International Journal of Electrical and Computer Engineering (IJECE)
Vol. 6, No. 1, February 2016, pp. 160~166
ISSN: 2088-8708, DOI: 10.11591/ijece.v6i1.9343

Defect Detection in Ceramic Images Using Sigma Edge Information and Contour Tracking Method

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Article Info

Article history:

Received Aug 18, 2015
Revised Nov 9, 2015
Accepted Nov 27, 2015

Keyword:

Ceramic image
Contour tracking method
Defect detection
Non-destructive testing
Sigma edge information

ABSTRACT

In this paper, we suggest a method of detecting defects by applying Hough transform and least squares on ceramic images obtained from non-destructive testing. In the ceramic images obtained from non-destructive testing, the background area, where the defect does not exist, commonly shows gradual change of luminosity in vertical direction. In order to extract the background area which is going to be used in the detection of defects, Hough transform is performed to rotate the ceramic image in a way that the direction of overall luminosity change lies in the vertical direction as much as possible. Least square is then applied on the rotated image to approximate the contrast value of the background area. The extracted background area is used for extracting defects from the ceramic images. In this paper we applied this method on ceramic images acquired from non-destructive testing. It was confirmed that extracted background area could be effectively applied for searching the section where the defect exists and detecting the defect.

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1. INTRODUCTION

Non-destructive testing is a special method by which the status, characteristics, internal structure and existence of flaw can be analyzed without affecting the original shape and function of the material or the product. Non-destructive testing includes magnetic particle testing, liquid penetrant testing, electromagnetic induction testing, radiographic testing, ultrasonic testing, leak testing, visual inspection, acoustic emission testing, infrared testing, deformation testing and more. For non-destructive testing of ceramic material liquid penetrant testing is used [1]. In liquid penetrant testing, penetrant solution is firstly spread on the surface of the specimen. Overflowing penetrant solution is removed and developer is applied. The existence of a flaw on the surface and its location can be confirmed by detecting the exuding penetrant solution which was absorbed into the flaw in the surface of the specimen [2].

Non-destructive testing is performed to enhance the reliability of the product, improve manufacturing technology and reduce manufacturing costs. Thorough quality control enhances the reliability of the product, which allows the users to trust and use them with ease. Also applying non-destructive testing during the manufacturing stage would enable defective products to go under control at appropriate moment, saving time and resources. However, final confirmation of products or materials that underwent non-destructive testing is done by visual inspection. Since visual inspection is a manual process, it requires a lot of time and manpower. In addition, there would be differences among the test results during visual inspection due to intervention of inspectors' subjectivity. Thus, product becomes less reliable.

Ceramic materials that have high thermal resistance, low density, and high degree of hardness are a traditional NDT application area. However, cracks, spiracles, and other foreign substances that form various defects on the surface have negative influence on its reliability and hardness [3]. Thus, we need an effective method to detect them from ceramic image. Therefore, this research on automatically extracting the defects from the images acquired from non-destructive testing would save time and manpower, as well as enhancing the reliability of the test, eventually improving the quality of the test.

2. THE PROPOSED METHOD FOR EXTRACTING DEFECTS FROM CERIMIC IMAGES

Conventional method to extract defects from ceramic images[4] includes two processes, classifying the image into 9 clusters using the contrast values of the image and extracting candidate objects showing defects using each cluster's contrast values. However this conventional method has a problem that during the process of extracting 8mm image, due to low contrast value of defect area, noise area is extracted instead of the defect area. In this paper, in order to solve this problem we extract the defect area by detecting horizontal and vertical edges, then correcting the boundary of the defect area by applying contour tracking method to the detected edges. Process of analyzing defects from ultrasound images is shown in Figure 1.

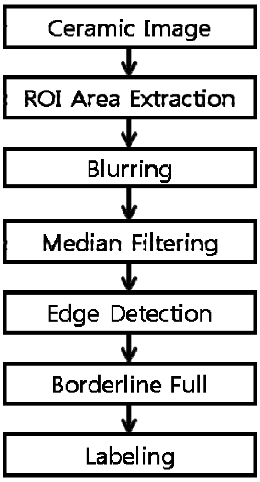


Figure 1. Process of extracting defects from ceramic images

Using the fact that defect area show brighter contrast than other areas in ceramic images, ROI area is extracted. Fine noise is removed by applying Blurring method to extracted ROI area. Then Prewitt mask method is applied to the ROI area for detecting vertical and horizontal edges. The detected edges are applied with contour tracking method to correct the boundary of defect area. Blob Labeling method is applied to the corrected image to extract the final defect area.

