Recent Advances in Highly Durable Piezoelectric Inkjet Print Head Technology

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Abstract

Piezoelectric inkjet print head is a preferred choice for drop-on-demand (DOD) industrial printing applications not only because it can handle a variety of jetting fluids very well but also due to its consistent high performance under harsh working conditions. With a proven commercial success in the past decade, Trident's piezoelectric inkjet technology has become a robust and cost effective solution for product marking and coding, graphics printing, industrial fluid dispensing and other applications.

The challenges in the design of such inkjet printheads essentially arise from different application requirements. There is no easy lesson in print head design. This paper focuses on some recent developments in highly durable and repairable printheads for product marking and coding. Discussions cover the principle of printhead operation and some unique features in Trident's printheads such as multiple orifices, repairable orifice plate and automated maintenance module (AMM). Reliability studies of both exiting products and the new high throughput four-inch wide 768 jet printhead have demonstrated that these printheads can reach more than 90 billions actuations without performance degradation.

Introduction

Product marking and coding are often used for tracking, identification or warranty purposes such as barcodes, lot numbers and date codes. Logos and symbols may also be printed to serve the needs for branding and advertising. These marking and coding images are characterized by alphanumeric characters, text, barcodes as well as graphics. The substrates may vary from traditional plain papers to corrugated cases, plastics, metals, textiles, woods and etc. Very often these printing systems operate in harsh industrial environments. Inkjet technology, especially piezoelectric printhead technology, is now a favorite choice for these applications because of its robustness and cost effectiveness. Trident, as a major manufacturer of inkjet printheads as well as inks for marking, coding and other industrial printing applications, has developed a family of highly reliable printheads. This paper will explore print head's operating principles, explain some unique features in existing products, and discuss reliability testing results.

Printhead Technology

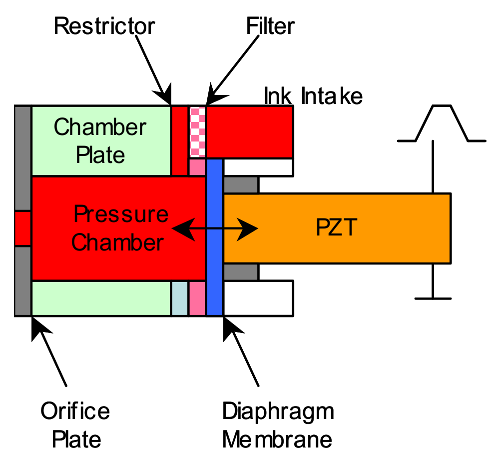

Figure 1. Trident's DOD piezoelectric printhead

Trident's existing printheads are developed based on the well known piezoelectric technology. Figure 1 shows the schematic of its working principle. In this design, PZT transducer is poled in its thickness direction to establish piezoelectric property. Since electrodes are placed on the top and bottom surfaces of the transducer, electric fields established by the applied voltage pulses make PZT extend or contract, which in turn pulls or pushes the thin stainless steel diaphragm membrane. In a fill before fire mode, piezoelectric transducer first pulls the membrane back and creates a vacuum to draw ink into the pressure chamber through the filter and restrictor. When the applied fire pulse is released at a proper time that matches the maximum positive pressure wave in the pressure chamber, the membrane further pressurizes the ink and a pressure doubling effect occurs. Once the pressure wave propagates to the orifice and overcomes its resistance a high-speed drop is ejected. While the fire pulse plays an very important role in driving the transducer, a print head's performance may also be affected by many other factors such as the property of piezoelectric material, the stiffness and acoustic characteristics of internal structure, the property of jetting fluid, the manufacturing processes and etc. The development of a print head is a delicate process that balances various factors to maximize the output efficiency while satisfying various requirements for drop ejection. Both numerical analyses and experimental studies are performed at Trident in optimizing print head designs. Recent advances have also been made in print head packing density. The native resolution of a print head has been steadily improved from 17 dpi to today's 64 dpi. Higher resolution is also possible with the implementation of MEMS technology.

Multiple Orifices

To maximize the use of all energy created by the high efficient piezoelectric material, many Trident's existing products employ a unique multi-orifice jetting technique, which uses every active channel to eject multiple drops through multiple orifices.

Figure 2 is an example of a six-orifice design, and Figure 3 shows eleven orifices firing simultaneously from one active channel. This technique works especially well for printheads that are primarily used for bar coding or area coating because the number of active channels is minimized while still providing enough drops to print solid lines or areas.

