Image-based Cylinder Surface Inspection System

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Abstract

The image quality of many printing systems is dependent on the surface characteristics of a variety of rollers, cylinders and belts that are components of the print engine. Once cylinders and rollers are integrated into the print engine assembly, print testing can be used to verify overall system performance, but often diagnostics can be challenging and reworking costs can be prohibitive. To keep costs down, parts are often inspected visually prior to assembly into the print engine. As with all subjective analyses, this process can be time consuming, fatiguing and variable.

Automated inspection requires high-speed, automated processes to support production volumes. Challenges such as illumination, image capture, defect analysis and throughput need to be addressed.

This paper will present a novel inspection approach using line scan camera technology and mature image analysis software for inspecting the surfaces of cylindrical components.

Introduction

Image quality of the output of many printing systems is dependent on the surface properties of rollers, cylinders and belts as well as on the nuances of the imaging technology itself. In many cases, parts that may impact image quality are inspected visually prior to assembly into the print engine. Visual inspection can be quite sensitive and experienced evaluators can inspect a drum in a matter of minutes. Defects can be measured and categorized based on the experience of the evaluator. To augment visual analysis of the part, print testing is also used to assess part quality. Defective rollers or drums may impart repeating defects on prints. Again, experienced evaluators can be very sensitive to print defects and evaluation of printed materials can require at least several minutes to complete.

Successful visual inspection requires educated, patient, tireless evaluators. The development of an automated analysis system grew out of a customer request to augment and off load the burden of proof from the evaluator to an objective measurement device. During this development and product roll-out process, it became clear that automated inspection allows for more thorough analysis and classification of defect types than visual inspection alone. Quantitative, objective analysis lends itself to process tracking, communication with vendors, and once in production, this data can assist in failure analysis in production.

Cylinder Inspection System Description

The machine vision based cylinder inspection system is a breakthrough for high-speed, automated analysis of cylindrical surfaces. As the cylinder is rotated, circumferential images of the surface are acquired. Defects are detected and characterized by size and/or shape automatically allowing for failure analysis, part dispositioning and real-time process control.

The ImageXpert cylinder surface inspection system relies on line scan camera technology for image capture. Single, high magnification images can be captured without the need for multiple-image stitching. On cylindrical surfaces, the benefit of a single line of best focus allows for image capture without distortion during cylinder rotation.

Line Scan Camera Description

Line scan cameras are 1-D CCD cameras that use a single line of CCDs to capture an image.

2-D images are built up by taking sequential 1-D images.

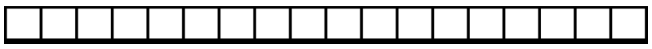

Figure 1a. Representation of a line scan sensor array

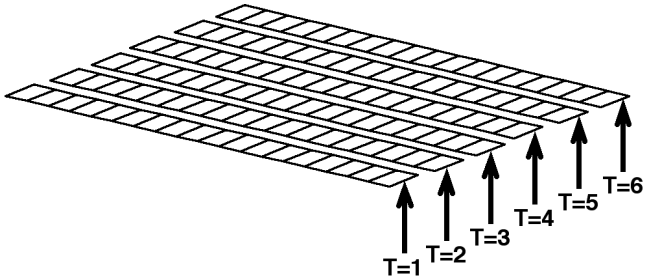

Figure 1b. 2-D images are built by assembling multiple 1-D images

Success of this system is dependent on careful synchronization of image capture speed to motion of the camera or sample. In the case of cylinder inspection, images are captured as the part is rotated. Thus, careful synchronization between the sample rotation and image capture speed is critical. ImageXpert uses encoders to ensure synchronization between cylinder motion and image capture.

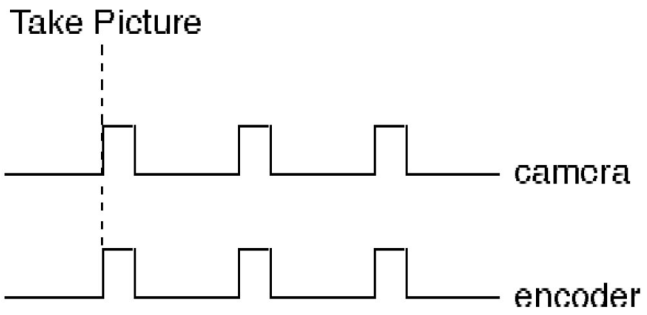

Figure 2. Encoder and camera synchronization

System Configurations

System configurations are available for both low-volume applications such as R&D and for high-volume, high throughput production environments.

The off-line system relies on a single camera and light source held stationary during image capture of one circumferential section of the cylinder. As the first image is analyzed, the next image is captured, maximizing efficiency. The camera and light source are then moved along the cylinder to the next location, enabling imaging of sequential sections of the surface. This process is repeated until the entire length of the part has been inspected.

