Single-pass Inkjet Digital Printing Technology for Commercial Printing Markets

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Abstract

Single-pass inkjet digital printing devices can have over 100,000 nozzles per system for a 4-color B2 format size. Ultimately, an inkjet printing system's success relies on stable and reliable printheads, inks and marking process to produce crisp round dots, and image processing techniques to compensate for process artifacts such as "dot migration or interference" which can cause undesirable streaks and other image defects.

At drupa 2012 held in May, several inkjet technologies were introduced and will be reviewed by features and potential.

Basic Specifications Required by Commercial Offset Printing

Conventional high quality offset printing often uses line ruling of 200 lpi and greater. This is accomplished with a physical resolution of 2,400 dpi or higher. As a result, it is possible to generate smooth tone/gradation by area coverage modulation using a single small uniformly spaced dot.

Inkjet achieves nearly identical image quality using only a few dot sizes, with a relatively low resolution of 1,200 dpi referred to as grayscale printing. The well shaped dots produced by inkjet produce good granularity similar to the high image quality associated with offset printing.

Precise color plane registration and accurate front- to back-side registration is critical for high quality printed results. This is accomplished using very precise paper handling mechanism and drum-to-drum transfer.

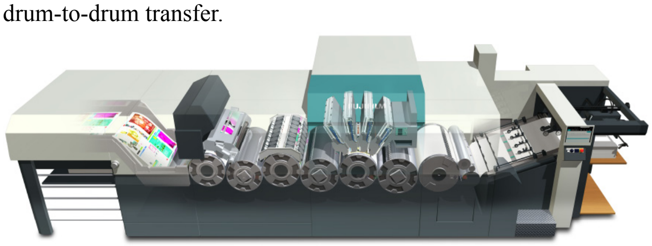

Fig.1. FUJIFILM JetPress720

Advantages of Inkjet System

One of the major drawbacks of offset printing is the amount of time needed for offset inks to dry or harden so they can withstand abrasion and set-off from post process finishing operations. This makes fast, short run printing problematic. Until recently electro photography has been viewed the only viable fully digital solution. However, electro photography is not without its limitations such as color instability at print-startup, and running cost, etc., the same elements that are significant advantages of inkjet based solutions. Also, inkjet inks have a wider color gamut as a result of better color purity and transparency using nano-size pigments.

The trade-offs of inkjet systems are higher power consumption, a larger footprint, and need to contend with streaks and bandings of images resulting from dot interference or migration.

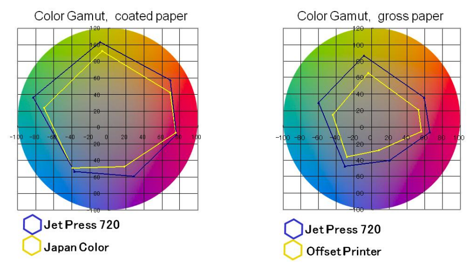

Fig.2. Color Gamut of JetPress720

Fundamental Technical Issues in Single-pass Inkjet System

Streaks and Bandings

In the case of single-pass inkjet, each nozzle prints just one line. Therefore, even tiny defects from a nozzle's mis-directionality or positional error can cause a visible streak. With over 100,000 nozzles for B2 paper size with four colors (CYMK), maintaining precise error-free jetting on a sustained basis is the challenge. Error correction technologies are essential in achieving overall print quality while making printheads last as long as possible.

Banding, especially printhead connection areas are corrected by overlapping adjacent printheads. These overlapping areas can have a tendency to show periodic or fixed bandings. To solve these problems, precise mechanical adjustments and printheads with highly accurate nozzle positioning are critical.

Dot Interference or dot migration

During high speed jetting, adjacent dots can unite at irregular intervals. This is due to water content in the ink formulation allowing the latter jetted dot to migrate toward the former, which is called dot interference or dot migration. This can occur in single-color and between colors and is undesirable. To resolve this issue a total systems solution approach is required.

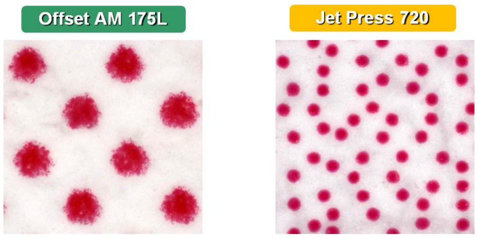

Fig.3. Halftone dot comparison

The inks developed for the FUJIFILM JetPress720 enables high speed coagulation reaction when combined with a pre-conditioner which is primed onto papers. This avoids dot interference or migration by anchoring pigments at precise location quickly and insuring a uniform round shape and size.

