Estimation of Debonded Area in Bearing Babbitt Metal by C-Scan Method

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Abstract. The debonding area which had a complex boundary was imaged with a immersion technique, and the acoustic image was compared with the actual area. The amplitude information from focused transducer can discriminate between a defected boundary area and a sound interface of dissimilar metal. The shape of irregular boundary and area was processed by a histogram equalization, after that, through the clustering and labelling, it makes the defect area cleared. . Each pixel has ultrasonic intensity rate and represents a position data. The estimation error in measuring debonding area was within 4% by image processing technique. The validity of this immersion method and image equalizing technique has been done for the inspection of power plant turbine's thrust bearings.

Introduction

Turbine bearings in power plants are used to support the heavy turbine in high speed rotations. They are a crucial component in the power plant and their reliability and safety must be ensured. If the turbine bearing have the serious defects, such as a large debonding area, vibrations can be resulted in operation and jeopardize the turbine. Periodic inspections of the interface between the babbitt and base metal using the ultrasonic pulse echo method should be performed, according to a plan of in-service-inspection.(ISI) Currently, the C-scan method, which takes into consideration the amplitude of the reflected echo from the interface layer in compared with the loss of the back wall echo, is widely used to ascertain measurement of the debonding area. To assure the area of debonding, we should get the edge of defects and calculate pixels within them. To enhance an precise area, the scan resolution and scanned pixels should be specified in details.

PC based ultrasonic immersion equipment of C-Scan

PC based ultrasonic immersing technique and C-Scan method are the terms used to describe imaging process at different magnification and frequencies. A typical ultrasonic C-Scan equipment system is shown at schematic diagram in Fig. 1[1]. And the field set up is in Fig.2. Ultrasonic immersion technique process forms the images by acquiring spatially correlated measurements of the interaction of high-frequency sound waves with materials. This is specially true, since almost all commercial ultrasonic imaging systems use transducers producing focused beams and can display magnified high-resolution images.
Ultrasonic C-Scan imaging was developed largely by the ultrasonic nondestructive testing industry. Over a 50-year period, better and better broadband transducers, electronics, and

scanners were developed for operation at progressively higher frequencies, now ranging from 1.0 to 100MHz.

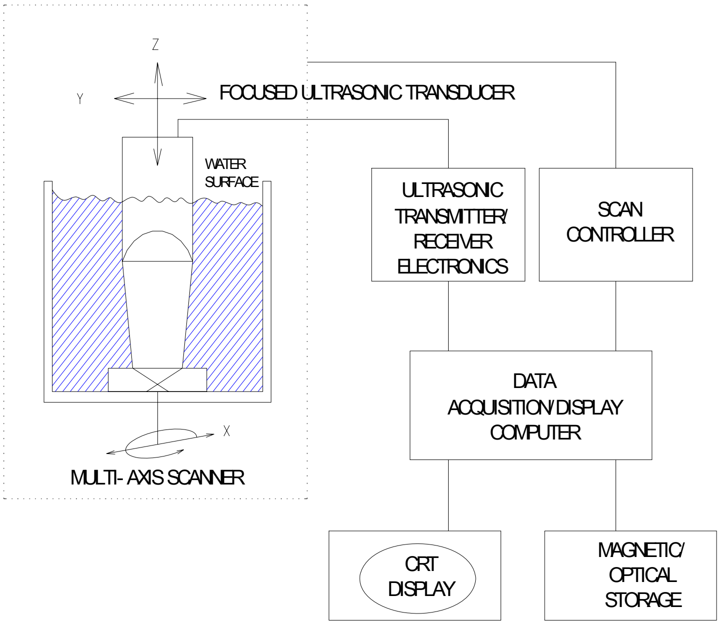


Fig. 1 Schematic Diagram of C-Scan System

Fig. 2 Field set up of C-Scan equipment

Histogram equalization[2]

The C-Scan ultrasonic images have a limited range of colors, or are lacking of contrast. Enhancing the image can allow not only improved detail, but also machine vision operations such as clustering. For instance, refer to the example images as below (Fig.3, Fig.4). Now