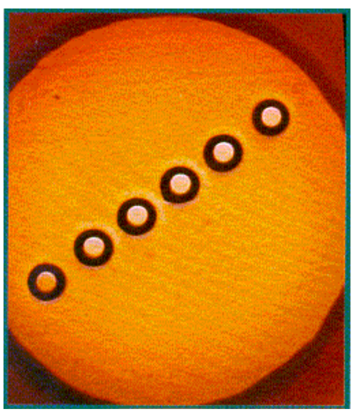

Figure 2. Six orifices are in one channel

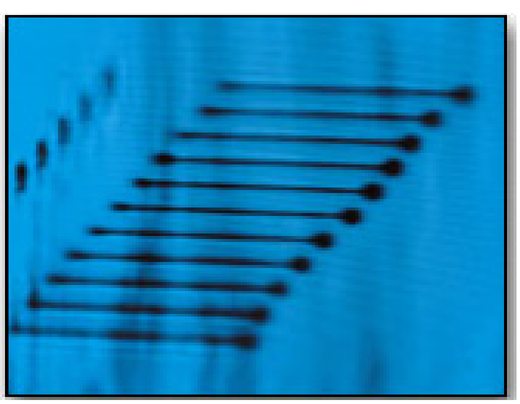

Figure 3. Eleven jets fire simultaneously from one channel

While the multiple orifices may have some limitations on high-resolution printing, a tradeoff may be made based on the needs for barcode readability as well as visual image effects. Different orifice configurations ranging from a single orifice to more than 11 per firing channel have been designed to meet different application requirements.

Repairable Chamber Plate and Orifice Plate

The stainless steel diaphragm membrane shown in Figure 1 is not only a key displacement element, but also an interface isolating PZT transducer from chamber plate and orifice plate (CPOP). This configuration offers a good opportunity to make the CPOP replaceable. Therefore it is possible to repair or replace CPOP if orifices are clogged or damaged.

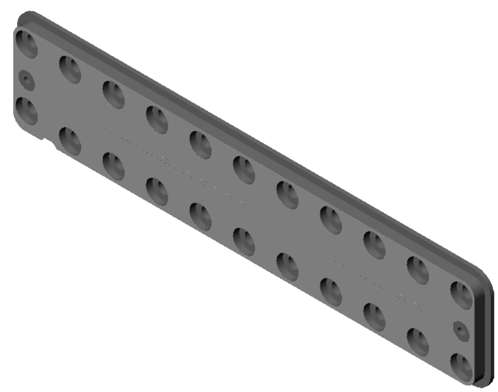

Figure 4. Repairable chamber plate and orifice plate

Like many other key components directly contacting jetting fluid in the printhead, CPOP is made of stainless steel for excellent corrosion resistance. To end users, the thin orifice plate and a much strong supporting chamber plate are seen as one component because they are bonded together. An example is shown in Figure 4. Many Trident's printheads have replaceable CPOP. System manufacturers, distributors or even trained end users may clean or replace a CPOP. Since the orifice clogging is one of major failure modes in the field, the replaceable CPOP makes it possible to return a system back to working order quickly. This approach also significantly extends the life of a print head and reduces the total cost of ownership.

Automated Maintenance Module

Printheads working in harsh industrial environment unavoidably expose to dusts, debris and other particles that are often the major causes of jet outages. To address this issue, Trident has developed an automated maintenance module. The primary function of the automated maintenance module is to allow the system to self-clean the face of orifice plate unattended on a periodic basis, in dusty installations, raising the overall system printing reliability to a new level. By reducing the need for wipes and operator intervention, the chance of debris getting into the orifice holes is greatly reduced, the amount of mess generated is reduced, the requirement for disposable wipes is greatly reduced and the ability for the operator to keep his/her hands clean is greatly increased. The system is also very effective at priming the printhead and eliminating trapped air in the printhead and ink feed tubing.

As shown in Figure 5, the automated maintenance module can effectively recover jets drop out in the field.

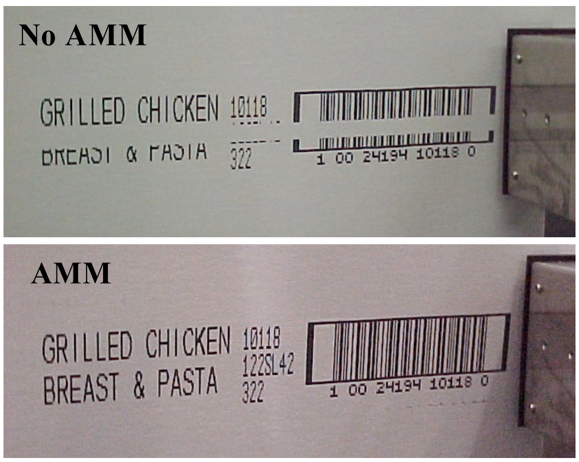

Figure 5. Effectiveness of automated maintenacne module. Top image: a bank of jets drop out due to clogged orifices. Bottom image: AMM recovers lost jets suceefully.

