Development of an Aqueous Compatible Piezoelectric Drop-on-Demand Printhead Module for Textile Printing Applications

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Abstract

A novel 100 dpi 256 channel aqueous compatible piezoelectric drop-on-demand inkjet printhead module has been developed for scanning system textile printing. Both the use of water as a solvent and the high chemical reactivity of typical textile inks present challenges to the design of industrial inkjet printheads. Considerations for printhead component material selection and driver electronics protection will be reviewed. The changes made to the design in order to be compatible with typical aqueous based textile inks will be discussed. Next results from jetting performance testing of the new printhead will be compared to the baseline design using model fluid. Finally the adjustable binary mode and grayscale operation of the new printhead using VersaDrop^{TM} jetting technology will be examined.

Introduction

Digital inkjet printing is seen as a breakthrough technology for the textile industry. Its abilities to enable new products, reduce labor costs, and produce more economical shorter run lengths for mass customization are factors driving the growth of inkjet usage in textile printing market [1]. In addition, inkjet technologies offer greener solutions for the textile market by reducing the amount of waste generated. The ability to agilely develop inkjet printheads that are compatible with textile aqueous inks is paramount to this effort. This paper will discuss the development of a 256 jet DOD (Drop-On-Demand) piezoelectric printhead produced by leveraging an existing architecture. Ink compatibility considerations for typical aqueous textile inks, performance validation, and the demonstration of multi-pulse binary and grayscale capability using VersaDrop^{TM} are included.

Base Printhead Architecture

In order to decrease time to market, the recently released Sapphire QS-256/10 printhead platform was chosen as a starting point for the design of the new Aquamarine printhead. The QS-256/10 printhead features 256 independently addressable channels, arranged in a single row of nozzles at 100 dots-per inch spacing. The printhead is designed to eject adjustable 10 to 30 picoliter drops in binary jetting mode or a 10-picoliter fundamental drop in grayscale jetting mode. This is done at a nominal 8-meters per second drop velocity when jetting fluids in the 10 to 14 centipoise range.

Desired Ink Set & Compatibility

Typical aqueous based textile inks usually fall into one of four categories: reactive dye, disperse dye, acid dye, and pigmented. More detailed discussion of these types of inks and their application to textile printing can be found in references [2] and [3]. The following are the major differences that have been observed while testing materials for ink compatibility:

- Typical textile inks can be in the range of 30-50% water with some published values up to 90% [3], whereas typical UV or Solvent inks may only contain up to approximately 10% water. Water, known as the universal solvent due to its relatively small molecular size and polar nature, has the ability to penetrate small defects in material surfaces and to be absorbed by a number of polymers. Thus high water content inks can migrate into adhesives and other polymers that are impervious to many organic solvents.
- The high reactivity of aqueous inks can attack metals aggressively. This is primarily due to the polar nature of water which allows it to combine with dye colorants and release free Chlorides. These ions can then react with exposed metal resulting in corrosion and pitting. Of the specific inks tested it was determined that the reactive based textile inks appeared to be the most aggressive producing corrosion quickly.
- Also, owing to the ionic nature of these inks, they are electrically conductive and thus detrimental to electronics should they come in contact with printhead electrical interconnect or driver chips themselves.

Design Modifications

The QS-256/10 was designed to be compatible with a wide range of fluids, with its primary focus on UV and Solvent inks. The first step in the development the Aquamarine printhead, was to review each component of the QS-256/10 for compatibility with the chosen ink set. Next a strategy to replace or protect those components that would be attacked was devised.

After reviewing the QS-256/10's components against a known database of materials and testing unknowns with typical inks, Kovar, used in the printhead fluid path was shown to be incompatible. A number of new candidate metals were explored and stainless steel was found to have superior performance and chosen as a replacement. Figure 1 shows the results of accelerated soak testing on two candidate materials. Material 2 has clearly performed better and is a more robust choice. Material 1 has a darkened appearance and shows a significant amount of corrosion from interaction with the test fluid. Material 2 is the type of stainless steel used to replace exposed Kovar material in the Aquamarine nozzle plate stack as shown in Figure 2.

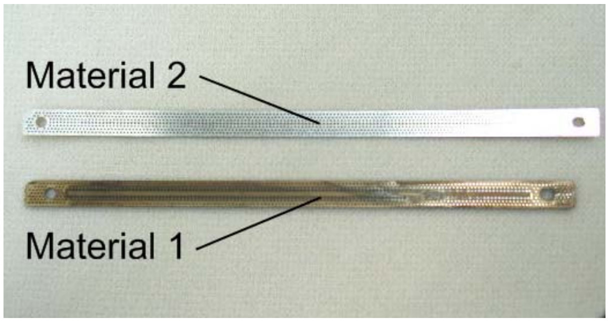

Figure 1 - Material 1 & Material 2 After Soak Test.

