Continuous Improvement: Performance and Reliability in Shear Mode Piezo Ink Jet Printing

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Abstract

Since the introduction of the carbon edge shooter array, Spectra 256 jet products have been used in a variety of applications. The modularity of this design has allowed the development of a family of products based on a 128 jet carbon module. Improvements in performance mean that Spectra printheads can meet demanding applications with respect to duty cycle and image quality. Additional printhead enhancements have enabled the reliable jetting of a wide variety of jetting fluids, including solvent, aqueous, and wax-based inks.

The jet is activated using Spectra's proprietary shear mode piezoelectric driver. This method of DOD printing has no wear mechanism, allowing billions of actuations per jet with no measurable degradation. The robustness of this jet design has been demonstrated in a single pass printer using thousands of jets, firing at high duty cycles and line speeds. Life testing of these devices has demonstrated high reliability, in the laboratory and in the field. Test results discussed in this paper will include thermal cycling, jet actuation, ink immersion, and volume of ink jetted. All test results confirm the suitability of Spectra carbon array technology as a solution for high performance industrial applications.

Introduction

The digital printing market continues to expand, with many new industries incorporating ink jet technology. DOD printheads have moved beyond the consumer market into industrial and commercial applications such as the printing of addresses, labels, textiles, banners, and billboards. New applications and unique jetting fluids require stringent materials compatibility. With more jets, higher speeds and greater duty cycle demands, the printhead must evolve to meet the performance challenge. Reliability is still a critical issue. As print performance improves, consistent operation over time remains an important feature.

Modular Carbon Technology

High speed piezoelectric drop-on-demand ink jets are provided using a patented shear mode design. Modular carbon printhead products are based on the 128 jet edge shooter design. In this module, shown in Figure 1, two piezoelectric plates are bonded to cavity plates, which are then bonded to the carbon body. By scaling of the dimensions of the pumping chambers, 600 dpi and 300 dpi jet designs were created.[1]

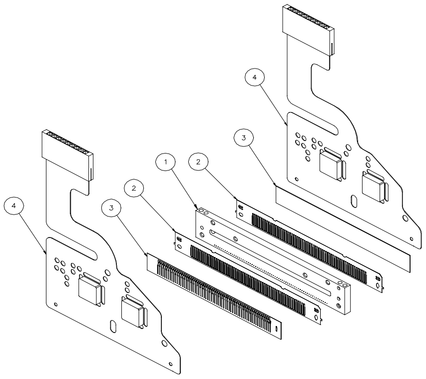

Figure 1. Illustrations of 128 jet array module. 1: Jet array body; 2: Cavity plates; 3: Piezoelectric ceramic plates; 4: Flex circuits.

Two 128 jet arrays were combined to create a single row of 256 jets at 100 dpi. This embodiment provides flexibility to the end user, as saber angle and interlace printing are easy to implement. The printhead can be angled to provide any desired resolution in the cross process direction, known as saber angle. The 256 design is also practical for scanning applications, where interlace patterns are used to provide a range of resolution. The 256 jet printhead is designed to perform at 125C with hot melt inks. Other qualified jetting fluids include UV curable ink, solvent ink, and aqueous inks.

When twelve of these modules are combined with a single nozzle plate, a printer with 1536 nozzles is created. The nozzles are interlaced to provide full coverage 600 dpi printing in a single pass. The single pass printhead (Figure 2) has been demonstrated on a continuous web press with UV curable inks.[2]

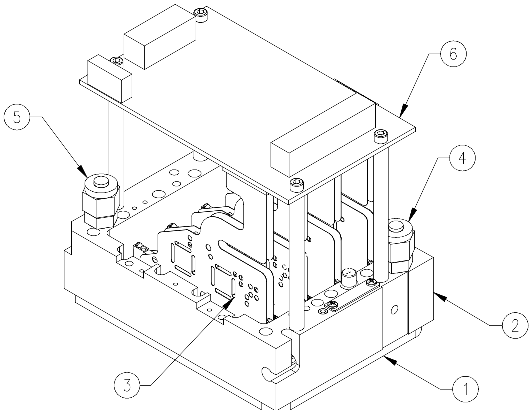

Figure 2. 2.56 inch wide print swath assembly. 1: Nozzle / manifold assembly; 2:Supporting frame; 3:Twelve Jet modules; 4 Ink outlet; 5: Ink inlet; 6: Swath drive electronics interface board

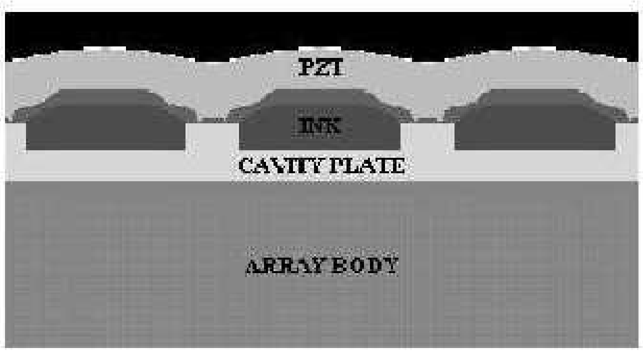

Figure 3. Spectra's shear mode technology: a cross section view of three ink pressure chambers of the 128-jet array.