Fig.3 image is extremely gray, it lacks detail since the range of colors seems limited to mid-gray levels. We can verify this by looking at the image's histogram. A histogram of image is used to display the distribution of gray-values in the image. An 8-bit image has 256 gray-level raging from absolute black and to absolute white. The intensity mapping is a nonlinear operation, it involves pointwise mapping of intensity value to another globally. Often the foreground and background intensities are quite close and it is difficult to differentiate them, hence there is a need to separate them spectrally. At other times, details are lost because a large percentage of pixel have a similar value. By re-scaling these values, the dynamic range can be increased.[3] A histogram simply plots the frequency at which gray level occurs from 0(black) to 255(white). Here you can see how majority of the gray levels in the image can bunch between about 120 and 210(Fig. 3).
So given this data, with histogram equalization can expand the colors the image to fill the entire 0-255 spectrum (Fig. 4). To do this, we need to calculate the cumulative frequencies within the image. If we assume the cumulative frequency is stored in an array, our histogram equalization can be written as:[4]

Alpha = 255/numPixels --(1)

For each pixel

g(x,y) = cumulativeFrequency[f(x,y)]*alpha ---------------------------(2)

Histogram equalization is thus achieved by choosing the level transformation function as the integral of the probability density, that is, as the (cumulative) distribution function.[5] Image quality can be enhanced by modifying its histogram. Generally, the output image has higher contrast and better subjective quality than the original image. However, it has to be noted that histogram equalization tends also to amplify noise.[6]