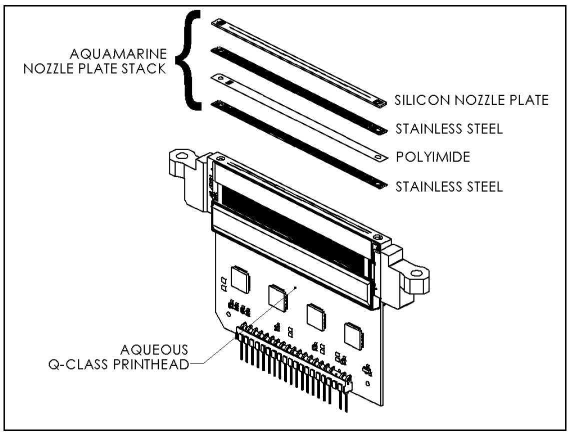

Figure 2 - Aquamarine Printhead with Stainless Steel components shown.

In some cases, replacement of materials with more compatible ones may not be feasible, for example due to component cost or other material requirements, like strength or thermal expansion. In these cases, conformal coating with a compatible material may be an option. In a family of second generation products, including Spectra™ NOVA AAA, this strategy has been extremely successful, producing products that are compatible with typical aqueous textile inks. Adopting this strategy also reduced risk, since it leveraged a known core competency in conformal coating and allowed for a reduction in testing due to known field performance. One potential down side to internal coating is that it may change the acoustic response of a printhead. Since one of the goals of this program was to maintain similar performance to the standard Sapphire printhead, the impact of internal conformal coating required evaluation.

Also, a review of the printhead electrical interconnect was performed. The Sapphire printhead uses a wirebonded interface that is encapsulated with a robust fill material known for moisture resistance that is also used in military applications involving harsh environments. Further more, the encapsulated interconnect and other electronics are conformally coated with Parylene. The Sapphire printhead interconnect was soak tested in reactive dye based aqueous ink and an aggressive high Chloride content aqueous ink designed to accelerate failures. The interconnect was evaluated periodically throughout the test and passed at 60 days of immersion with no failures.

Jetting Performance Evaluation

Based on soak testing, materials that were not compatible with textile ink were replaced and those that could not be replaced were conformally coated. The resulting design was then tested for performance with model fluid and compared to the baseline Sapphire printhead design.

To evaluate possible shifts in the jetting performance of the Aquamarine printhead design, the small drop frequency response was measured using model fluid and compared to that of the baseline Sapphire printhead design.

Figure 3 shows drop velocity normalized at 8 kHz and plotted vs. driving frequency. The two plots are very similar with no significant shifts, indicating that the changes made in order to jet aqueous textile ink have had minimal impact on performance. The mass frequency response, shown in Figure 4, indicates that the Aquamarine and Sapphire printhead designs also exhibit similar mass vs. frequency performance.

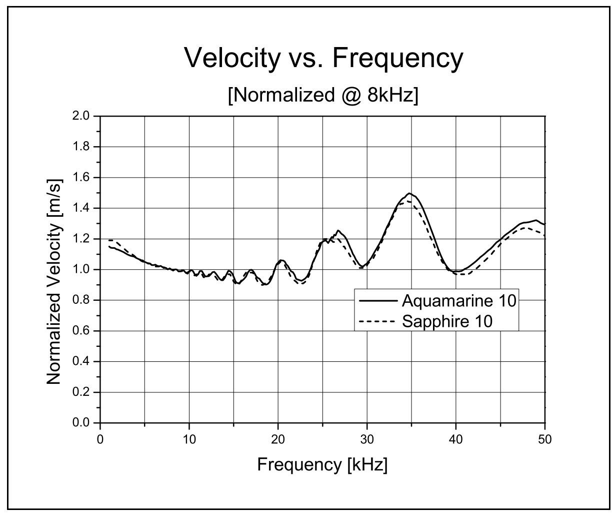

Figure 3 - Velocity Frequency Response Comparison.

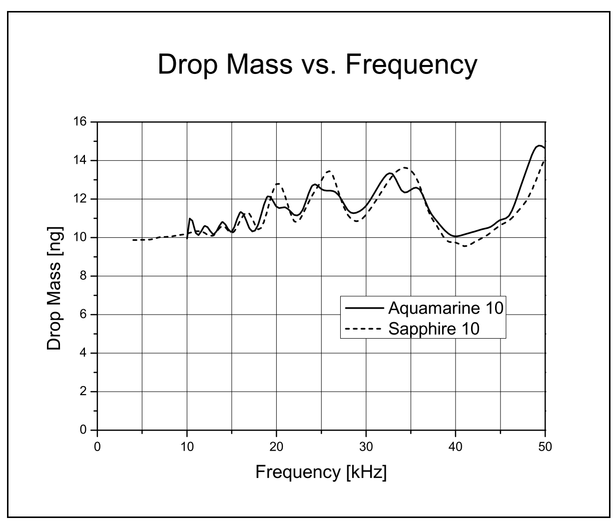

Figure 4 - Mass Frequency Response Comparison.