Performance Improvements

In the PZT jetting structure, diagrammed in Figure 3, shear mode deflection is generated along the roof of the pumping chamber. Using a fill-before-fire jetting mode, the roof lifts and generates a negative pressure pulse, which pulls ink from the refill chamber. At the end of the pulse, the roof falls and the resulting positive pressure wave causes the drop to eject. With this technology, all jets are able to fire at full frequency.

Through finite element analysis, design changes have reduced the interactions between jets, known as crosstalk.[3] The improved jet structure operates at lower drive voltages. An additional benefit comes from the addition of a polyimid layer between the ink and the electrodes. This layer provides additional compliance in the refill chamber, allowing sustainable performance over a large operating window.

Material Compatibility

The materials used in the improved array are designed to provide chemical stability over a wide range of conditions. The structure is machined from Graphite, which is coated to eliminate porosity. The nozzle plate is made from stainless steel, which is very resistant to most ink chemistries. An added benefit of the steel nozzles is its robustness, as defined by resistance to wiping and other contact. The materials forming the flow passages are shown in Table 1.

Table 1. Materials in contact with ink.

Jet location	Material
Nozzle	Stainless steel
Flow passage	Carbon
Pumping chamber	Kovar®
	Polyimide

An important feature of improved array is the presence of the polyimide layer between the jetting chamber and the electrodes, shown in Figure 4. This layer provides tremendous protection from inks with chemistries that could cause corrosion of the electrodes. Additionally, conductive fluids, such as water or carbon pigments, are isolated from the drive electronics.

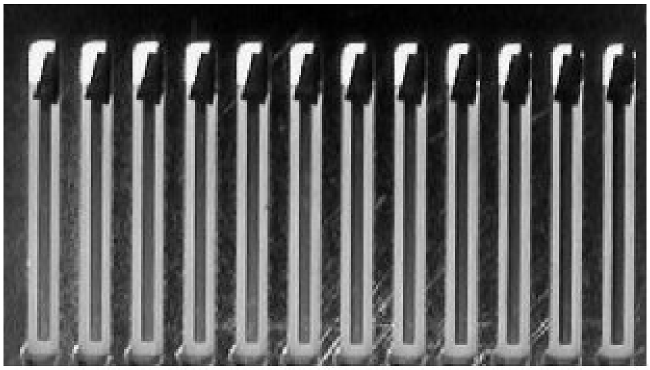

Figure 4. The drive electrode is located in the center of the pumping chamber, visible through a protecting layer of polyimide.

Printhead Reliability

The features mentioned above are important to the life and reliability of the modular carbon printheads. Product reliability requires testing of electronics and inks in an integrated system. At Spectra, rigorous testing is performed in the laboratory to confirm that the printhead is a reliable part of the system.

Thermal Cycling Test

PZT material is energized through a poling process which orients the dipoles and creates the piezoelectric property. Other factors drive an aging process by which the PZT loses a small fraction of its electromechanical property. This aging process can be driven through thermal cycling.

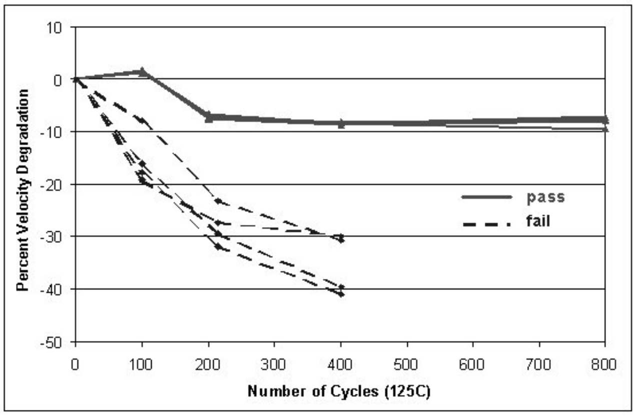

Figure 5. Thermal cycle testing shows PZT degradation over time for two different configurations.

