Automated Inkjet Print Head Sustainability Testing

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Abstract

As inkjet technology becomes more broadly integrated as a core technology in digital fabrication of products ranging from printed electronics to biotech test strips and 3-D structures, increased attention will need to be spent on assessing print head performance over time and characterizing failure modes.

Traditionally, print head life testing (sustainability) is performed using print tests and visual inspection to assess elapsed time to the initiation of jet drop-outs. To decrease waste, and to increase efficiency and objectivity, several machine vision-based systems have been developed to assess print head performance during life tests.

This paper will introduce several automatic methods that have been developed to address print head life testing using both existing and novel systems.

Introduction

Sustained and well-characterized print head performance is necessary for successful inclusion of ink jet technology in production environments. Sustainability (life testing) helps systems engineers understand the time to failure expected for their printing system. With such knowledge, accommodation can be made for replacement, cleaning, or redundancy in a system that relies on the integrity of the print head for digital printing and/or part fabrication.

Machine vision based systems exist for objective analysis of drops in flight to help optimize system performance and fluid formulation [1], but analysis of longer-term print head performance usually requires extensive print testing and, often, visual assessment of a significant number of prints for determination and characterization of print head failure. Print-based life testing is costly from both a materials perspective (the substrate consumed), and from a personnel perspective (the need for trained operators to provide visual analysis).

Several system options have been developed to address the need for sustainability testing for print head, print system and fluid developers.

Option 1 is to use a JetXpert system with automated motion to step and repeat across the print head, moving back and forth until failure criteria has been met.

Option 2 is a linescan-based system that images the drop streams caused by ejected ink and looks for breaks in the streams indicating jet-outs. Imaging a much wider swath than the JetXpert system, it can look at the entire print head for heads 60mm or smaller.

Option 3 also includes a linescan camera, but instead of imaging the drop stream, the print head jets a pattern on a drum and the jetted image is analyzed before it is wiped clean prior to being reprinted. The drum is carefully positioned at the appropriate throw distance to act as a virtual substrate.

These three system options are detailed below.

Option 1: JetXpert Step and Repeat

JetXpert is a fully integrated machine-vision based system that has been developed for visualization and measurement of drops-in-flight from non-contact dispensing systems such as ink jet. The print head is positioned such that it fires droplets between a high-powered LED and a camera (figure 1).

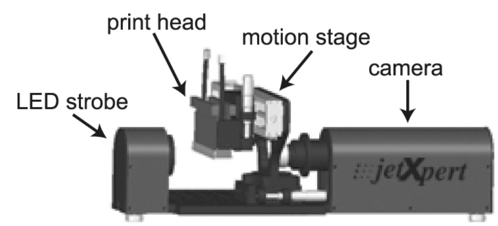

Figure 1:JetXpert system with motion stage and S-Class head shown as an example of a mounted print head.

Please note that figure 1 does **not** show virtual substrate, which is necessary for sustainability testing. The virtual substrate serves two purposes: it acts like a substrate in that it is positioned so that the print head has an appropriate standoff from the "substrate" surface, and this virtual substrate can also be used for ink collection and control.

In order to predictably and repeatably image drops in flight, image capture and strobe firing are synchronized with the firing frequency of the print head (figure 2):

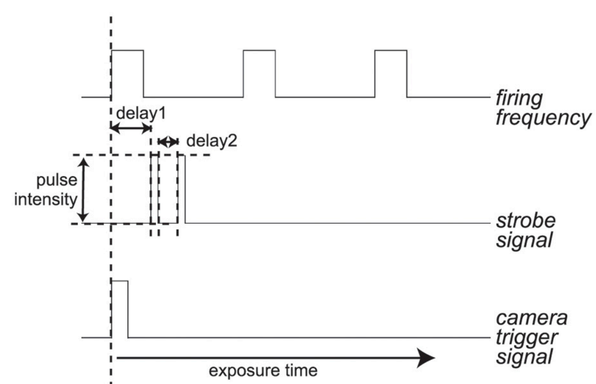

Figure 2: Conceptual sketch of a double drop (two strobes, two delays) signal relationship between dispensing head firing frequency, the camera, and the strobe, assuming a rising edge trigger.

