Automating Cylinder Surface Inspection

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Abstract

It is well known that surface characteristics of imaging surfaces can negatively impact the image quality of the printed output. In all EP printing systems, failure modes must be well understood and characterized to minimize premature customer replacement and to identify and control causes of damage sustained during manufacturing.

Traditional inspection techniques include both visual inspection and print testing. Both methods are time consuming and subjective by nature. Successful automation requires inclusion of the positive aspects of visual assessment (such as defect classification) while increasing throughput and measurement repeatability. Inspection must also generate meaningful quantitative results for performance tracking and manufacturing process control. Ease of use is another critical factor for systems integrated into production environments. User interfaces for machine control and data feedback must be intuitive and complete.

In this paper, we will be presenting a case study of the integration of an automated cylinder inspection system into production. System architecture will be discussed as will design considerations and user interface development.

Introduction

The manufacturing quality of image-forming or imaging-bearing cylinders in an electrophotographic engine influences the quality of the printed output. A variety of automated tools are available to measure many properties of a cylinder, such as length, diameter, and cylindricity, identified as critical to the printing process. The detection, however, of defects resident on the surface of a cylinder, such as scratches or coating irregularities, continues to depend primarily on human visual inspection. Since surface defects can manifest as objectionable features in the printed image, it is critical that these defects be identified and mapped to the manufacturing process by a method that is extremely accurate and repeatable, has high throughput, and readily integrates into the manufacturing process. Human visual inspection proves inadequate to these criteria: 100% visual inspection can take excessive time with results that vary greatly depending on the experience of the evaluator.

A method of automating cylinder surface inspection has been developed and its feasibility accessed. The details of the ImageXpert system, its image capture and defect analysis, are described. A sample of 30 cylinders used as intermediate transfer components in the NexPress 2100, prepared with specific surface defects, were inspected both traditionally by trained inspectors and on the automated system. The results of these inspection processes are compared. The automated inspection system proves to be highly accurate, repeatable, user-friendly and adaptable and greatly reduces the measurement time and stress on the evaluator.

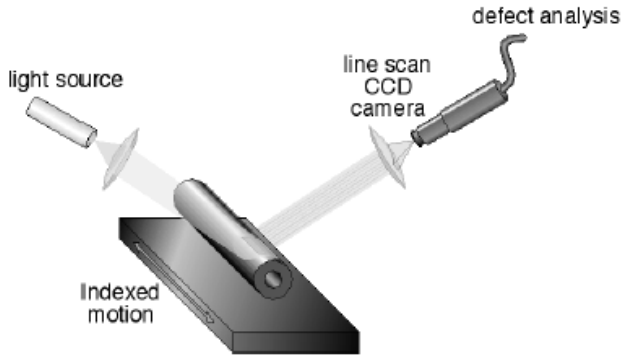

Figure 1. Cylinder surface inspection system.

Description of the Cylinder Inspection System

As shown in Figure 1, the automated system implements a line scan camera and mature image analysis software to inspect the surfaces of cylinders.[1] The line scan camera uses a single array of CCDs to capture an image. By taking sequential 1-D images, 2-D images are assembled. As the cylinder is rotated, a single camera and light source are held stationary during image capture of one circumferential section of the cylinder. The camera and light source are moved along the axis of the cylinder to the next location, enabling imaging of sequential sections of the surface. The

process is repeated until the entire length of the part has been inspected. The image capture speed of the individual circumferential sections is carefully synchronized to motion of the sample by use of high-precision encoders.

Image analysis occurs in parallel with image capture; as the first image is analyzed the next image is captured, for maximum efficiency. The software is based on the ImageXpert image quality analysis software package, so defect analysis capabilities are superior and customizable. A defect is automatically detected and highlighted if its perimeter is continuous and an estimated diameter exceeds threshold. The threshold input by the operator reflects the minimum defect dimension particular to the application. After the entire length of the part has been inspected and image analysis complete, the operator has two options: allow the program to automatically decide part disposition without detailed defect classification or manually review the results on the computer screen, classifying them into the defect categories and applying the reject condition. The manual option allows for random audits of the manufacturing process for real-time process control.

Inspection Results

30 cylinders were inspected with the ImageXpert automated system and visibly by three trained evaluators of varying experience. The cylinders are used as intermediate image transfer components in the NexPress 2100. The defects present on the surfaces were representative of production process errors and handling damage that may occur during manufacturing of the cylinders.