Defect area shows brighter contrast than other areas in ceramic images as shown in Figure 2(a). Using this fact, areas with lower contrast value than defect area was considered as noise and removed. The result is shown in Figure 2(b).

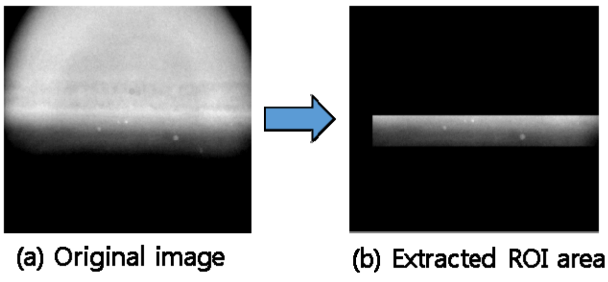
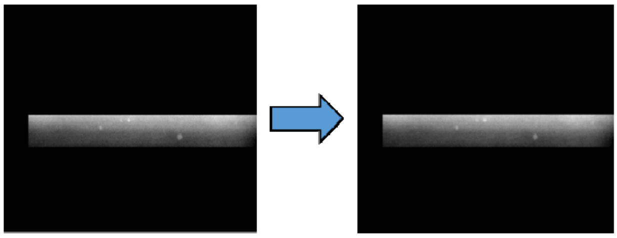


Figure 2. Extracted ROI area

Blurring method is a method used to remove fine noise area from extracted ROI area by blurring the background or the focus. Figure 3(a) is extracted ROI area whereas Figure 3(b) is extracted ROI area applied with Blurring method.



(a) Extracted ROI area (b) Blurring

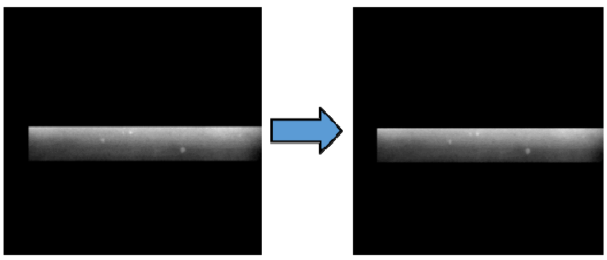
Figure 3. Result of applying blurring method

Figure 4 shows a 3x3 mask in which new value for a specific pixel is determined as the average of surrounding pixels' values. The values in the 3x3 mask in Figure 4 is set up to make the weight of the mask to be 1 for blurring.

1/16	1/8	1/16
1/8	1/4	1/8
1/16	1/8	1/16

Figure 4. Weight mask for blurring

While conserving edges in fine noise removed ROI area, impulse noise is removed by applying Median filtering method which is used to remove remaining noise in the ROI area. Figure 5(a) shows the result of applying Blurring method. Figure 5(b) shows the result of applying Median filtering method on fine nois removed ROI area.



(a) Blurring (b) Median filtering

Figure 5. Median filtering

In noise removed ROI area, part where the brightness shows dramatic change is considered to be the slope. The edge is detected by using the fact that first derivative value of the slope is very large or small. Equation (1) shows the primary differential operation.

$$\Delta f = [G_x, G_y] = \left[\frac{\delta f}{\delta x}, \frac{\delta f}{\delta y}\right] \quad (1)$$

In equation (1) vector(Δf) is the slope of image $f(x,y)$. G_x exists for differentiation in horizontal direction and thus vertical edge corresponding to column is detected. $G_y$exists for differentiation in vertical direction and thus horizontal edge corresponding to row is detected. Therefore, G_x is a column detector and $G_y$is a row detector. By applying two detectors simultaneously with gradient vector (Δf), edges can be clearly detected [5]. In this paper among various primary differential masks, we use Prewitt mask method which is less sensitive than Sobel mask in detecting change of brightness. Figure 6 shows Prewitt mask.