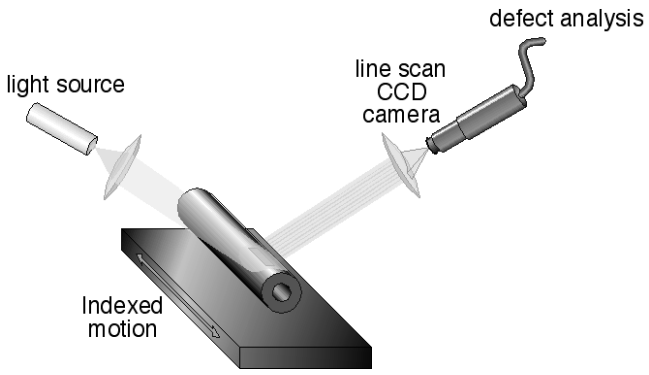

Figure 3. Single camera configuration

The production unit is based on the same concept, but it uses multiple cameras to capture images of the entire surface simultaneously. This allows for complete surface inspection in one revolution.

Alternatively, multiple cameras can be used to capture images sequentially without the time delay stemming from camera and light source re-positioning. The number of cameras for this kind of set up is determined by the resolution required and the resultant field of view.

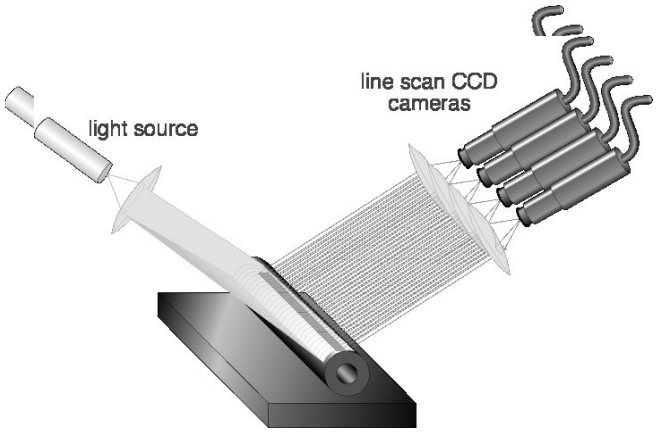

Figure 4. Multiple camera configuration

Defect Detection and Classification

"Cylinders" refer to everything from rollers used in paper handling to photo-conductive drums and belts, to belts made of screen printing screens. Cylinder defects are dependent on the materials, the manufacturing process, handling, assembly into print engines and degradation due to age, environment or use. Since each material and process has its own characteristics, various image processing techniques and analytical methods might need to be used for a given application.

In general, there are two main categories of defect analysis: detection and classification. Detection requires sufficient system resolution to have at least four image pixels subtend the area of the defect. Any fewer and defects might not be identified as separate from the background noise. Successful detection does not automatically lend itself to characterization. If the roundness of a defect is of interest, or if the area is critical, many more pixels should subtend the smallest expected defect. In order to classify defects repeatably and reliably, significantly higher magnifications are necessary. The extent of this increase is dependent on the application and other factors that must be determined based on the specific requirements of the customer. As a rule of thumb, where it takes at least four pixels to detect a defect, it would take at least 40 to classify it in a repeatable, reliable way. In some cases, where differentiation is more subtle, even more magnification might be necessary.

When designing this system, it was critical to include the flexibility to offer different camera magnifications depending on the needs of the user and the characteristics of the samples to be evaluated.

Operating Ranges

For each system, the operating parameters span a large range allowing for multiple configurations depending on the inspection requirements and part sizes.

The high-resolution end of the operating range allows for a resolution of 5 microns/pixel where the maximum part diameter is 2" (~50mm) for single image. The maximum swath width is 20mm and the minimum defect diameter required for characterization and classification is 25 microns, and just 10 microns for successful defect detection.

The low-resolution end of the operating range has a resolution of 50 microns/pixel. The maximum allowable part diameter (for a single image) at this resolution is 20" (~500mm). The maximum single image width is 200mm and the minimum defect diameter required for classification and characterization is 250 microns with defect detection requiring defects of at least 100 microns in diameter.

Special Considerations

Since rollers, drums, belts and cylinders have such different characteristics based on their materials, in many cases there has been modification to the choice of illuminant, and to the angles of both the camera and the illumination source. No one set-up works for all sample types. Some materials are matte, some translucent, some highly reflective. Each of these properties provides its own challenges to effective imaging and image analysis.

Production

ImageXpert systems can be integrated into production environments since all data is reported in tab-delimited text format. This allows export to or import into a wide range of software packages for data analysis and tracking. OCR and barcode decoding can be used for automatic part ID and data file labeling and annotation. Data and images can be sent via Ethernet to other computers for review or storage. The software that the cylinder inspection system is based on is the full ImageXpert image quality analysis software package, so defect analysis capabilities are strong and customizable. One customization that we enabled for part inspection is called "review reject". This option allows an operator to review images of each defect if they wish, so it can be used to disposition parts that are not clearly differentiable by the software.

Conclusion

The capabilities of a line scan camera based cylinder inspection system have been proven both in the lab and at the customer site. Creation of a flexible system that can be configured for various sizes of parts and magnification requirements has enabled a wide range of part inspection capabilities.

Biography

Mr. Kipman is the founder and president of ImageXpert Inc., the industry leader in automated image quality inspection systems. Mr. Kipman founded ImageXpert in 1989. Over the past decade, Mr. Kipman has guided the company to the forefront of the image quality industry. ImageXpert now offers a diversified product line that addresses the needs of a wide range of markets including image quality and related fields. 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.