The Quality Plan for the Manufacture of an Ink Jet Print Assembly with 1536 Jets

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Abstract

High-speed digital printing with drop on demand ink jets requires a jet for every pixel. One approach to meeting this need is to construct multiple jet modules that can be aligned to provide high resolution variable printing at widths used in printing labels or even as add-ons to offset printers. Spectra has developed a single jetting assembly or print swath assembly with 1536 jets that prints at 2.5 inch wide, 600 dpi and line speeds up to 100ft/min. The quality plan used to manufacture this print swath assembly to insure 1536 jets are performing to specification will be presented. An overview of the print swath design and manufacturing process will be given. The relationship of the product specification to material requirements, to in-process verifications and to the final acceptance test will be shown. The requirements of nozzle assembly parameters and clean room contamination control to resultant image quality will be discussed.

Introduction

The large format print swath assembly requires that the all 1536 jets perform to specification to insure image quality requirements are met. Therefore the start of the quality plan begins with a product specification that defines image quality and performance capability. The bridge between the design intent, product specification and process documentation is the quality plan. The quality plan is a flow chart documenting all the process documentation from the bill of material, part drawings to incoming inspection, in-process quality controls, process documentation to the final acceptance test, Figure 1. In this context quality is defined as the measure by which specifications are exceeded.

The print swath assembly is constructed with 12 jet module assemblies of 128 jets each, mounted to a single nozzle plate/manifold assembly, Figure 2. The nozzle plate assembly consists of 12 rows of 128 nozzles, 1536 total, mounted to an ink manifold. This assembly is then screwed to a frame that contains the ink inlet and outlet fittings as well as mounting features. The details of the jet module and print swath assembly have been previously reported.[1,2]

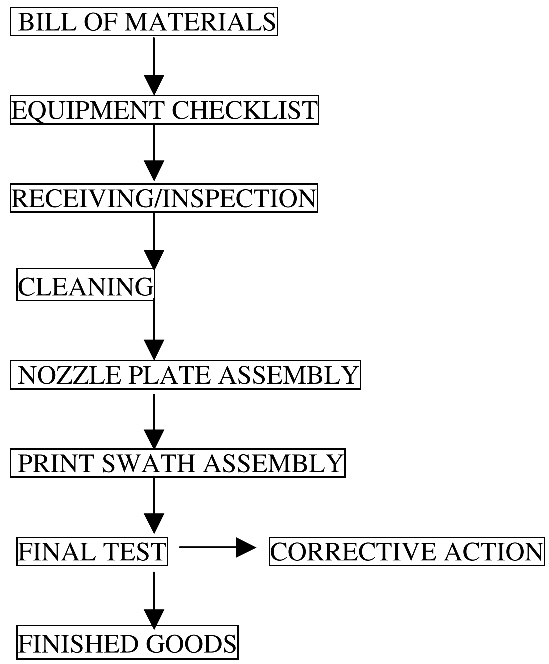


Figure 1. Quality Plan Summary

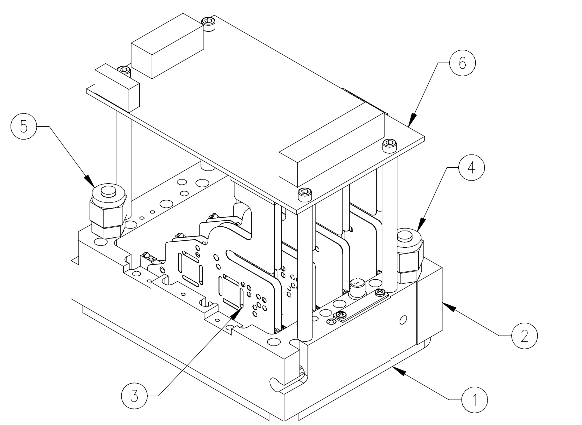


Figure 2. 2.56 inch wide print swath assembly. 1: Nozzle / manifold assembly; 2:Supporting frame; 3:Twelve Jet modules; 4 Ink outlet; 5: Ink inlet; 6: Swath drive electronics interface board

Development of The Quality Plan

The quality plan is developed early in product development during the design phase and prototype builds. It is an iterative process, of building and testing until the process capability is acceptable. The first specification is the design specification, which later evolves into the product specification. Following the design specification are the part drawings and proof of concept builds which evolve from the process documentation and ultimately the quality plan. Parts or processes outside the quality plan are typically covered by part drawing specifications or additional quality plans.