-1	0	1
-1	0	1
-1	0	1

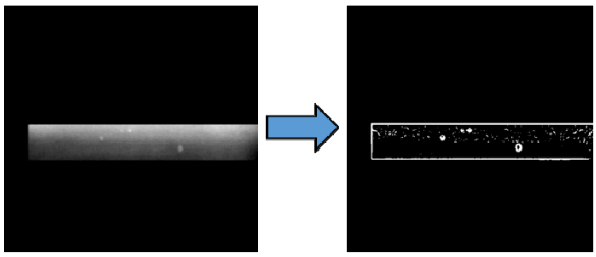
(a) G_x mask

-1	-1	-1
0	0	0
1	1	1

(b) G_y mask

Figure 6. Prewitt mask

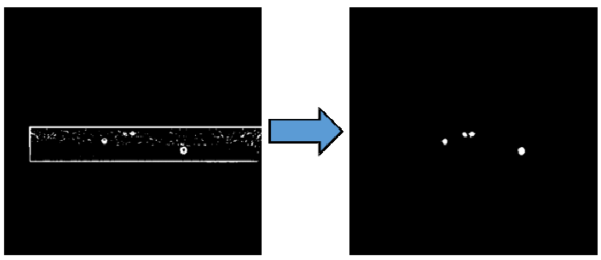
Figure 7(a) shows the result of applying Median filtering method [6] and Figure 7(b) shows the result of applying Prewitt mask to noise removed ROI area.



(a) Median filtering (b) Prewitt masking

Figure 7. Result of applying Prewitt mask to ROI area

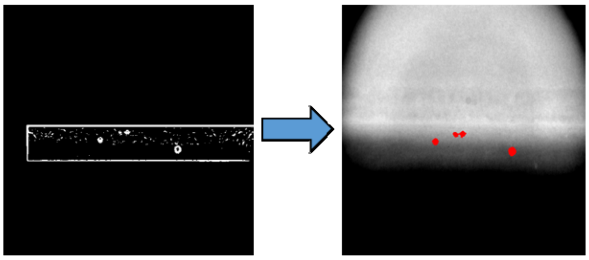
Objects are extracted by applying contour tracking method to detected edges [7]. Among the extracted objects with bright contrast, objects with smaller size than the average size is considered unnecessary and removed. Objects with average size is considered candidate defect area and its boundary is corrected. Figure 8(a) is the result of applying Prewitt mask and Figure 8(b) shows the result of correcting the boundary of defect area in Prewitt mask.



(a) Prewitt masking (b) Corrected boundary of defect area

Figure 8. Application of contour tracking mehod and correction of defect area boundary

Blob Labeling is applied to ROI area, in which the boundary of the defect area is corrected, to extract the final defect area. Figure 9(a) shows the image with corrected boundary of defect area. Figure 9(b) shows the final defect area acquired from the boundary corrected image by applying Blob Labeling method.



(a) Prewitt masking (b) Blob labeling method

Figure 9. Detection of defect

3. EXPERIMENT AND RESULT ANALYSES

In this paper, proposed method to detect the defect area was implemented by Visual Studio 2010 C# on PC equipped with Pentium(R) Dual-Core CPU T4200 2.00GB RAM. 1360x1024 size images acquired from 8mm and 10mm obtained from different non-destructive tests were used as specimens for the experiment. The result of detecting defects using the method proposed in this paper is shown in Figure 10.