Printhead Reliability

UltraJet II is a widely used print head for various marking and coding applications. Figure 6 shows a recent study of its in-service time for more than 6000 print heads. This result indicates that about 99% print heads are still in good working condition at the end of three-year warranty for this product.

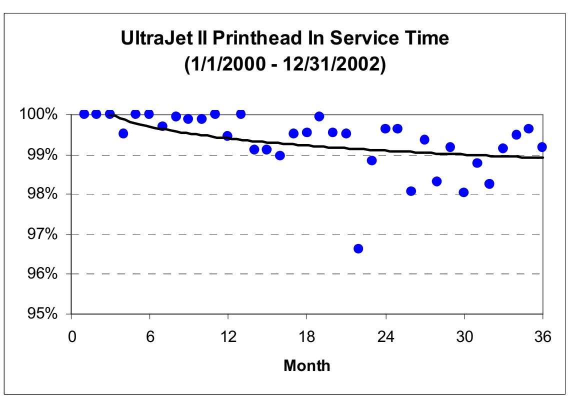

Figure 6.UltraJet II in-service time

More recently, Trident launched a new product 768jet print head, which has 256 addressable channels and each has three orifices. This print head shown in Figure 7 is capable of printing four-inch tall images in a single pass. It is very useful for printing large characters and graphics for case coding and other applications. To test its reliability, two print heads operating at two different operating temperatures for different inks went through a long-term reliability test jetting more than 90 billion drops per orifice. The protocol includes print head dynamic endurance test, all channels firing frequency sweep stress test and thermal cyclical printing test. Each printhead was characterized at approximately every two weeks to exam if there was any significant performance change over the time. Both printheads have successfully passed the rigorous test. As a result, 768jet printhead is also offered to customers with a three-year warranty. An example of characterization data before and after the reliability test is shown in Figure 8. The measurement is each channel's firing voltage for a constant jetting velocity of 11m/s. There was virtually no change in characterization readings.

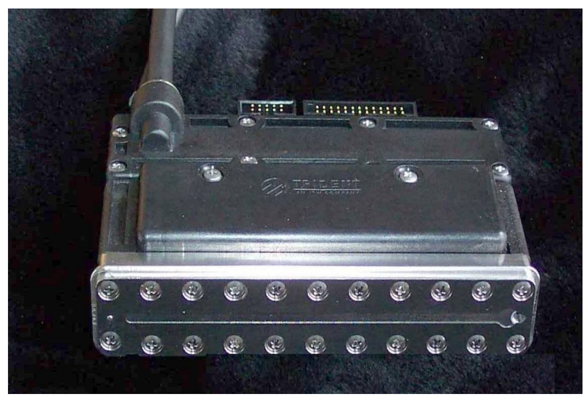

Figure 7. 768jet Printhead

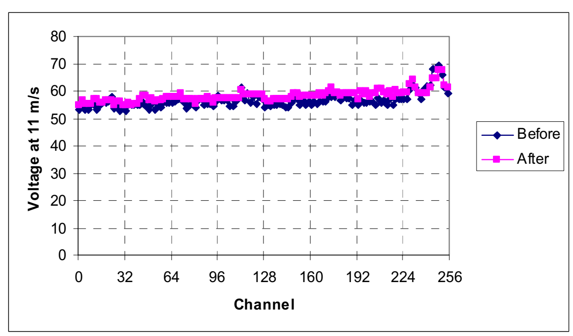

Figure 8. Channel drive voltage changes of 768jet printhead before and after 90 billion drops jetting.

Summary

Piezo ink jet technology offers solutions to various printing opportunities. It is clear that Trident's piezoelectric print heads have demonstrated very long jetting life and are very reliable for industrial printing applications. Enhancements disused in this paper can improve print head's reliability, performance and efficiency.

Biography

Dr. Zhou received his Ph.D. in Engineering from Thayer School of Engineering, Dartmouth College. He is Director of Engineering at Trident, an ITW company, designing, manufacturing and marketing ink jet print heads and inks for industrial applications. Dr. Zhou joined the staff at Trident in 2002 after 7 years inkjet printhead development with Spectra, Inc. Dr. Zhou's principal area of focus is the development of advanced printhead technology and high performance print engines for industrial applications. His interests include high efficiency piezoelectric transducers, acoustics, fluid-structural interactions, and design optimizations. He is a member of the IS&T.