The product specification is shown is Figure 3, which describes the goal of the quality plan. Process controls are used to insure that the process is repeatable and predicts that product will meet the product specification. Key variables are measured which are known to correlate with performance. Experience has shown that determining the process variations that relate to image quality is critical. Referring to the product specification, the key image quality parameters are jet trajectory and drop mass uniformity as measured by line straightness and line width, respectively. It is important to note that line width and straightness are quantitative values that can be measured and correlated to the image quality that an end customer visualizes. The image quality parameters are quantitatively measured with a test fluid that predicts performance of end user inks. Typical inks used in the field are UV reactive.[3] The focus of this paper will be the nozzle plate assembly and image quality parameters of straightness and line width.

Product Specification

1. Number Of Addressable Jets ….1536
2. Nozzle Arrangement…….……12 rows of 128 orifices, interlaced
3. Resolution, cross process ………600 dpi
4. Print Width …………………….2.56 in
5. Operating Frequency Range…….0-12kHz
6. Nominal Average Drop Mass…..27 ng
7. Range of Average Drop Mass…..20-30 ng
8. Nominal Drop Velocity…………8 m/s
9. Operating Temperature…………<70 C
10. Jetting Assembly Internal Ink Volume…13 ml
11. Test Specification
12. Test Fluid
13. Line Width Tolerances
14. Jet Straightness Tolerance
15. Interface Control drawing

Figure 3. Product Specification Summary 1536 Print Swath, proprietary data not show.

The nozzle assembly is a three-piece design consisting of the nozzle plate with 1536 nozzles, the manifold and the adhesive. The critical nozzle plate and manifold parameters include diameter, feature location, geometric tolerances and other proprietary specifications are called out on the part drawing. Inspection data is taken showing the parts meet specification before assembly.

In process controls, that can be controlled in real time, simultaneously with the builds are optimum, e.g., continuous monitoring of process temperature, pressure or clean room controls. Since the fundamental nozzle parameters are determined by the critical nozzle plate and manifold drawings the assembly quality plan must control the process variables which effect performance. One of the dominant process variables is level of contamination in the print swath assembly. While the nozzle and manifold parameters correlate to the line width and straightness, contamination that works its way to the nozzles will cause out of specification jets and can be controlled by the quality plan. Additional parameters considered in the development of the quality plan include the amount of adhesive, alignment of the nozzle plate to the manifold and to the jetting modules.

While in-process controls are the preferred process control, the 1536 swath required development of a final acceptance test to insure all components, mechanical, electrical and software function together. Final acceptance test data includes the critical image quality parameters of line straightness and width to measure performance and sustainability testing to predict reliability. Non-conforming parts are analyzed for corrective action and continuous improvements of the process through autopsy or inspection.

Build Data and Analysis

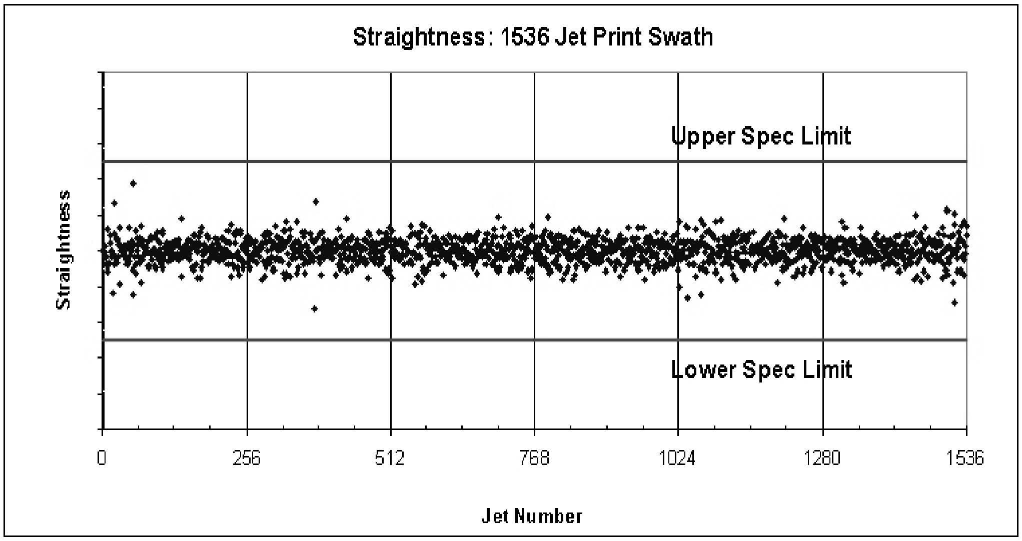
During the build a database is generated that tracks critical build data. The electronic traveler links the material lots to print swath serial numbers and records critical process data. The final acceptance data provides a quantitative measure of the product performance for each of the 1536 jets.