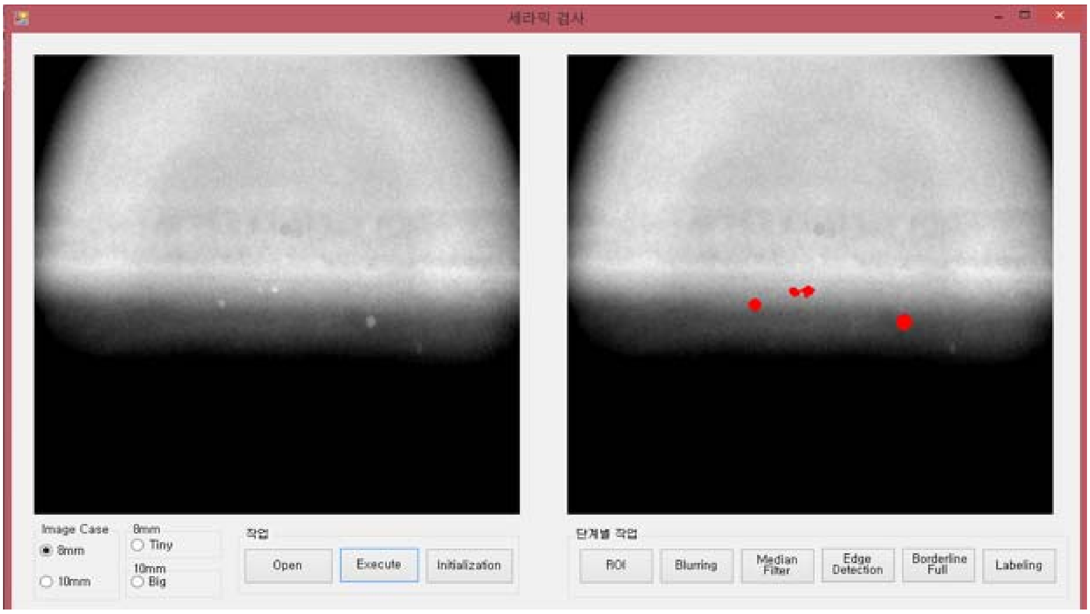


Figure 10. The proposed process of detecting defects

Figure 11(a) shows the result of extracting candidate defect object by applying the conventional method [4]. Figure 11(b) shows the result of extracting candidate defect object by applying the method suggested in this paper.

As shown in Figure 11, conventional method of detecting defects in ceramic images [3] applied K-means algorithm to extract candidate defect areas based on clusters' contrast data. However during the clustering process defect area was clustered with noise area. Thus the defect area could not be extracted. However, method proposed in this paper detect defect area by applying contour tracking method on edge data analyzed from ROI area. Table 1 shows the number of images that were successful in detecting defects among 12 ceramic images by applying proposed method.

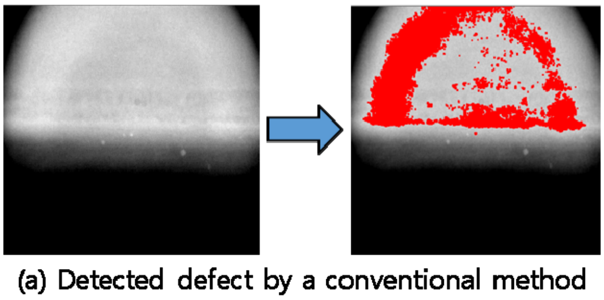


Figure 11. Comparison of defect detection methods

Table 1. Number of success and failure of defect detection

Type	Success	Failure
8mm	5/9	4/9
10mm	3.3	0/3

Figure 12 shows two examples of failure in detecting defect while applying the proposed method.In some 8mm ceramic images, object size of defect area and noise area was similar. In these cases noise areas were extracted as defect areas.

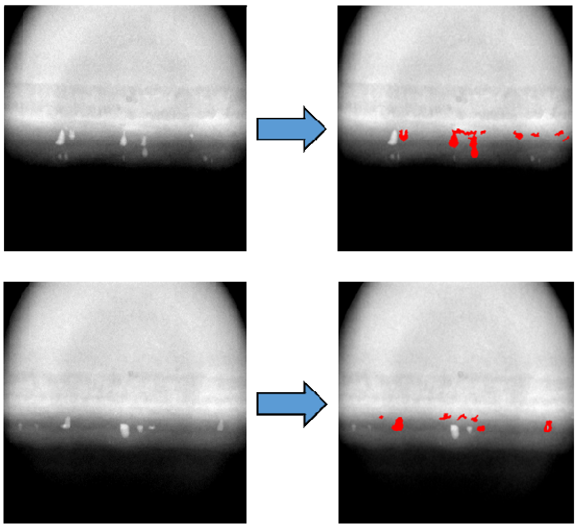


Figure 12. Two Examples of failure in detecting defect

4. CONCLUSION

In this paper, we proposed a method to detect defects in ceramic images acquired from non-destructive testing. Using the fact that defect area show brighter contrast than other areas in ceramic images, ROI area is extracted. Fine noise is removed by applying Blurring method to extracted ROI area. Median filtering method is applied to remove remaining noise in fine noise removed ROI area. Then Prewitt mask method is applied to the ROI area for detecting vertical and horizontal edges. The detected edges are applied with contour tracking method to correct the boundary of defect area. Blob Labeling method is applied to the corrected image to extract the final defect area. Future research would be focused on solving the problem of being unable to extract defect areas from some 8mm, 11mm, 16mm, 22mm ceramic images. To solve this problem, defect area extraction performance would be enhanced by applying Fuzzy inference method to analyze defects' various morphological features.

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