UKACC International Conference on Control 2012
Cardiff, UK, 3-5 September 2012

Automatic Detection of Circular Defects During Ultrasonic Inspection

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Abstract—**In the non-destructive testing of materials, the use of imagery allows for more than only a qualitative representation of the results. Imagery can aid in automatically carrying out operations of detection, location and sizing of defects present in a structure. The rapidity of the calculators and their graphic performance allow us to use classical tools of image processing today, even though they require a large number of calculations. This work consists of applying the Hough transform to detect inclusions in a material by analyzing an ultrasonic c-scan image. In the first step, this image is binarized using the –6dB method, which reduces the defects to their real sizes. The Hough transform is then applied to the edges to detect the circular forms that characterize the inclusions.**

Keywords-Non Destructive Testing; Ultrasonics; Imagery; Pattern Recognition.

I. INTRODUCTION

In non-destructive testing (NDT) of materials, the automatic characterisation of defects allows for faster decision making [1]. With the appearance of computing systems that are able to process recorded signals rapidly and create images, the possibilities of ultrasonic imagery in NDT improve steadily [2,3,4,5]. In addition to aiding in the control and decision-making processes, automation allows for control under dangerous conditions of high-level radiation or in some industrial processes with low or null visibility due to the environment.

The Hough transform is a classical tool for pattern recognition [6]. It allows for the detection of parameterized forms, such as lines, circles, parabolas, etc. Because it requires a large number of calculations, it had been abandoned for ultrasonic imagery applications since its initial development in 1962 by Paul Hough. However, its robustness and its capacity to detect even incomplete edges keep it on the list of the most interesting tools for pattern recognition.

In precedent works, we have used Hough transform to detect cracks defects by analyzing another type of ultrasonic images, called TOFD (Time Of Flight Diffraction). In this case, sets of parabolas appear on the image and their recognition allows the crack detection [7].

This paper describes how the Hough transform can be used on an ultrasonic image produced by non-destructive testing to detect inclusions characterised by circular forms.

The c-scan image used here displays ultrasonic waves reflected by the defect at each position of a transducer moving on the structure. In Section 2, the synthesis of this type of image is described. The application of the –6dB method to the objects detected to reduce them to their real sizes is explained in Section 3 [8]. This operation also allows us to transform the image into a binarized one. Section 4 describes how the Hough transform can be applied to detect and locate circular forms corresponding to inclusions.

II. IMAGE FORMATION

An automatic scanning system was used to move an ultrasonic focused probe step by step on a rectangular surface of the structure in a controlled manner.

At each position, an ultrasonic signal was emitted, and the reflected signal was detected and stored [9,10].

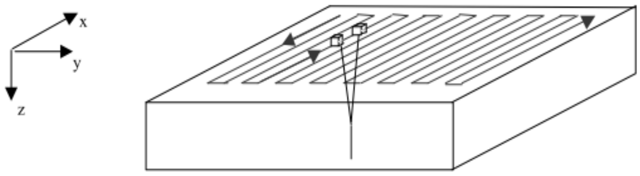


Figure 1. Displacements of the probe.

Figure 2 shows an example of the reached signal. Where appear the defect signal between surface echo and the backwall one.

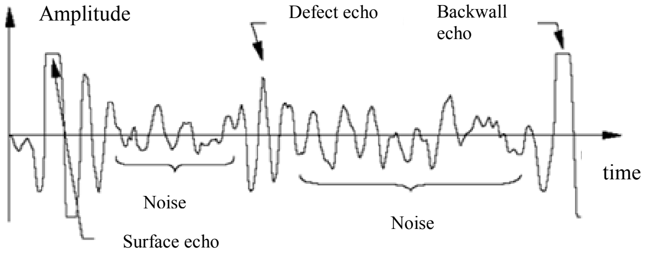


Figure 2. Example of a reflected signal.

The maximum amplitude of the echo corresponds to the value of the pixel at the corresponding coordinates of the probe. Figure 3 shows the results obtained by scanning a square area on the structure.

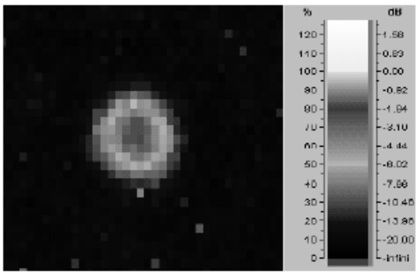


Figure 3. C-scan image containing a circular defect.

To detect small inclusions, the probes must be focused. The image used in this work was formed with measurements taken with focused transducers of 5 MHz on a Ti-Al part with steel inclusions (Figure 4).

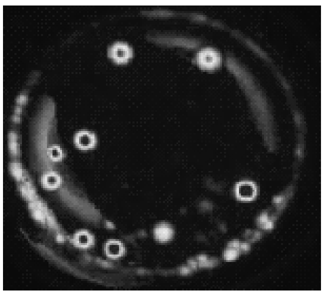


Figure 4. C-scan on a Ti-Al part with steel inclusion.

To reduce the objects in the c-scan image to their real sizes, we must take into account the surface of the ultrasonic beam. Figure 5 illustrates the principle behind the –6dB method. The probe is moved along the defect, and the distance over which the signal amplitude is above half of the maximum corresponds to the length of the defect.