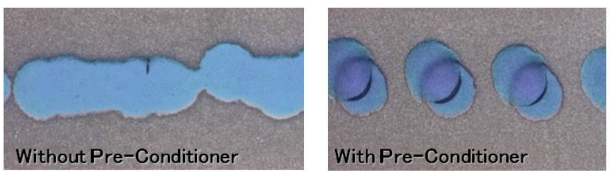

Fig.4. Effect of Coagulation

New Inkjet Concept Introduced at drupa 2012

New proposals and demonstrations were introduced at drupa 2012 in Germany.

Ink Technologies

Until recently, aqueous or water based ink formulations have been the most widely used inks for the commercial inkjet printing. Konica Minolta recently introduced a UV-curable based inkjet system. UV-curable ink has several benefits as it does not need a drying mechanism. This can result in an overall simpler systems design. However, it brings about a new set of challenges like ink pile-height, unpleasant odor and cationic UV-curable inks have significant cost disadvantages. Another potential issue is how to achieve high quality imaging without pinning effects by half-hardening each ink surface, which further complicates systems design.

FUJIFILM has developed a range of high performance aqueous ink for the JetPress720 and aqueous UV ink for JetPress F with rapid coagulation reaction, and anti-curling, etc. These two inks cover wide range of markets and applications including commercial, label, packaging, and others.

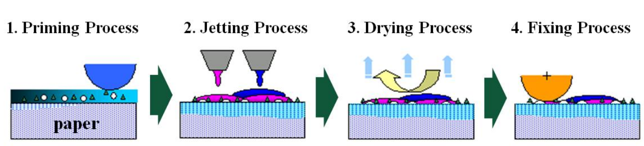

Fig.5. Marking Processes of FUJIFILM JetPress720

Direct Jetting and Indirect Jetting

It is more common for inkjet systems to jet inks directly onto a substrate but at drupa 2012, an indirect jetting technology, which jets on to a belt and then transferred, was shown. Belt-transferred systems have around for some time. Belt-transferred system have the potential to suppress dots interference or migration as a result of their ability to dry inks very quickly but new technical issues arise, such as dot size control, belt durability, color registration over the long and heated belt, and durability and stability of the printheads when exposed to this high temperature environment.

Technologies to Eliminate Streaks in Single-pass Inkjet System

Control of dot interference or migration is essential in resolving streaks and image degradation. In addition to an instant coagulation type of reaction, influencing factors are also discussed.

Inkjet Printhead

Precise jetting directionality is critical for good image quality. In case of 1mm gap between a printhead and substrate and 3 micro-radians jetting directionality, 3 micro-meters displacement can occur on paper. This can be categorized as a streak. To resolve this, FUJIFILM Dimatix has developed its full-Silicon MEMS printhead, "SAMBA™". SAMBA achieves superb jet straightness and nozzle positioning which is one digit better than that of mechanical process. Another prominent printhead feature is continuous ink recirculation at the nozzle. This is used to maintain a constant ink temperature and to keep faster drying inks from solidification.

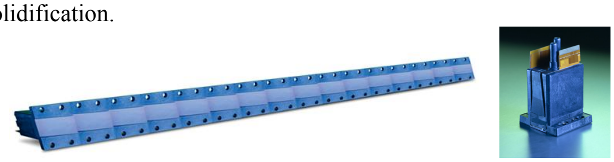

Fig.6. SAMBA Si-MEMS printhead and printbar

The main features of SAMBA are:

- ✓ 1,200 dpi native dpi
- ✓ 2.0 picoliter drop size
- ✓ 2,048 nozzles per module
- ✓ Continuous ink recirculation
- ✓ Frequencies to 100kHz
- ✓ VersaDrop™ grayscale and multipulse capable
- ✓ Scalabable narrow to wide printbars

SAMBA printheads have superior accuracy regarding nozzle position and directionality due to full MEMS design and produce no image defects like bandings even around the connection areas.

Moreover, FUJIFILM Dimatix has developed a method of forming PZT films on silicon substrates with a high piezoelectric coefficient using RF sputtering instead of bulk PZT. The PZT film has an unusually high content of Nb dopant which results in much higher piezoelectric coefficient than sputtered PZT films previously reported. This results in an extremely uniform, reliable and lower power-consuming printhead.

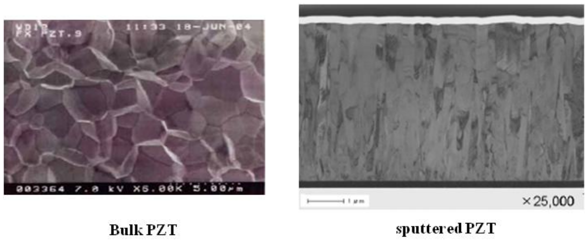

Fig.7. TEM micrograph of bulk and sputtered PZT cross-section

Another key technology applied to SAMBA printheads is a non-wetting coating on the nozzle's surface. This coating is composed of a highly hydrophobic fluorinated antifouling material and is applied using a unique deposition method. It significantly contributes to accurate and stable jetting.

VersaDrop grayscale technology is another key contributor to superior drop placement accuracy on paper by producing a single droplet at high speed without reducing production speed.

