Automated Inkjet Print-head Quality Analysis

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Abstract

In response to a highly competitive marketplace, Xerox has enabled 100% inspection of inkjet cartridges in production. Tests are performed to assess both mechanical function-ality and image quality. In-line inspection processes need to be highly automated, efficient and reliable in order to balance the desire for high quality output and a high level of customer satisfaction with time and cost considerations.

This paper will discuss the automated inspection systems and methods, the print quality tests, and the data handling that have been integrated into the print head manufacturing process to improve part quality.

Introduction

Traditional print head assembly inspection methods are time consuming and tedious. For example, traditional print test methods include manual installation of a print head into a test printer, printing several test pages, comparing the test pages to visual standards and determining whether the part meets the necessary standards or not. This process takes approximately 3.5 minutes per part for an experi-enced auditor and is subject to the variability inherent in subjective analysis.

As we moved from prototyping into production, the need for increased throughput and decreased variability required us to evolve our inspection process. Integrating an automated inspection system was the natural choice.

Considerations

Once the decision was made to integrate an automated system, additional considerations had to be taken into account during the actual selection process. Cost, system flexibility, and ease of use were very important to us. Our goal was to maintain the ability to be autonomous in being able to set the system up and make required changes. In addition, a positive vendor relationship with a successful history of installations at Xerox was an additional deciding factor.

Inspection Systems

The inspection systems are fully automated and integrated. Part handling is performed via a PLC, print head actuation for both electro-mechanical testing and print testing is driven by LabVIEW™ on a Windows NT platform, print test analysis is performed by ImageXpert™ software, data is fed into a Microsoft Access™ database and Applied Stats™ statistical software for SPC. The cross-platform integration was performed in-house and is seamless to the operator.

Process

The inspection process begins at two audit stations where physical assembly parameters are measured and verified for a part lot. The audit stations are driven by a machine-vision based image analysis system that is common to all of our print head inspection stations.

Three print quality stations share the load for 100% inspection of the print heads. The first step at these stations is the evaluation of electro-mechanical aspects of the parts. Specific thermal oscillation response characteristics are measured and optimized settings are determined based on the results and burned into the circuitry. The parts are then shuttled to a priming station followed by a wet “burn in” process where 50,000 drops are ejected per jet. After the wet burn-in, the parts undergo a second 2-stage priming (full-face vacuum priming followed by wand priming to minimize false missing jets). The priming process is followed by a print test. After the print test, the parts are steam cleaned, and a final pass/fail determination is made based on the test results. Sorting of parts into pass and fail bins is performed robotically. The entire inspection process has a cycle time of approximately 12 seconds per part.

Print Test

Prior to the print test, the print heads are primed with cyan ink. Cyan was chosen for both color print head analysis and black print head analysis after extensive studies were conducted to verify that the print mechanics were effec-tively comparable. In the case of color print heads, the cyan ink has similar properties to the magenta ink while maintaining a lower cost. The black print heads use a carbon based ink, which is nearly impossible to flush from the part post-inspection. Using a dye-based rather than carbon-based ink allows for thorough cleaning post-inspection and decreases overall inspection costs. The choice of using a single ink also decreases inspection system complexity as only one color is used regardless of print head configuration.

Each print head is marked with a barcode containing a serial number and an indication of whether the print head is color or black. This barcode is read by a standard bar code reader (PSC) and is used to identify the data file and the requisite print tests that need to be applied. All print tests consist of printing each print head in both directions, which emulates the actual printing method employed by the print engine. A test image similar to that shown in Figure 1 is printed.