Multi-pulse Jetting Demonstration

In addition to model fluid testing, it was desired to develop multi-pulse waveforms tuned for an aqueous textile ink and demonstrate that the printhead could meet jetting requirements for a typical scanning printing application. A reactive dye based cyan ink was chosen for the waveform development. The goal was set to demonstrate full grayscale operation with small medium and large drop sizes of 10ng, 20±5ng, and 30ng respectively up to 23 kHz.

VersaDrop™ multi-pulse binary and grayscale waveforms were developed for the chosen reactive dye ink. The wave form is made up of multiple segments that can be independently switched on and off to give the desired drop size for a particular channel. The printhead can then be operated in either binary mode with each channel firing the same drop size or in full grayscale mode with individual channels firing a small, medium, or large drop size as needed (illustrated in Figure 5). A brief discussion of the VersaDrop™ application space can be found in reference [4]. The VersaDrop™ waveforms increase the volume of a fluid drop before it detaches from the nozzle using multiple pulses to increase drop size. The waveforms developed for this application are shown in Figures 6 – 9, beginning with the full waveform and showing how segments are toggled to generate the small, medium, and large drop sizes. The active segments are indicated by solid lines in the respective plots.

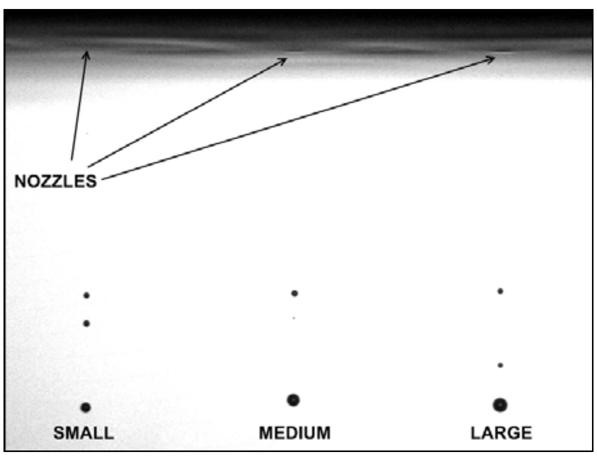

Figure 5 - Image of QS-256/10 Jetting Different Drop Sizes from adjacent jets.

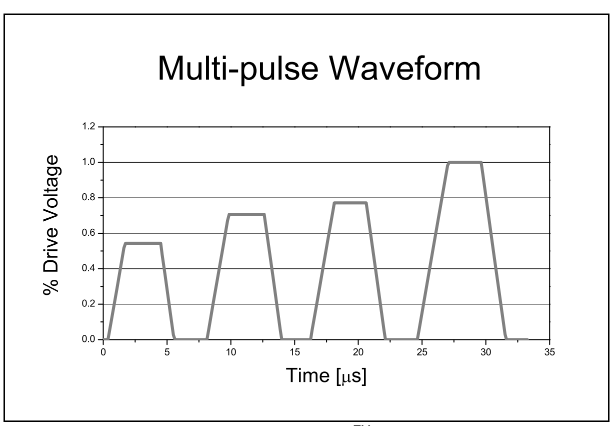

Figure 6 - Full VersDrop™ Waveform

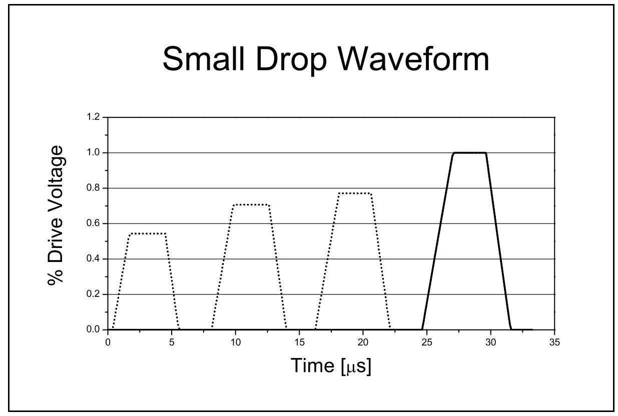

Figure 7 – Small drop segment enabled.