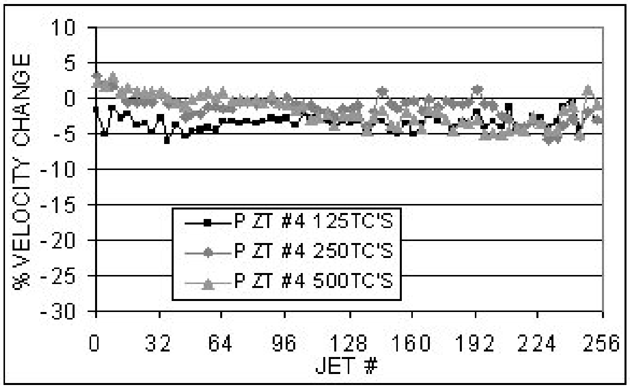

Figure 6. Thermal cycle results for a single printhead.

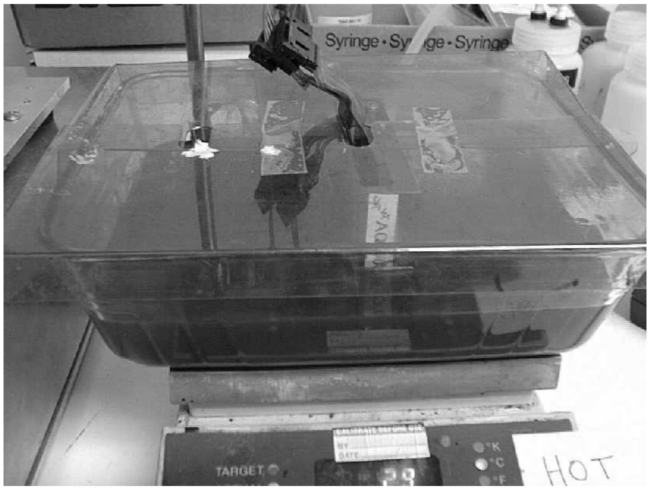

Figure 7. Laboratory setup for immersion testing.

In this test, the printhead was filled with hot melt ink, heated to an operating temperature of 125°C and then cooled rapidly to room temperature with a fan. The procedure was repeated hundreds of times, to simulate the potential impact of daily thermal cycling. The chart in Figure 5 shows that careful design of the PZT is required to pass this test. In Figure 6, the thermal cycle results are shown for each jet in the array.

Immersion Test

In order to measure the interaction of the printhead with the jetting fluid, the printhead was immersed in a tank of fluid and jetted for sustained periods. Failures generated by this test could include: corrosion, electrical shorts or partial degradation. Figure 7 shows a typical setup for printhead immersion testing.

Jet-to-Life Test

This test measured performance of the PZT after billions of activations. The initial velocity profile was measured, and the jetting test began. Using high duty cycles and frequencies, billions of activations per jet were generated in a relatively short period of time. The printhead was retested at regular intervals to determine the impact of the jetting. Figure 8 shows the result of an accumulated 54 billion activations per jet. Table 2 calculates the volume of ink jetted by firing all jets for that duration.

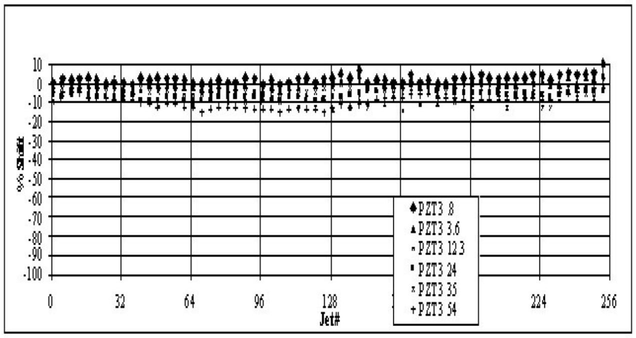

Figure 8. Change in velocity for Spit-to-life head with 54 billion activations per channel.

Table 2. Calculated volume of ink jetted / billion activations for 80ng drop size.

Billions of Drops	Ink per jet (g)	Ink per 256 jets (kg)
1	80 g	20 kg
10	800 g	200 kg
50	4000 g	1000 kg

Conclusion

Test results have demonstrated that modular carbon printheads are capable of demonstrating consistent performance over significant product life. Other system components play an important role in determining the performance of the printhead. Careful system integration is always an important aspect in the design of a reliable printing device.

References

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2. Y. Zhou, Applications of Page Wide Piezo Inkjet Printing to Commercial and Industrial Market, IS&T, Springfield, VA, 2000, pg 28.
3. M McDonald, Crosstalk Study of a High Speed Shear Mode Piezo Ink Jet Printhead, IS&T, Springfield, VA, 1999, pg 40.

Biography

Marlene McDonald received her BA from Dartmouth College and her MSME in Fluid Mechanics from the University of Massachusetts at Amherst. Since 1994, she has worked as a development engineer at Spectra, Inc. in Hanover, NH. She has focused on computational modeling, jet design, and new product development.