Applications of Page Wide Piezo Inkjet Printing to Commercial and Industrial Market

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Abstract

Most drop-on-demand digital printing engines on the market must make several passes to print the required information. The multiple pass print architecture limits the use of digital printing in many commercial and industrial applications. To meet the demands for high-speed and high quality digital printing in these applications, page wide single pass print engines with high printing speed and resolution have been developed using Spectra's shear mode piezo inkjet technology. This paper reviews the development work and discusses the potentials of page wide single pass print engines.

It has been demonstrated that a large page wide print engine can be built with multiple 2.56-inch wide print swaths using modular design approach. The print engine can reliably operate several thousand nozzles to print 600x600 dots per inch images at 1.6 meters per second. Technical feasibility studies have shown that it meets the requirements of the commercial and industrial application. Examples of using the page wide print engine as a digital add-on to Heidelberg's Quickmaster offset press will be discussed.

Introduction

There are growing demands for high quality and high-speed digital imprinting in various commercial and industrial applications. Digital imprinting often requires the use of a high-speed page-wide printing engine. Although Drop-On-Demand (DOD) inkjet printing engines have been widely used, most of them are designed for office printing applications, where a whole page image is often printed in multiple passes. The low ejection frequency of these engines also limits their use for high-speed inline printing. To meet the requirements for commercial and industrial digital printing, Spectra has developed a high performance, high-speed, page-wide single pass print engine, SP12.8/600, for variable inline printing based on a proprietary shear mode piezoelectric drive mechanism and modular design approach. Using the SP12.8/600 print engine, Heidelberger Druckmaschinen AG has successfully developed a prototype inline variable data imprinting unit, which can be attached to a Quickmaster offset printing press to provide fully variable highlight color to offset documents. Extensive tests have shown that the print engine can consistently print good-quality images at more than 300 feet per minute.

Spectra's single pass print engine includes 128-jet array modules, 2.56-inch wide single pass print swaths, ink delivery and head drive electronics. The imprinting unit developed by Heidelberger Druckmaschinen AG is a digital add-on device. Each offset press of the Quickmaster series can be upgraded to combine high quality static offset print with variable data inkjet print. The main features of Spectra's print engine, SP12.8/600, and Heidelberg's imprinting unit are listed in Table 1.

Table 1 Features of SP 12.8/600 Print Engine and Quickmaster Imprinting Unit

SP12.8/600 Print Engine • Drop-on-demand, page-wide, shear mode piezoelectric inkjet technology • 12.8 inch print width • 600 DPI • 7680 addressable jets • 38 kHz maximum jetting frequency (1.6m/s print speed) • 18 nanogram drop mass • Liquid UV curable ink • Continuous ink circulation
Imprinting Unit • Upgradable to all Quickmaster printing machines • Paper size up to A3+ • Vacuum belt transport system • Integrated UV dryer • Variable print speed up to 10,000 A3 or 20,000 A4 sheets per hour (= 1.6 m/sec)

Page-wide SP12.8/600 Print Engine

To build the large page-wide single pass print engine, a modular design approach is adopted. The basic building block of the SP12.8/600 is a 2.56-inch wide single pass print swath, which consists of twelve 128-jet array modules. The jet array module is the fundamental working element of the print engine. Its design is based on Spectra's shear mode piezoelectric technology. Figure 1 is a cross section view of one side of a jet array module. There are two piezoelectric transducer plates made of lead zirconate titanate (PZT) piezoelectric ceramic in a jet module. Each piezoelectric transducer is bonded to a metal plate, which has multiple cavities and is also epoxy bonded to the jet array body to form 64

pressure chambers. The electrode patterns on the surfaces of piezoelectric transducer are designed to ensure effective shear mode movement of the transducer when proper voltage pulses are applied. Since the piezoelectric transducer forms one wall of the pressure chamber, a firing pulse causes it to shear and, consequently, change the volume of chamber and pressurize the ink in the chamber. Each ink pressure chamber is connected to a nozzle. A drop of ink will be ejected once the pressure wave propagates to the nozzle. A jet array module can drive a total of 128 jets independently.

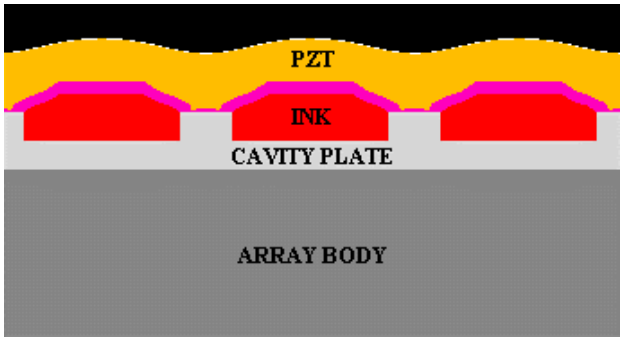

Figure 1. Spectra's shear mode technology: a cross section view of three ink pressure chambers of the 128-jet array.