Since the print head is positioned such that it fires between the LED strobe and the camera, the ejected drops are imaged in silhouette (figure 3):

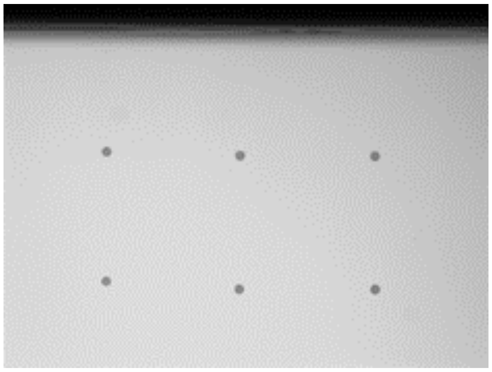

Figure 3: Double drop image of three firing nozzles on S-Class head

By stepping across the print head using an integrated 1-axis automated motion system, JetXpert can be used to sequentially assess jet presence in each firing location. Depending on the magnification chosen for the optical system, multiple jets can be imaged in one frame. As the system moves the print head from position to position, jets that are not in the field of view may drop out. The time resolution for detecting a jet drop out will depend on the size of the print head, and the magnification chosen (the number of jets imaged per move). The time delay would most often be less than one or two minutes.

One significant benefit of using JetXpert with automated motion as a tool for sustainability testing is the flexibility to use all of the current JetXpert tools (measuring drop velocity, volume, and trajectory; enabling the wetting visualization option for imaging the faceplate during firing to view ink buildup and flow) and also be able to invoke expanded test capabilities to include sustainability testing.

Another benefit is financial-- the JetXpert system is relatively inexpensive. While step and repeat may result in a lower time resolution than some other methods (see below) for recognizing and reporting jet outs, the tradeoff between cost and capability is worthy of consideration.

Option 2: Novel Linescan Camera-Based System

Since many companies ideally want to assess the performance of an entire print head at once, a novel linescan camera based-system has also been developed to analyze print head sustainability without the need for substrate consumption or visual assessment.

The system uses a 6k-element linescan camera and a specialized light source to capture images of drop streams in silhouette for entire print heads of up to 60mm in length.

A virtual substrate is necessary for sustainability testing since print heads behave differently when a substrate is in position rather than having a long throw distance between the print head and an ink collection system. The virtual substrate is placed such that the print head is positioned at an appropriate standoff from the "substrate" surface, and this virtual substrate can also be used for ink collection and control.

In this system, a monochrome linescan camera captures images of streams of drops in flight. ImageXpert software is used to analyze the captured images in near-real-time to identify jet drop outs and to report features such as jet ID and time to dropout or failure depending on the needs of the specific application and customer.

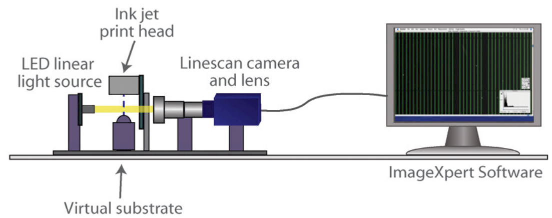

Figure 4: Line scan system set-up including a virtual substrate

The linescan camera captures images of drop streams using the inherent motion of the drops in flight to draw "lines" down the image indicating jet presence. Using special optics and lighting for optimal image contrast and illumination allows the ImageXpert software to detect when a jet drops out.

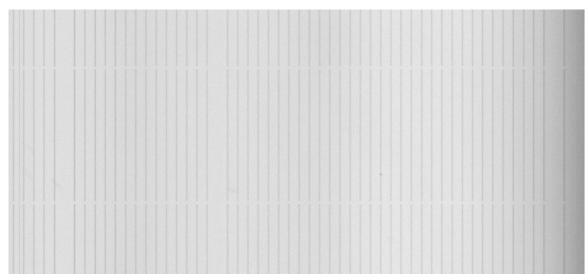

Figure 5: Partial image of jet streams as imaged by linescan camera and specialized optics. (Image lightened for publication).

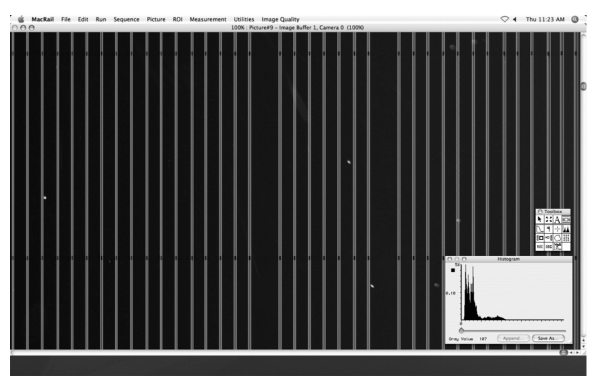

Figure 6: Partial image of jet streams as imaged by linescan camera and analyzed by ImageXpert software. Note that missing jets are obvious as missing lines in the image.

The system can be used to identify which jets drop out, and at what time from the beginning of the test (reported to the second). Also, other criteria such as adjacency (are jet outs adjacent?), time to first failure, and time to nth failure can also be used to trigger data collection and test completion.