In process data is used to insure repeatability, minimize variation and therefore predict the production specification is met. Nozzle parameters are measured and controlled and can be correlated to image quality, e.g., nozzle diameter and line width. Adhesive uniformity is controlled by qualitative measurement of mass, pressure, and temperature.

The final acceptance test data, together with inspection and in-process testing predict that the product specification is met. The image quality data shown in Figure 4 is a measurement of the line straightness and line width uniformity measured by printing on a precision test station with minimal printing errors caused by paper transport, and therefore directly measures the performance of the print swath. By using a special test fluid, variations caused by ink are minimized and true variations in the production process can be measured. An acceptable swath is shown in Figure 4, showing resultant straightness and line width uniformity data for all 1536 nozzles. A histogram and corresponding normal-quantile plot, shown in Figure 5, provide another view of the data and allow for inspection for special causes. If jetting performance is found to be outside the specification limits deductions can be made whether the cause is incomplete priming, contamination in the nozzle or due to the jet modules. Therefore, the final acceptance test data insures that the product meets specification or can also be used for process improvement and failure analysis if jet recovery techniques do not correct the problem.

Conclusion

The use of a systematic quality plan to control process documentation allows a complex product to be manufactured to specification. The quality plan for the print swath assembly consisting of 1536 jetting nozzles has been reviewed showing the relationship of the parts requirements, in-process tests, final acceptance test to the product specification.