The performance of a single pass print engine relies on the quality of the jet array modules. The design of the jet array module affects the crosstalk, drop mass, jet velocity, sustainability, uniformity and other performance characteristics of the print engine. Various possibilities to enhance the performance of a jet array module have been explored using the results from analytic studies, finite element analyses, dynamics simulations and experimental tests. The current jet array modules can operate all jets reliably within the required frequency range.

The jet modules are laid out in a matrix that produces 600 dpi. The total addressable jets in a swath are 1536. Since a raster line is not all printed at the same time due to delays between jet modules, the position of each jet module is carefully arranged to improve the image quality. The 2.56-inch wide swath employs an optimized jet interlace pattern, which minimizes the jet-to-jet adjacent error. Each swath forms an independent thermal control zone. An inkjet printhead requires good thermal management because of the narrow operating temperature window of the ink. Using installed heaters and thermal sensors, an external thermal controller can maintain the swath at desired operating temperature.

Each swath can be built and tested independently prior to the final assembly of a single pass print engine. Various jetting tests and image sample measurements can be conducted at swath level to ensure the quality standard is satisfied. The modular design makes it possible for the replacement of defective jet array modules and other parts. A routine swath test and rework procedure has been established. The procedure can thoroughly test many aspects of a print swath and eliminate many potential problems in the final assembly process.

The SP12.8/600 single pass engine employs five single pass swaths of 2.56 inches each to cover 12.8-inch print width. The maximum jetting frequency of SP12.8/600 print engine is designed to operate up to 38 kHz at 600 dpi. Correspondingly the maximum paper speed reaches 1.6 meters per second or 316 feet per minute. Since some sheet-fed and narrow-web presses operate up to this speed, this high-speed print engine satisfies the requirements of many different applications.

Figure 2 illustrates the assembly of the SP12.8/600 single pass print engine. The arrow indicates the direction of paper travel. Five 2.56-inch wide print swaths are tightly assembled in two rows in the frame. Ink is fed into the print engine through a 5 µm last chance filter and returned to an outside ink reservoir from the J-tube. The major role of the J-tube is to maintain proper vacuum pressure in nozzles to prevent weeping. It is also used to purge the nozzles for jet recovery and maintenance.

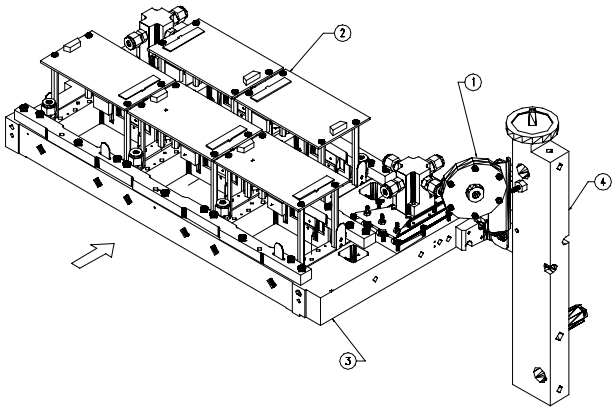

Figure 2. SP12.8/600 Single Pass Print Engine. 1: Last chance filter; 2:Five 2.56 inch print swaths; 3:Frame; 4: J-tube

This print engine jets UV curable liquid ink-jet inks. Ink consumption can be high when an image with large coverage is printed because of the large number of nozzles and high jetting frequency. To manage the ink refill, a robust ink delivery is required. A prototype off-head circulating ink delivery system has been developed for this print engine. It circulates the ink in the system continuously to provide fresh degassed ink to jet modules.

There are a total of 7680 addressable nozzles in the print engine. All of them must be properly aligned to print images correctly. The alignment mechanism designed in the print engine can adjust the position of each swath accurately. The fine adjustment is performed on Spectra's Final Acceptance Test station. The center

swath is first aligned to the web travel direction. The remaining four swaths are then adjusted to align with the center one. The alignment error can be quantitatively determined by measuring the test print samples using QEA IAS-1000 image analysis system.

To drive such a complex, high-speed, large single pass print engine Spectra has successfully developed a complete set of electronics. It consists of power supply unit, print swath drive circuit, swath interface board, stand alone phase lock loop for converting encoder signals to a desired print resolution and PC based command control system. It is capable of driving all jets up to 38 kHz and load various images fast enough to print 100% variable data. All major components or subsystems of the driving electronics are also designed using a modular approach, making it easy to configure and test any number of swaths in a print engine. Therefore, it has full potential to drive different multiple swath print engines.