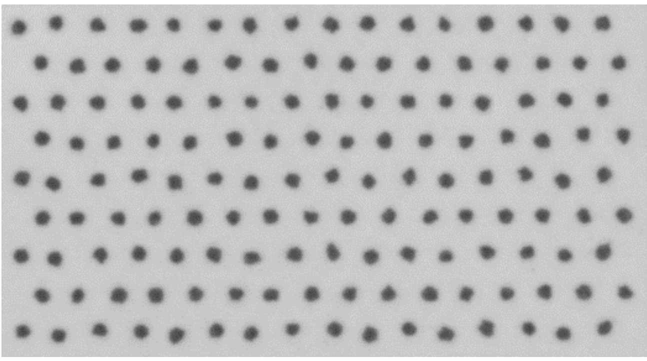


Figure 1: Test Pattern

The resulting image is scanned using a line scan camera (a 1-D CCD array) which allows high speed capture of a single image. A 1-D camera was chosen above the traditional 2-D cameras to avoid the need for step and repeat image capture methods which are time consuming and then the need to be stitched together into a final, single image prior to analysis. The line-scan camera captures a single image in one pass, allowing for very fast image capture and analysis without the traditional limitations.

Use of a line-scan camera also avoids traditional limitations of illumination uniformity.

Once the image is captured, features of interest are identified by the software and image analysis is performed on those features. Figure 2 shows the graphical feedback provided by the software indicating the locations of all of the dots.

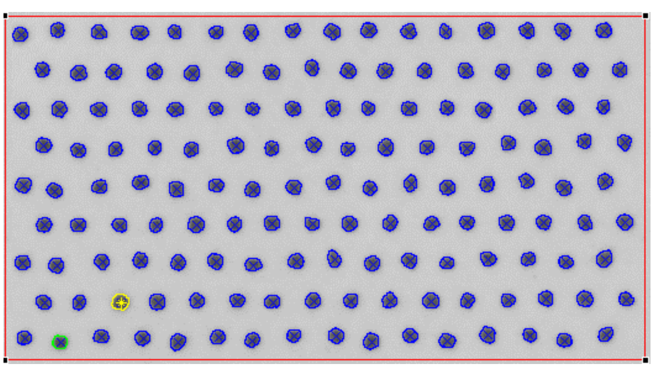
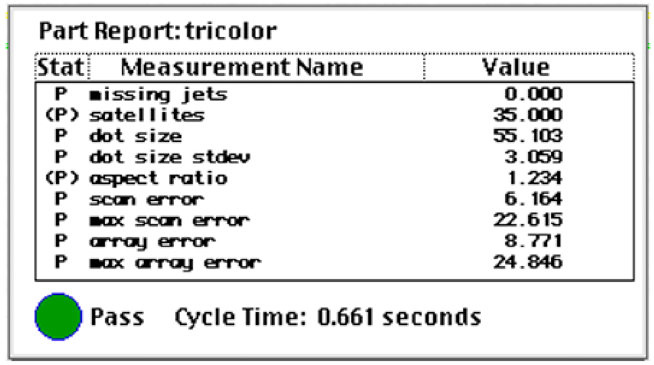


Figure 2: Test Pattern with Graphics



Part Report: tricolor

Stat	Measurement Name	Value
P	missing jets	0.000
(P)	satellites	35.000
P	dot size	55.103
P	dot size stdev	3.059
(P)	aspect ratio	1.234
P	scan error	6.164
P	max scan error	22.615
P	array error	8.771
P	max array error	24.846

Pass Cycle Time: 0.661 seconds

Figure 3: Report

Image analysis includes tests for dot placement (x,y locations of centers), size and size variability, shape, and the presence of satellites.

A test report is generated for each print head showing the results of the image quality analysis including pass/fail determinations for each measurement as assessed against a set of tolerance limits. An abbreviated example of one of the report files is shown in Figure 3.

Once the part is evaluated for print quality, the part is cleaned and then rejected or passed as a result of the test data.

A summary of the print test process is diagramed in Figure 4.