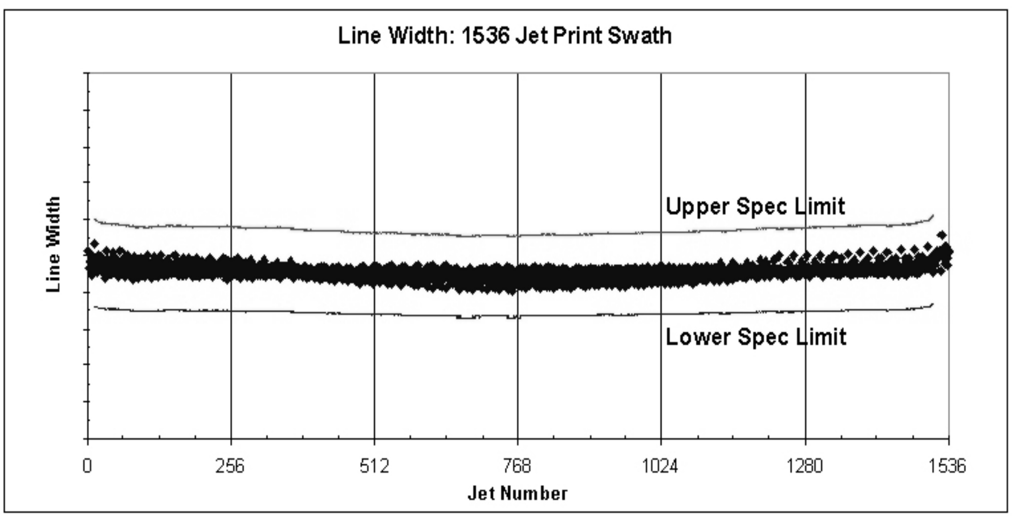
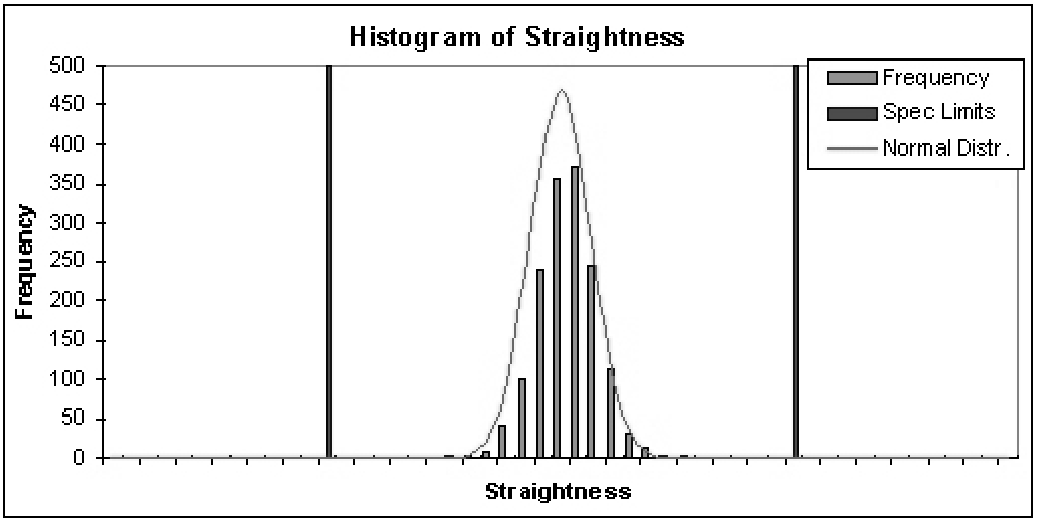


Figure 4. Build Data, showing plots of line straightness and line width uniformity for all 1536 pixels for a print swath assembly that meets specification.



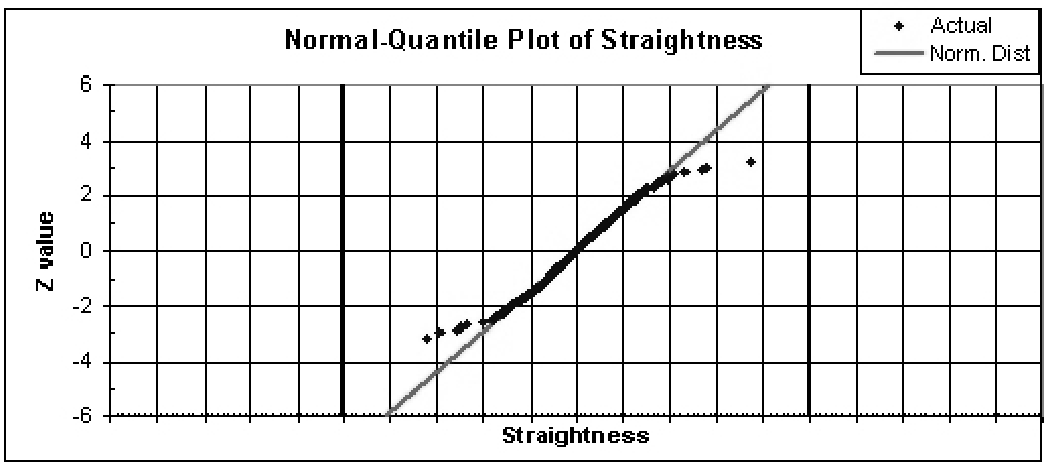


Figure 5. Analysis of build data, histogram and Normal-Quantile Plots.

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.
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Biography

Carl Tracy is a Manufacturing Engineer at Spectra Inc, Lebanon, New Hampshire. His professional background includes 19 years of engineering experience in project management, manufacturing, mechanical design and materials. He has 10 years of inkjet printhead engineering experience including manufacturing support, mechanical design, materials science and controlled experimentation. He received a Masters in Mechanical Engineering from Northeastern and a Bachelors in Mechanical Engineering from the University of Vermont.