscraper mode' during a long print run. Printing is performed into an exhaust while printouts are produced in intervals of two or four minutes*

being taken in intervals. Figure 8 displays such printing into an exhaust with a Xaar1001 printhead in 'skyscraper' mode.Magenta UFX uv-ink and a print pattern density of 27% (representing a typical graphic image) were used. Analysis of the printouts revealed that dot placement performance was constant over the full length of 60 minute print runs in 'skyscraper' mode. As the data from figure 9 indicates the 3s y-landing error = 10µm, and the 3s x-pitch error = 4µm are well below the specified max y-landing error <30µm, and max x-pitch error < 10µm, respectively.

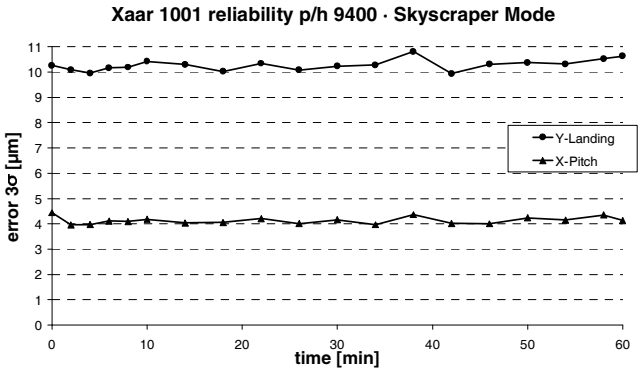

Figure 9. *Small dot placement errors are maintained throughout the full 60 minutes length of a print run in 'skyscraper' mode printing at 27% pattern density.*

7. Throughput, Productivity and Cost

The present 6 kHz maximum firing frequency of Xaar1001 printheads enable a maximum substrate feed rate of 0.42 m/s, when printing 360 dpi resolution in 7 dpd greyscale mode. The printwidth of a single printhead is 70 mm, so that ganging of multiple printheads is required for wide format applications. Based on a patented mechanical interface Xaar1001 printheads can be precision mounted into print bars. These special mechanical features allow to reintroduce or to replace individual printheads into the print bar with a present accuracy of +/-10 µm. This enables true 'plug and print' operation without the need for further alignment of the printheads and thus meets another requirement of high throughput industrial printing with low downtime and high productivity.

The printbar containing up to 6 Xaar1001 printheads in figure 10 is the heart of Nilpeter's CASLON printer, which was built by FFEI Limited [1]. This printer is one of the first outstanding examples of industrial single pass inkjet print machines.

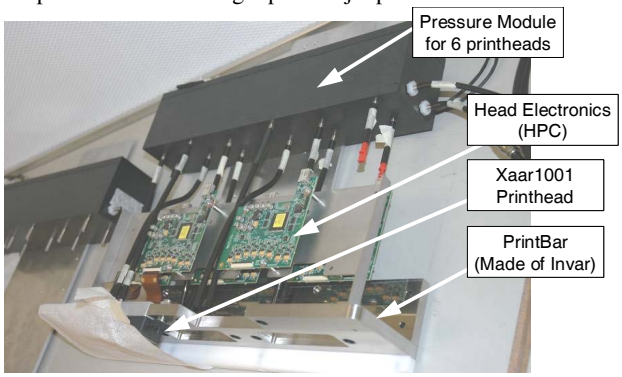

Figure 10. *The print bar for multiple Xaar1001 printheads as produced by FFEI Limited for Nilpeters's CASLON printer [1]. With permission by FFEI.*

Cost of Ownership is favorably met by the Xaar1001 due to its greyscale capability, which allows to save ink and facilitate drying operations (no light colours needed), and to avoid the need for redundant nozzles (high reliability), and especially by the high productivity enabled by single pass print operation.

8. Industrial Single Pass print applications

Though 'single pass' inkjet printing remains a frontier area of digital imaging there are several such printers already commercially available. Some examples are the Nilpeter/FFEI CASLON (4 colour graphics), the PAT Rotoworx (uv-varnish coater) which use Xaar1001 printheads. The Jetrion 4000 Series, and the Agfa Dotrix contain Xaar318 and SunChemical's SolarJet uses Xaar760 printheads. All five examples use Xaar greyscale technology. These 'single pass' printers will serve such diverse markets like Commercial Print, Commercial Colour Labelling, Packaging Print, Finishing/ Coating. The adaptation of further inks as well as of functional fluids to the Xaar1001 printhead will further widen the range of applications.

Summary

The advent of the high class inkjet printhead Xaar1001 makes single pass printing a reality, which provides high quality and high throughput inkjet printing with high productivity and low cost of ownership.

Reference

[1] Peter Walsh, 'Incorporating single pass InkJet into a high-end Label Press', 17th Annual Inkjet Printing Conference, Orlando, Florida, USA February 6-8, 2008

Author Biography

Werner Zapka earned his PhD in Physical Chemistry at the Max-Planck-Insitute for biophys Chemistry in Göttingen, Germany (1980). Since then he has worked in R&D at IBM in USA and Germany before joining MIT-Inkjet (1995). Since 1999 he is R&D manager at XaarJet AB where he focuses on the development of new inkjet applications.