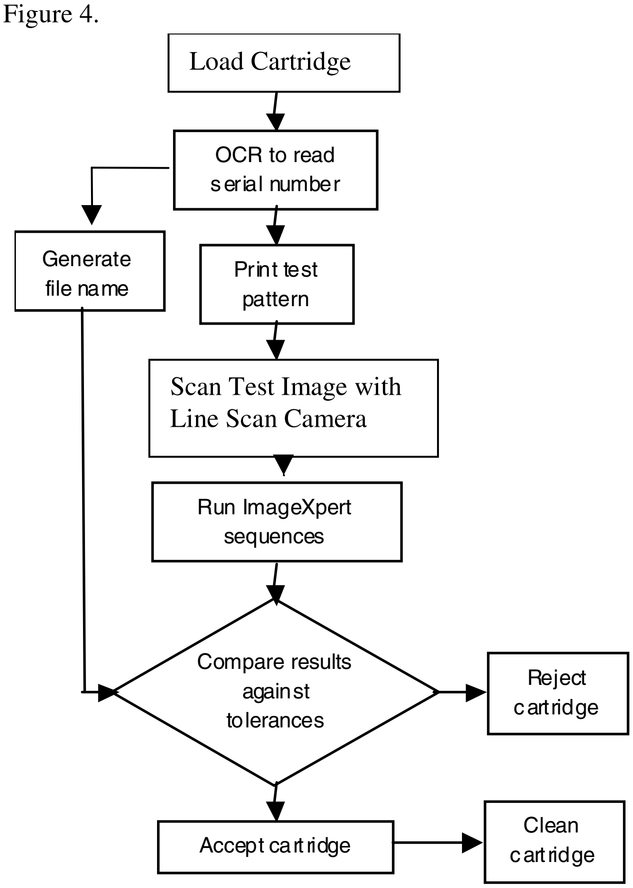


Figure 4: Print Test Flow

Additional Media Considerations

One major consideration when performing "in-line" inspection is ink dry time. Since the image analysis is performed in such a time-constrained environment, variability due to ink spread can cause spurious results during the image scanning and can lead to contaminated data. To avoid the issues that ink spread might cause during image capture and print inspection, a special coated paper is used to discourage ink wicking.

Data Handling

Data is immediately collected from the analysis of the test image and compared against tolerances. All of the data is then exported from ImageXpert to a Novell server. From the server, data is read into Access for archiving and into Applied Stats for SPC run chart generation.

Benefits

The cost per part for manual inspection is approximately $0.84. The cost per part for automated inspection is $0.07. Time savings resulting from automated measurement when compared with manual inspection is similarly impressive: less than 20 seconds per part versus 3.5 minutes per part.

Next Steps

In addition to the post-print-head-assembly inspection, we are enabling additional ImageXpert-based machine vision systems for inspection of ink jet nozzles prior to print head assembly. These ImageXpert systems also use a line-scan camera for single image capture and analysis.[1] Both top side and front face analysis will be automated and will take the place of visual inspection and slow 2-D CCD camera based analysis. Pass/fail determination of the nozzles at the stage prior to assembly will result in lower manufacturing costs and a decreased failure rate in the final assembly analysis.

Conclusion

Automated inkjet print head quality analysis has enabled us to inspect 100% of our final print head assemblies. In addition, the manufacturing cost savings is over 90%. This process supports increased quality and decreased costs of the products that are delivered to the consumer.

References

1. Yair Kipman, A Non-Contact High-Speed Inspection System for Ink Jet Nozzles, *Proc. NIP15*, pg. 217. (1999).

Trademark Information

LabVIEW is a registered trademark of National Instruments Corporation. www.ni.com/labview/
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Biography

Yasuhiro Oba received his M.Sc. and B.Sc. in Chemical Engineering from Tokyo Institute of Technology in 1988 and 1990 respectively. Then he joined Oji Paper Company and worked as a research scientist at the Pulp and Paper Research Laboratory. With funding from Oji, he studied paper physics at UMIST (the University of Manchester Institute of Science and Technology) between 1997 and 1999. After receiving his Ph.D., he has been working at the Imaging Media Development Laboratory at Oji. Email: yasuhiro-oba@ojipaper.co.jp