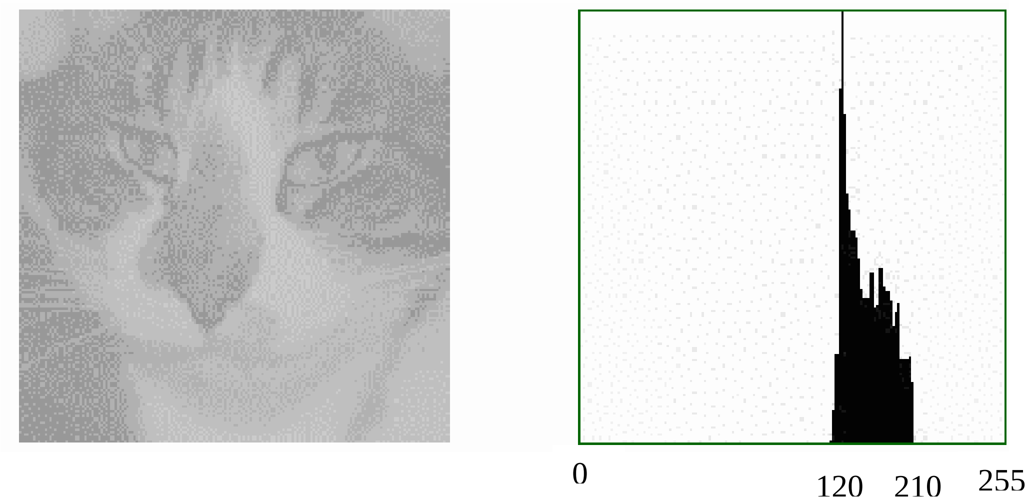


Fig. 3. Before histogram equalization

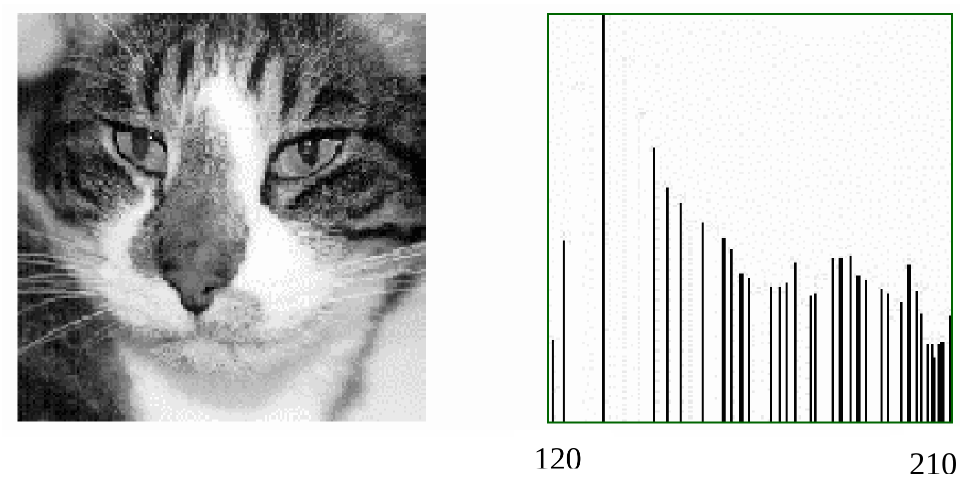


Fig. 4. After histogram equalization

Image clustering

From the clustering program, we can handle the histogram equalization and clustering size. Using the minimum clustering size, it can make neighboring pixels one unit (Fig. 5)[7].

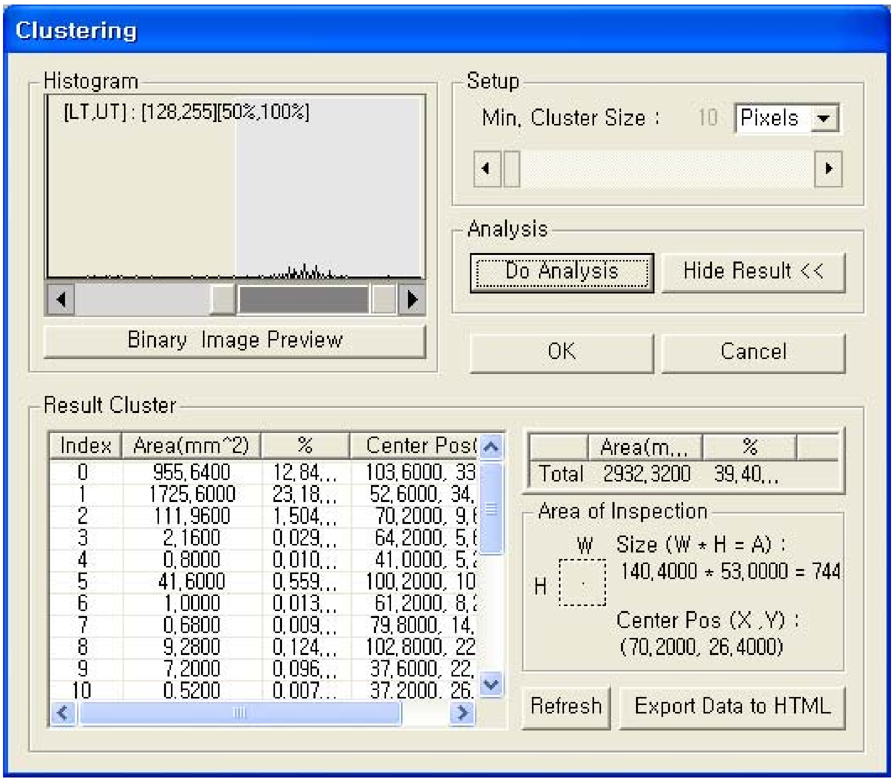


Fig. 5 Image processing window of clustering

We have treated enhanced ultrasonic C-Scan images automatically by clustering method. Clustering method involves turning a color or grayscale into a 1-bit binary image. It has been done by allocating every pixels in the black or white image, depending on its value. The pivotal value is used to decide whether any given pixel is to be black or white in the threshold. With threshold and clustering, we can make the specific image into a boundary area. Each boundary area has its own label number. The scanner resolution and the numbers of pixels turn into area. For example, Fig. 6 shows the C-Scan image by clustering and labeling data of journal bearing specimen. All artificial defects are machined flat bottom hole and each diameters are 16mm, 14mm, 12mm, 10mm, 8mm, 6mm. Clustering and labeling process is performed first four defects within dotted square box. The transducer is focused 15Mhz and 6mm diameter element size, and focal length is 25mm long.