For print heads wider than about 60mm (~2.35”), manual stages (or, if necessary, automated motion stages) can be used to reposition the print head to assess the head in sections.

Similarly, for multiple-bank print heads, each bank may need to be assessed separately, but manual stages can be used to reposition print head between runs as necessary.

The system has a very small footprint (main unit is <24” wide) for lab use. It can be set up to detect and respond to specific failure criteria such as time to first jet out, adjacent jet outs, or total number of jet outs. And the detection method is robust against satellites and rogue droplets.

Capturing data from single or multiple runs, ImageXpert’s linescan system can allow a systems engineer to get statistical information about head performance under simulated operating conditions.

Option 3: Drum Imaging with a Linescan Camera-Based System

Similar in configuration to the direct-jet-inspection process outlined in option 2, the drum imaging system uses a linescan camera (6k elements) to image a rotating drum onto which ink is being jetted. The drum itself acts as a virtual substrate and is positioned at the appropriate throw distance for the print head under inspection.

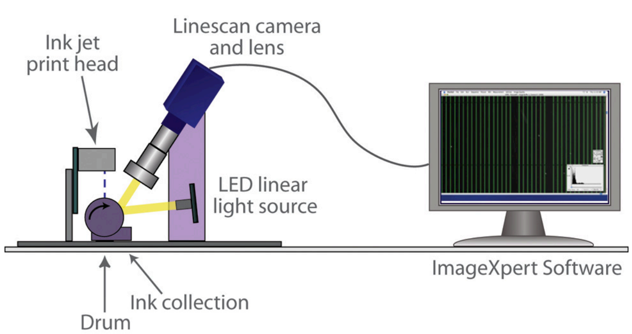

Figure 7: Line scan system set-up for imaging print drum during firing for sustainability testing

Image capture requires specialized lighting and optics to successfully image the printed pattern at a resolution and contrast that allows for repeatable and reliable inspection.

Since the drum is made of a shiny material, very careful illumination design is critical to success. In addition, the behavior of the ink once it is deposited on the drum ink mobility and flow) may impact whether single jet outs can be detected.

In this configuration, ink management is also clearly an issue, as the drum must be cleaned of any printed ink after inspection to enable a fresh “substrate” during the next rotation. A squeegee or other mechanical wiper may be used to remove the ink before the next rotation.

An alternative to drum printing could be a roll-to-roll paper feed in place of the drum, but this option is more complex mechanically, requires the use of a consumable, and also does not address the desire to avoid undue waste of materials during testing.

Since the linescan camera has 6k elements and is set up to measure the full print width for print heads of 60mm width or less, print heads that are wider than about 60mm (~2.35”) will require manual stages (or, if necessary, automated motion stages) to reposition the print head to assess the head in sections.

This system can be used to identify that jets have dropped out, and at what time they have dropped out from the beginning of the test. Other criteria such as jet out adjacency and time to first failure will require further characterization of the fluid on the drum surface.

Conclusion

There is little question that as inkjet becomes more and more prevalent in the field of digital fabrication where a missing jet is more than an aesthetic issue, but has functional implications, careful characterization of the printing system performance over time will become increasingly important. In addition, since novel fluids are being jetted, many systems may not operate under standard conditions and may have very different performance over time than they would with an optimized fluid.

Several machine vision based options have been proposed to address the increasing need for automated print head sustainability testing. Each option has its own benefits and limitations.

The multi-purpose solution of using a JetXpert system with one axis of automated motion is the most cost effective while offering the widest range of capabilities. But, since it is not specifically optimized for sustainability testing, the time resolution to report failure is longer than the other linescan based systems.

Line scan systems are inherently more expensive and both are designed specifically to address sustainability testing. The hardware is specialized to the specific task, so the flexibility in the JetXpert system, for example, is not as readily accessible in these systems. The most expensive and complex system is the linescan system that assesses the image as printed on the drum.

All three options offer increased efficiency and objectivity of sustainability testing compared with traditional assessment methods, while decreasing waste both in terms of consumed printed paper and personnel time for visual inspection.

References

[1] Yair Kipman, et al, “A strobe-based inspection system for drops-in-flight”, Proc. SPIE Vol. 7242, 72420H (Jan. 19, 2009)

Author Biography

Mr. Kipman is the president and founder of ImageXpert Inc., the industry leader in automated machine vision systems for image, part and process inspection. Since 1989, ImageXpert has offered a diversified product line to a wide range of markets including digital printing and fabrication, non-contact dispensing, and microfluidics. Mr. Kipman holds a M.S. in mechanical engineering, with a major in electro-optics from the University of Connecticut and a B.S. from the Technion Institute of Technology.