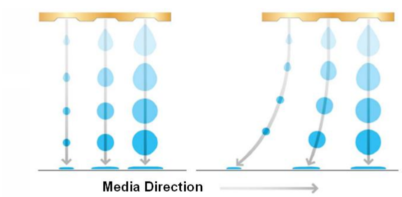

Fig.8. Effect of VersaDrop

Image Correction Technologies

Image correction technology to address process defects is essential for superior image quality as well as economic considerations regarding printhead lifetime.

In-line sensors and sophisticated software are used to detect, evaluate and compensate for poorly conditioned nozzles.

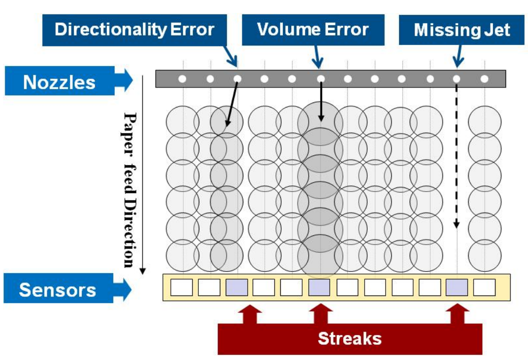

Fig.9. Nozzle defects and Sensing mechanism

FUJIFILM JetPress720 produces four levels of grayscale to generate different dot sizes using proprietary VersaDrop technology. As a result, overlapped areas can be different in size by combination of different dot sizes. Additionally, FUJIFILM has developed its "Distributed Halftone with Restricted Dots Arrangement". This is used to eliminate the effect of streaking in overlapped areas by implementing several compensation algorithms to address different image defects.

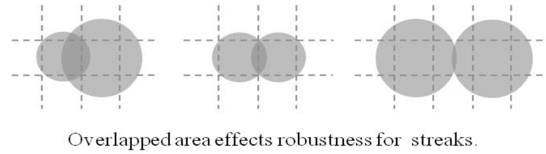

Fig 10. Basic Consideration for Distributed Halftone with Restricted Dots Arrangement

Figure 11 illustrates the relationship between physical parameters, and image quality with targeted solutions for optimizing the FUJIFILM JetPress720.

Commercial printing requires combinations of state-of–the-art printheads, ink, other attendant chemicals, and algorithm for image compensations.

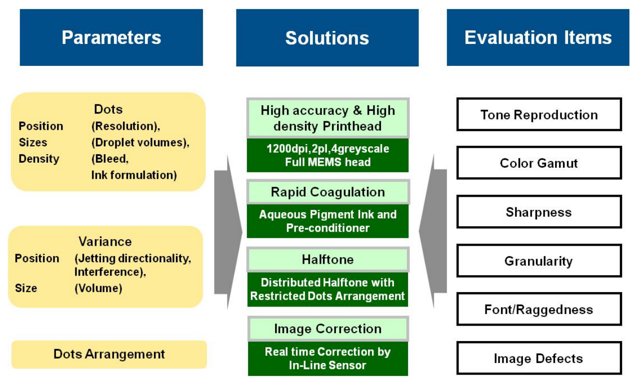

Fig.11. Relation among System Parameters, Evaluation Item and Solutions in Image Correction

Consideration for Environment

There are a number of significant environmental benefits with the FUJIFILM JetPress720. These include reduction of make-ready waste papers, VOC free, elimination of hazardous pressroom consumables, smaller carbon footprint, and safety. Another important consideration is de-inking of paper.

De-inking

De-inking is the removal of printing ink from the substrate for recycling purposes. It is one of the most important environmental indexes. Generally, aqueous inks with dyes and pigments are difficult to remove from paper pulp, but the FUJIFILM JetPress720 has achieved a certificate with the highest possible rating of "good deinkable" from INGEDE, International Association of the Deinking Industry. This is due to reduced ink absorption into the paper using coagulation and pre-conditioning technology.

Future Trends of Inkjet Systems

HP Indigo was the first digital printing system to achieve commercial success in digital commercial high image quality markets, through its many refinements over the years. Other companies have followed suit with similar technology such as liquid toner electro photography. Inkjet web systems have established a position within the market of direct mail, transactions and book printing. Now, several inkjet companies have entered into high quality commercial market with different technologies, and it will take some time to prove which technology will most likely lead the market.

Author Biography

Hidetoshi Shinada is Chief Technology Officer and Executive Vice President of Research & Development at FUJIFILM Dimatix and is also the General Manager of Advanced Marking Research Laboratories at FUJIFILM Corporation. He joined FUJIFILM Corporation in 1983 and has developed and led product development for COMs (Computer Microfilms), imagesetters and CTPsetters. Additionally he leads the Inkjet R&D of the FUJIFILM Group. Shinada holds an MS in Electronics Engineering from Hokkaido University in Japan.