

The Application of Piezo Ink Jet Technology to High-Speed DOD Single Pass Printing

Yong Zhou
Spectra, Inc
Hanover, New Hampshire /USA

Abstract

To meet the ever growing demands for high quality and high speed digital printing in various commercial and industrial applications, many printing system manufacturers search for high performance, page-wide, digital single pass print engines. This paper describes the development of a high-speed drop-on-demand 12.8 inch wide single pass print engine using Spectra's unique shear mode piezoelectric technology and modular design approaches.

It is demonstrated that Spectra's single pass print engine can reliably operate thousands of jets at very high jetting frequencies, making it possible to print at more than 300 feet per minute and at a resolution of 600 by 600 dots per inch. Using the modular design approach, a custom-made large format print system can be configured by using multiple 2.56-inch wide print swaths. Such a single pass print engine is capable of printing 100% variable data from one page to the next, providing excellent solutions for high speed, high flexibility and high quality variable data printing applications.

Introduction

Although Drop-On-Demand (DOD) ink jet printing engines are good candidates for high speed printing applications, most commercially available products have not utilized their potential. The ejection frequencies of ink jet print heads are typically below 20 kHz. Print speeds of these products may be limited not only by the performance of a particular print head, but also by the print system architecture. For instance, a drum print system often needs multiple passes to print a whole page image. In contrast a high-speed, page-wide, single pass DOD ink jet print engine would offer high productivity to meet the demands of various commercial and industrial users. Using a proprietary shear mode piezoelectric drive mechanism and modular design approach, Spectra has recently developed a high performance, high-speed, single pass print engine for variable inline printing applications. This ink jet print engine can be attached to a conventional offset printing press to provide fully variable highlight color to offset documents. It may also be used in other applications. Extensive tests have shown that the print engine can consistently print excellent image quality 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 intent of this paper is to describe the technology embodied in this print engine with a focus on the print engine architecture and the functions of its core components. The main features of this print engine, SP12.8/600, are listed in Table 1.

Table 1. Features of SP 12.8/600 Print Engine

Print technology	Drop-on-demand, single pass, shear mode piezoelectric ink jet
Print width	12.8 inch maximum
Print resolution	600 dpi
Number of jets	7680 addressable
Number of jet array modules	60. Each has 128 pressure chambers
Number of 2.56" wide print swath	5. Each has 12 array modules operating 1536 jets to print 2.56" wide swath
Print frequency (Print speed)	38 kHz maximum (316 feet /minute)
Drop mass	18 nanograms
Ink	Liquid, UV curable
Ink delivery	Continuous circulation system

128-Jet Array Modules

The performance of a single pass print engine relies on the quality of its fundamental working elements, the jet array modules. Figure 1 is an exploded view of a typical 128-jet array module developed by Spectra.

The jet array module is based on Spectra's shear mode piezoelectric technology[1]. The most outside layer is the flex circuit. It connects to the electrodes sputtered on the surfaces of piezoelectric transducers made of lead zirconate titanate (PZT) piezoelectric ceramic to provide electrical drive signals. The piezoelectric transducer is then bonded to a metal plate, which has multiple cavities and is also epoxy bonded to the array body to form 64 pressure chambers. The electrode patterns on the surfaces of piezoelectric transducer are designed to cause the 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. If a nozzle plate is mounted on the bottom of the jet array module, 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.

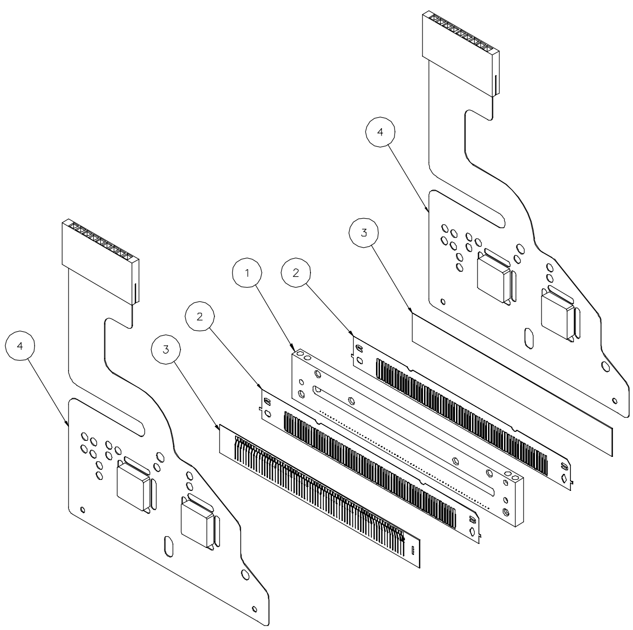

Figure 1. Illustrations of 128 jet array module. 1: Jet array body; 2: Cavity plates; 3: Piezoelectric ceramic plates; 4: Flex circuits.

The design of the jet array module affects the crosstalk, drop mass, jet velocity, sustainability 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[2,3]. The current jet array modules can operate all jets reliably within the required frequency range.