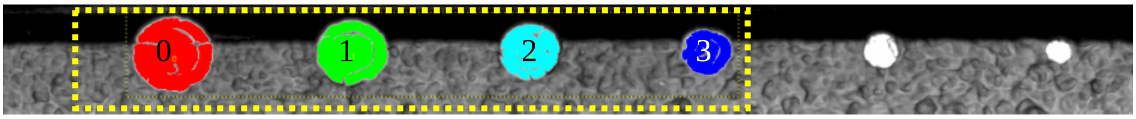


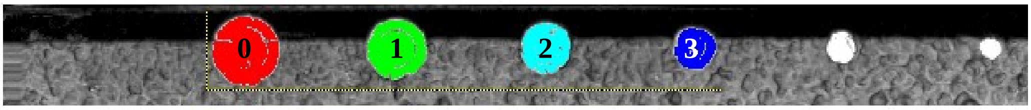
Fig. 6 Clustering and labeling of defect data

Estimating of defect area

After performing the clustering and labeling procedure, all labeled region turn into area automatically according to below method.

Area = Scanner resolution × count of pixels within labeled region.-----(3)

The results show each labeled area and we have confirmed that the difference between flat bottom's area and measured area is within 4%. We can assume that the error comes from missed clustering pixel and machining errors (Fig. 7).



ScanAnalysis2 - Clustered Result Data

Area of Inspection
Width(mm) : 134.7135
Height(mm) : 18.6019
Area(W*H mm^2) : 2505.9212

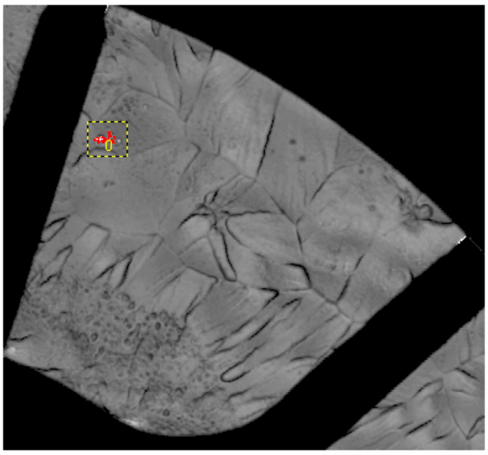
Total Clustered Area : 21.688879%(543.5062 mm^2)

Index	Area (mm^2)	Percentage	x (mm)	y (mm)
0	203.3732	8.1157%	63.4563	10.9511
1	154.2909	6.1571%	102.9103	10.5011
2	109.9795	4.3888%	141.9142	10.2010
3	75.8627	3.0273%	180.9181	10.3510

Fig. 7 Clustered result Data

Field test

During the overhaul of Bo-ryong Thermal power plant(Bo-ryong TPP) #6, October 18, 2005, we had performed bearing test by C-Scan method and got data as below Fig. 8. The result shows us entire inspected region and measured debonding area. Also it had not been able to detected correctly by manual contact ultrasonic test. From the result, we could provide directional report to customer with image file and deboning area. After then we can share common sense of test result.



ScanAnalysis1 - Clustered Result Data

Area of Inspection
Width(mm) : 16.0000
Height(mm) : 14.0000
Area(W*H mm^2) : 224.0000

Total Clustered Area : 7.812500%(17.5000 mm^2)

Index	Area (mm^2)	Percentage	x (mm)	y (mm)
0	17.5000	7.8125%	41.0000	53.5000

Fig. 8 Results of Babbitt metal C-Scan test

Result

Ultrasonic immersion test usually can become the C-Scan method. Compared with the contact method, the immersion test of C-Scan technique can get high resolution and precise test results. Especially in using turbine bearing's babbitt metal, this technique will be the best skill and image processing technique. Histogram equalization and clustering provide us with the reliable data of debonding area in turbine bearing.

References

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