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AUTOMATIC INSPECTION OF DRILL-HOLES AND THREADS

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Abstract: Due to the cylindrical shape of drill-holes and inner threads the acquisition of high-resolution images has not yet been solved satisfactorily. Different possibilities for taking pictures from the inside of a drilled hole are reviewed and evaluated with respect to the quality of the images. Results show, that a ring-shaped CMOS-Sensor works best for the purpose of automatic inspection.

Additionally, the analysis of these images requires a special algorithmic approach, which is able to take care of the cylindrial shape of the object. To achieve this, the use of the Z-transformation is recommended for processing of such images, and it is shown to be superior to other image processing operators.

Keywords: Automatic Inspection, Inner Threads, Technical Diagnostic

1 INTRODUCTION

The automatic inspection of drill-holes and inner threads by image processing requires images of very high quality and high resolution. The cylindrical shape of the objects, however, makes it difficult to find the right set of lighting and optics. Different ways of taking images have been used, which are either based on a rotating endoscope or use a complicated transformation to convert the cylindrical image to a rectangular one [1]. Figure 1 shows a typical image and the transformation required to remove the distortions.

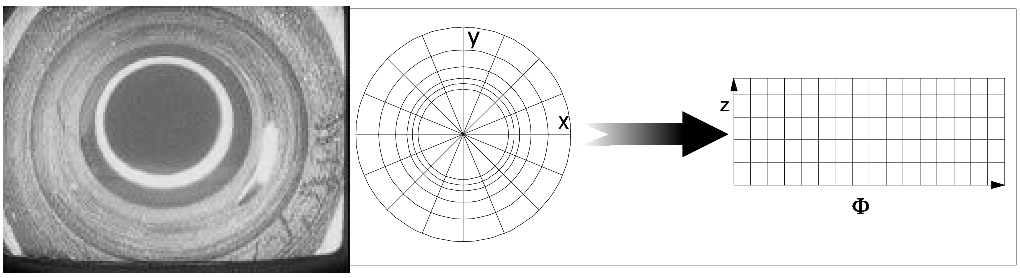

Figure 1. Taking an image from the inside of a drill-hole requires the conversion of a cylindrical shape to a rectangular one, either by optics or by software.

Once such a rectangular picture has been obtained, it is evaluated automatically to detect faults, like e.g. blowholes, scratches, or cracks on the inside of the hole. This evaluation is usually based on so called 'areas of interest', that define those areas of the image, which have to be processed. Even though the image has a rectangular shape on the screen and in the computer's memory, it has to be taken care that the underlying object is cylindrical. This causes some problems with standard image processing operators as proposed e.g. in [2].

2 METHODS FOR IMAGE ACQUISITION

2.1 Endoscope + Line-Scan Camera

The endoscope is looking at the inner side of the hole at an angle of 90°. A line-scan camera scans a height of approximately 10mm, while the endoscope is rotating around its axis. Thus the columns of the image correspond to the 360 degrees of the cylinder and the lines correspond to the height of 10mm. However, if the drill-hole is deeper than 10mm, which is often the case, the whole procedure has to be repeated. For the purpose of automatic inspection this method suffers from two major drawbacks. Firstly the stop-and-go forward motion and the 360° rotation of the endoscope are very time consuming and do not allow inspection at production speeds. Secondly - and more important - the image has a very inhomogenous brightness distribution, which makes the analysis of such images very complicated or even impossible.

2.2 Endoscope + Transformation

An endoscope with a 360° fish-eye lens is moved into the bore. During this motion a sequence of images - similar the one shown in figure 1 - is taken. From each of these images only the outer ring with a width of approx. 3-5 pixels can be used. The remaining part of the image does not have sufficient resolution and quality to be used for inspection. The single rings acquired during the forward motion have to be transformed to lines and have to be assembled to a full picture of the inside. Thus the lines of the final image correspond to 360 degrees and the columns correspond to the height of the hole.

If the transformation from the rings to the lines is done in real-time, then this method is much faster than the one described above. However, the transformation requires precise information about the shape of the drill-hole and is very sensitive to the position of the endoscope.

2.3 CMOS Ring-Sensor

Instead of the commonly used CCD-cameras, this sensor uses CMOS-pixels set up in the form of a ring. The CMOS-technology has the advantage of very high dynamic range, which provides good images, even if the brightness levels differ in magnitude.

The ring of 2048 CMOS-pixels automatically removes all the distortions and provides a single line representing 360°. Since only a single line is taken at each step, lighting is much more simple compared to other methods. The picture is taken ring-by-ring while the endoscope moves into the hole, no rotation is required. Consequently, it is usually fast enough to perform on-line inspection for most industrial applications. The brightness of the images is very homogeneous and the image has very high contrast, making the analysis of the image very simple.

3 ANALYSING THE IMAGE

If the inside of a drill-hole is converted to a rectangular image, the cylindrical shape of the object has to be considered when analysing the images, e.g during filtering. One problem occurs on the left and right edge of the image, since all the calculations have to take care of the 'wrap-around' effect, i.e. calculations should pass over the edge as if these were nonexistent. This, however, causes substantial problems with standard image processing operators. If e.g. a 5x5 neighborhood of pixels has to be considered, then we may easily run into trouble on the edges of the image, which makes the implementation of such algorithms very inefficient. A solution to this problem is found in the field of dynamical systems. To describe time-discrete dynamical systems the so called Z-transformation can be used. This allows the design of e.g. smoothing filters or edge-detectors, which have the advantage that only a single pixel instead of a neighborhood is required to perform the calculations. This automatically avoids any problems with the edges of the image.

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