2.56-inch Wide Single Pass Print Swath

A single pass print engine may be constructed in a number of ways using multiple 128-jet modules. Conceivably multiple 128-jet array modules may be directly attached to a common nozzle plate to construct a print engine with desired print width. However, this approach fails to produce large size print engines because of manufacturing difficulties. For example, a given nozzle manufacturing technology could limit the nozzle plate to certain size in order to achieve a reasonable yield. A quick analysis can show that it is too expensive to manufacture a large print engine in that way because of low yield. To make it easy to build single pass print engines with different print widths quickly, a modular design approach is adopted. The basic building block is a 2.56-inch wide single pass print swath. Figure 2 shows the assembly of a 2.56-inch wide print swath.

The 2.56 inch wide print swath consists of twelve 128-jet array modules, a nozzle and manifold assembly, an aluminum supporting frame, ink inlet and outlet, heating elements and thermal sensors, and swath drive circuit interface board. Twelve 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. The aluminum structure of the swath offers not only sound robustness, but also good manufacturability and thermal conductivity. An ink jet printhead requires good thermal management because of the narrow operating temperature window of inks. Using installed heaters and thermal sensors, an external thermal controller can maintain the swath at desired operating temperature.

The image quality standard of a particular print engine is often established based on the requirement of the application. Once the standard is available, 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.

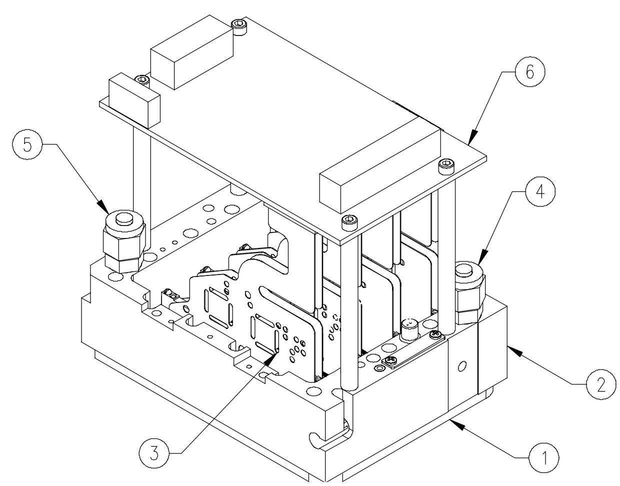

Figure 2. 2.56 inch wide print swath assembly. 1: Nozzle/manifold assembly; 2:Supporting frame; 3:Twelve Jet modules; 4 Ink outlet; 5: Ink inlet; 6: Swath drive electronics interface board

Page-wide SP12.8/600 Single Pass Engine

The SP12.8/600 single pass engine is developed to operate as an add-on digital imprinting system. The maximum print width is expected to be close to 13 inches. Therefore the print 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 many sheet-feed and web presses operate below this speed, this high-speed print engine satisfies the requirements of many different applications.

Figure 3 illustrates the assembly of the SP12.8/600 single pass print engine. The arrow indicates the direction of web 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.

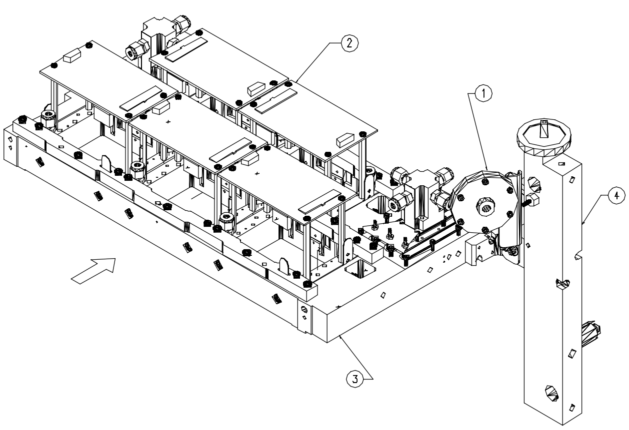

Figure 3. SP12.8/600 Single Pass Print Engine. 1: Last chance filter; 2:Five 2.56 inch print swaths; 3:Frame; 4: J-tube

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 web 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, though it is still a challenge. 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 ink jet 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.

Conclusion

Using Spectra's shear mode piezoelectric ink jet 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. A large single pass engine with different print width can be designed in the same way to meet the needs of different applications.

Acknowledgments

The author would like to thank the members of Single Pass technology development team for their efforts, support and valuable comments.

References

1. K. H. Fischbeck and A. T. Wright, US patent No. 4,584,590, (1986).
2. Y. Zhou, A Coupled Field Analysis Of An Ink Jet Printhead With Shear Mode Piezo Transducer, Proc. NIP13, pg. 809-812. (1997)
3. Y. Zhou, Measurement Of The Displacement Of A Shear Mode Piezoelectric Transducer Using Laser Doppler Vibrometer, Proc. NIP14, pg.23-26. (1998)
4. M. McDonald and Y. Zhou, Crosstalk study of a High Speed Shear Mode Piezo Ink Jet Printhead. Proc. NIP15, pg.40-43. (1999)

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.

Contact author’s e-mail address: yzhou@spectra-inc.com.