A large single pass print engine may jet several thousands jets simultaneously. It is crucial to have all of these jets print at the same drop size to meet image quality requirements. The drop mass of each jet in this print engine can be calibrated to meet specifications. The calibration process generates the required operating parameters for each jet module at different drop masses or line widths. It is therefore possible to vary the drop mass to some extent based on the calibration report. This function makes it easy to print on different substrates, which may require different drop masses for different applications.

Operating the system is not very difficult. A trained operator can quickly bring the engine to its full speed operation from cold start in 20 minutes. There is very little print engine tending work needed once the initial startup is done correctly. Like other inkjet devices, contaminants in nozzles or air in ink flow system are common causes of jet outages. Most of these problems can be resolved by purging the system and wiping the nozzle plates. The maintenance of the print engine is no more than the work required for operating a conventional print press.

A series of engineering tests have been performed to study image quality, jet sustainability and system reliability. It has been found that, the page-wide SP12.8/600 single pass print engine can reliably work many hours printing excellent 600 by 600 dpi images at high speeds.

This print engine opens up new dimensions for variable data printing. Traditionally, to accomplish variable data printing, static pages printed by conventional printing process such as offset lithography, must go through a second printing process off the line to add the variable information. With a page-wide single pass print engine, it is possible not only to add the variable information on each page as desired, but also to produce full page-to-page variable printing data when needed.

Inkjet Imprinting Unit

The Heidelberger Druckmaschinen AG has developed an inkjet imprinting unit to combine high quality static offset printing with variable data inkjet printing in one single pass. At Drupa 2000, which was held at Düsseldorf/Germany, Heidelberg had shown a prototype of this equipment as a Concept Study.

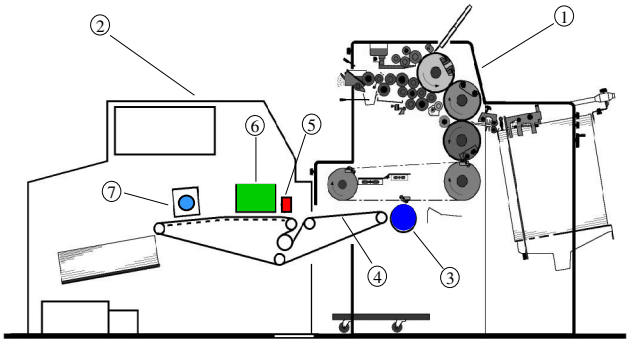

Figure 3. Combination of offset press and inkjet imprinting unit. 1: Quickmaster 46-1 offset press, 2: inkjet imprinting unit, 3: vacuum cylinder, 4:vacuum belt, 5:paper edge sensor, 6: inkjet heads, 7: UV dryer

Figure 3 is a schematic of this concept. On the right side of the figure there is a Quickmaster 46-1. This is a 1-color printing press, but it is also possible to use a Quickmaster-DI 46-4 (4-color). At the left is the inkjet imprinting unit. This unit can be moved on rollers for attaching to or detaching from the printing press. The inkjet unit is controlled by a separate PC based system. Print speed and paper feed is solely controlled by the printing press. The paper motion is from the right to left. It is first printed by Quickmaster with offset inks. The conventional offset printing process prints a high quality static image at this stage.

When the paper reaches the delivery of the offset press, it is transferred to the imprinting unit by a vacuum cylinder to a vacuum belt. The vacuum belt moves the paper underneath the inkjet heads. The imprinted image is controlled by a sensor that detects the leading edge of the paper and by an encoder at the drive cylinder. Paper transport has to be very precise, because any distortion of paper movement has a negative influence on the print quality.

Both offset ink and inkjet ink are UV curable inks. After the paper passes the inkjet printhead, an UV dryer cures inks immediately. Therefore the prints are ready to ship or go to additional finishing processes

Conclusion

Using Spectra's shear mode piezoelectric inkjet technology and modular design approach, a 12.8 inch wide DOD single pass print engine has been successfully manufactured. The print engine can reliably operate at print speeds greater than 300 feet per minute, making it

an excellent add-on digital print engine to achieve inline variable data printing.

Heidelberger Druckmaschinen AG has developed a prototype of an inkjet imprinting unit equipped with Spectra's inkjet technology as an add-on to conventional offset presses. This system was successfully demonstrated at Drupa 2000.

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Biography

Dr. Yong Zhou received his Ph.D. in Engineering from Thayer School of Engineering, Dartmouth College. He joined the staff at Spectra, Inc. in 1995. Dr. Zhou's principal area of focus is the development of Spectra's commercial compact printhead technology and high performance single pass print engines. His interests include high efficiency piezoelectric transducers, acoustics, fluid-structural interactions, and design optimizations. He is a member of the IS&T.

Dr. Clemens Rensch received his Ph.D. in Physics from the Institute of Applied Physics, University of Heidelberg, with the focus on applied laser physics. He joined Heidelberger Druckmaschinen AG in 1990. Dr. Rensch has been working at the Predevelopment Department with his main focus on inkjet applications since 1997.