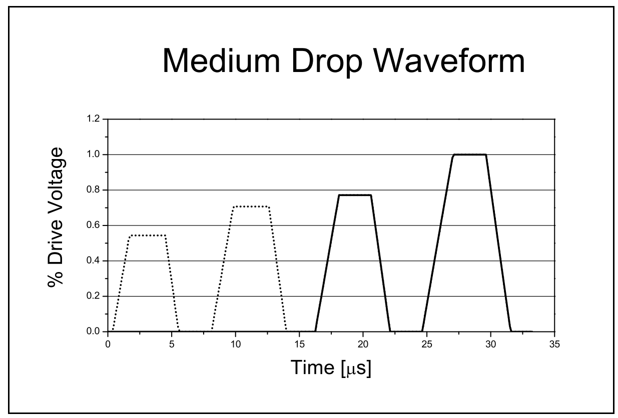

Figure 8 – Medium drop segments enabled.

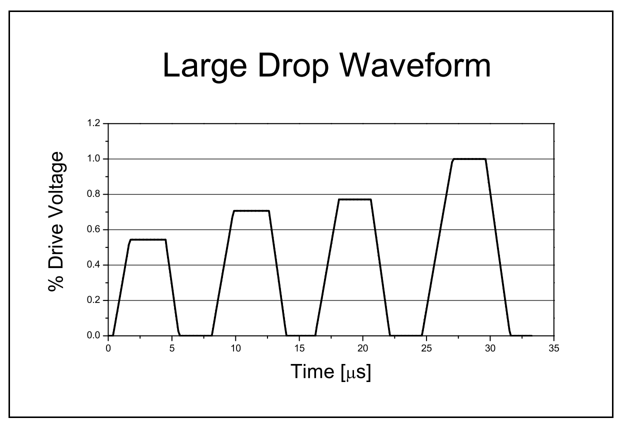

Figure 9 - Large drop segments enabled.

Figure 10 shows the resulting velocity and mass frequency response for the new Aquamarine printhead using the developed waveforms. All three targeted drop sizes were demonstrated with experimentally measured drop masses of 11.1ng (within 11% of target), 17.9ng, & 29.7ng (within 1% of target) at 8kHz. In addition, both the velocity and mass frequency responses are shown to be relatively flat up to the 23 kHz top frequency target.

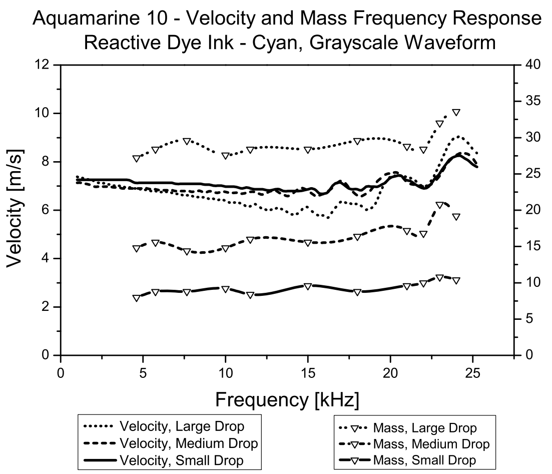

Figure 10 - VersaDrop™ Frequency Response.

Conclusions

A new 256 jet DOD Piezoelectric inkjet printhead for use with aqueous textile inks has been developed based on the recently released Sapphire QS-265/10 printhead architecture. Materials that were not compatible with aqueous textile inks were replaced or protected using proven conformal coating technology. The impact of these design changes was then evaluated against the baseline design with very little impact to the jetting performance. Finally VersaDrop™ multi-pulse and grayscale waveforms were developed for a specific aqueous textile ink. Target drop sizes and top frequency operation required for a typical scanning printer application were demonstrated.

References

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[2] Tyler, D., "Textile Digital Printing Technologies," *Textile Progress*, 37:4, pp. 1-65, 2005.

[3] Ali, M., "Chemistry of Textile Inkjet Inks," *Proc. of the 24th International Conference on Digital Printing Technologies, IS&T NIP 24*, September 6-11, pp. 542-545, 2008.

[4] McDonald M., "New Advances in Piezoelectric Carbon Printhead Technology," *Proc. of the 24th International Conference on Digital Printing Technologies, IS&T NIP*, September 6-11, pp 117-120, 2008.

Author Biography

Matthew Aubrey has been a Development Engineer at Fujifilm Dimatix, Inc. since 2004, working on piezoelectric inkjet printhead design. He received his Ph.D. in Mechanical Engineering (2004) from the State University of New York at Binghamton specializing in acoustic modeling of MEMS devices. He also holds B.S. (1993) and M.S. (1996) degrees in Mechanical Engineering from SUNY Binghamton and a B.S. (1993) in Physics from SUNY Plattsburgh. His prior industrial and academic experience includes development of piezoelectric and MEMS based inkjet printheads, large format digital Silver Halide printers, and electronic packaging strategies.