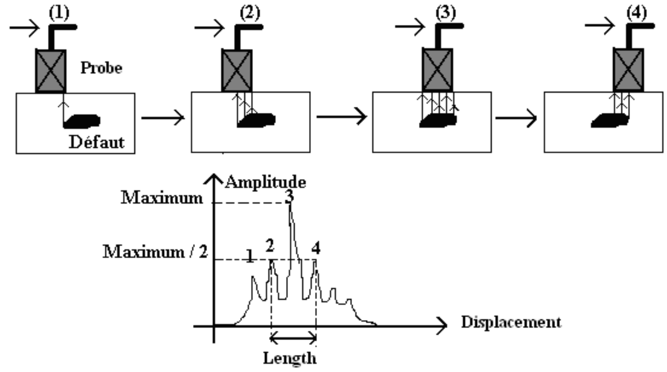
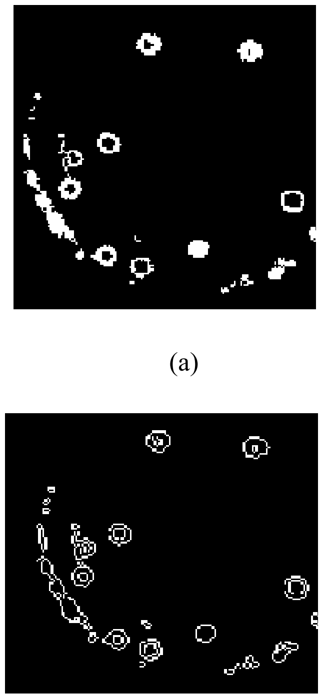


Figure 5. -6dB method for sizing defects.

Applying this method to the image in Figure 4 results in cancelling all the pixels for which the value is lower than half of the maximum signal. The remaining pixels take the value 1 to produce a binary image (Figure 6 (a)). The edges of the defects, which are sufficient for the application of the Hough transform, are then extracted, as shown in Figure 6 (b).



(a)

(b)

Figure 6. (a) Binarized image. (b) Resulting edges.

III. THE HOUGH TRANSFORM

A. *Principle of the Hough Transform*

The Hough transform was initially developed for the detection of points aligned on a straight line. More generally, it can detect more complex shapes as long as we know how to define a mathematical model for these shapes. The Hough transform consists of considering all the possible positions and orientations of the shape (for example, all the possible values for the parameters, a and b, of a straight line defined by the equation, y = ax + b, in the x-y plane). Then, for each position and orientation (defined by a particular value of the parameters, a and b), the number of contributing points in the source image is counted. In the decision step, all straight lines defined by the parameters (a,b) such that the number of contributing points in the source image is greater than a threshold are determined.

B. *Circle Hough Transform*

The Hough transform can be used to determine the parameters of a circle when the number of points that fall on the perimeter are known [11]. A circle with radius r and center (a,b) can be described by the following parametric equations:

$$x = a + r\cos(\theta) \quad (1)$$

$$y = b + r\sin(\theta) \quad (2)$$

When the angle θ sweeps through 360 degrees, the points (x,y) trace the perimeter of a circle.

If an image contains many points, some of which fall on perimeters of circles, then the job of the search program is to find parameter triplets (a,b,r) to describe each circle. The fact that the parameter space is 3D makes a direct implementation of the Hough technique more expensive in terms of both computer memory and time. In this work, a graph partitioning separates different populations of pixels [12]. Applied separately on each partition, the Hough transform in this case needs only to detect the co-ordinates (a,b) of the center; the radius is then calculated by taking into account the perimeter of the object .

C. *Application of the Hough Transforms*

For each pixel (x_i,y_i) of a given population of pixels, the Hough transform associates a circle in the Hough space with the co-ordinates (x_i,y_i). The radius was calculated previously using the length of the edges; the radius is the perimeter divided by 2π.

At the same time, the intersections of the circles are counted in an accumulator, and one is added for each cell crossed.

At the end of this process, the Hough space is analyzed by looking for the points with the maximum number of intersections. Relatives maxima correspond to the circles detected.

IV. RESULTS

Applied to the image of the edges, as shown in Figure 6, the Hough accumulator is obtained, as shown in Figure 7.

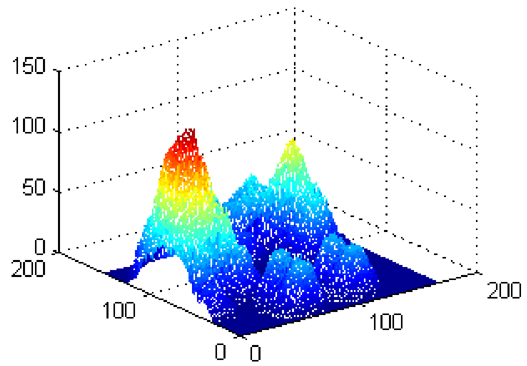


Figure 7. Hough accumulator.

The decision must take into account the highest value cell, which corresponds to the biggest inclusion. Thus, the lowest peaks are eliminated, depending on the precision needed. For this example, a threshold equal to half of the maximum peak was chosen. After detecting the coordinates of the other relative maxima, the corresponding circles were presented on the same image (Figure 8).

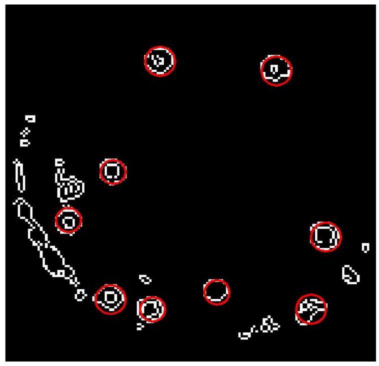


Figure 8. Detected inclusions.

V. CONCLUSION

In this work, the Hough Transform, a classical tool for pattern recognition, was applied to automatically detect inclusions in a structure, which are characterized by their circular forms.

Graph partitioning, which involves separating different populations of pixels, allowed us to leave the radius out of the parameters to consider. With a reduction to two parameters (the coordinates of the centre), the Hough space shows most of circles corresponding to inclusions. The overall result is promising.

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