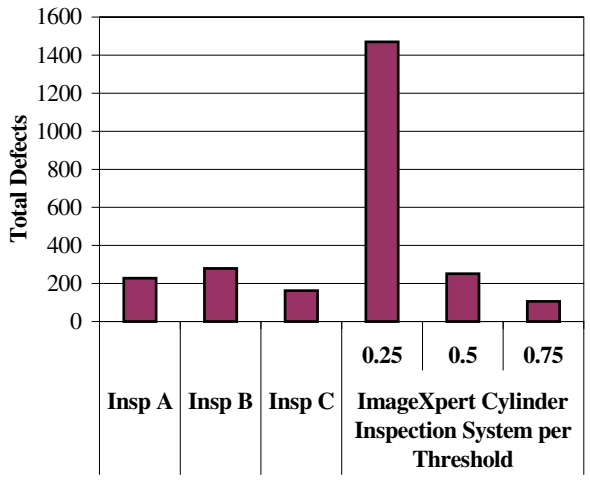

Figure 2. Total number of defects.

Figure 2 shows the total number of defects detected in the population for each inspection method. With 100% repeatability, the automated system is extremely capable of detecting features on a sample. At a minimum size threshold of 0.25 mm, over 1400 features are found. It is known from print evaluations of each cylinder that much fewer features cause objectionable print artifacts making a threshold of 0.4 – 0.5 mm a more suitable reject condition for this cylinder application. At a threshold of 0.5 mm, the number of defects identified by the automated system is similar to the number identified by the trained evaluators familiar with surface defects that cause image problems.

Figure 3 shows the actual number of printable defects and the number of defects detected and classified per part, in decreasing order. The results shown for the ImageXpert cylinder inspection system were detected automatically and classified in manual review. The defects reported by Inspectors A, B and C were detected subjectively and classified manually. Human visual inspection errors show a broad range: 3-31% of the actual number of defects. This range is difficult to reduce due to the subjective nature of visual inspection, with stress and strain on the evaluator further degrading the results. The automated inspection method with manual classification shows 4% total error: 3% due to minor issues in detection and 1% due to error in manual classification. Both error components have been analyzed, understood and improvements identified. The automated system consistently located 10 of the 13 defect classes. Three defect types alluded detection because of low contrast and/or discontinuous edges. This issue is resolved through slight modifications of the detection algorithm, further customizing the algorithm for this cylinder application. During manual review, the reviewer makes 1% classification errors that can be prevented with higher magnification and resolution of the review screen.

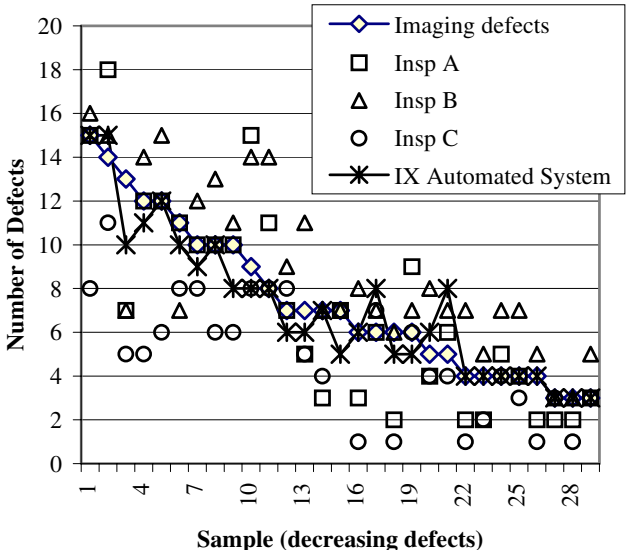

Figure 3. Inspection methods compared.

The time to complete inspection is shown in Table 1. The use of the ImageXpert system to detect defects reduces inspection time by at least 75%. Incorporating manual classification, the total part disposition time is reduced by at least 25%.

Table 1. Inspection times.

	Inspection (min)	Classification (min)	Total (min)
Insp A			8
Insp B			8
Insp C			9
ImageXpert Automated System	2	4	6

Conclusion

The capability of an automated cylinder inspection system has been assessed and compared to traditional human visual inspection. The automated system proves to be highly accurate and repeatable while significantly reducing the time for parts disposition. Through customization, the automated system is a suitable tool for insuring consistent quality of cylinders manufactured for digital print products.

References

1. Yair Kipman, "Image-based Cylinder Surface Inspection System," Proceedings of IS&T's NIP18: International Conference on Digital Printing Technologies, (San Diego, Sept. 24- Oct. 4, 2002), p. 571-573.

Biography

Diane Herrick obtained her PhD in Physics from the University of Rochester in 1996. Upon completion of her degree, she joined the Eastman Kodak Company to pursue research in electrophotography. Since 1999, she has been with NexPress Solutions, LLC, focusing primarily on the development and commercialization of toner-transfer subsystems.