Flaw detection in radiographic weld images using morphological approach

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***Abstract*—Evaluation of radiographic weld images to detect flaws and their types in classical method needs an expert. It's slow, subjective and sometimes hesitant even for an expert. It's desired to have an automated/semi-automated system for evaluating radiographic weld images. It's possible to have a semi-automated system due to manipulating radiographic weld images with the help of image processing tools. This paper includes an implementation of RS Anand and P Kumar's studies about flaw detection in radiographic weld images using morphological approach.**

Keywords*—*radiographic images; flaw detection; edge detection; dilation; erosion; closing.

I. Introduction

It's desired to join materials flawlessly in welding processes. But sometimes weldments may include some flaws due to different reasons. These flaws are seen in the form of gaps, cracks or pores and cavities. Common weld defects are lack of fusion, lack of penetration or excess penetration, porosity, inclusions, cracking, undercut, lamellar tearing etc. Any of these flaws may cause unexpected failure below the design load or in the case of cyclic loading, failure after fewer cycles than predicted [1].

Since failure because of welding flaws are mostly cause brittle fracture, it's a necessity to keep under control whole welding processes including pre-welding, during-welding and post-welding periods to prevent a failure caused by a welding flaw. Pre-welding is the period that welder/manufacturer provides some quality documents to prove that weld/welder/manufacturer is competent to execute the weldment and its mechanical properties. During-welding period is mostly handled by a welder but sometimes by an operator in robot welding. It's the period that most of welding flaws happen. Post-welding is the period that some tests are made.

We can group post-welding tests into two group as destructive testing (DT) and non-destructive testing (NDT) broadly. Destructive tests are accurate but it's not proper to damage a welded material because of it would be lose its function. This method applies to some specimen to have an idea about weld's mechanical properties but in general NDTs made to welded joints to prove their flawlessly. Common NDT methods are radiographic testing, ultrasonic testing, liquid penetrant testing, magnetic particle testing, eddy-current testing etc.

Radiographic testing is widely used NDT method for imaging weldments to detect flaws and locate flaws in them. In radiographic test method, inhomogeneity of the weldments cause variation in intensity in radiographic weld images. Lines seen in these radiographic images correspond to different types of flaws such as lack of fusion, lack of penetration, porosities, inclusions, cracks, undercuts etc. The thickness of material in welding process, weld type, weld position, etc. determines radiographic testing methods such as exposure time, distance and angle between energy source and material which plays an important role in image quality. Even it's possible to detect flaws during-welding process on hot welds, radiographic testing is mostly used as post-welding inspection method.

Radiographic testing is also preferred because of radiographic images can kept as quality records for years. A human expert analyses these images and determines if weld contains any flaws and he/she also determines flaw type, flaw location, flaw dimensions etc. It's expected an expert should be educated in radiographic testing and he/she must have some certifications in according to quality code such as ISO, ASNT, AWS, etc. Besides, expert needs to utilize his/her previous experiences to have accurate results when analyzing radiographic images. However, results still depends on expert's mental state and results for the same image varying from expert to expert [2].

It's desirable to develop some form of computer aided system to automatize and/or semi-automatize to radiographic image analyzing. Image processing plays an important role to manipulate radiographic images to have a more understandable and easier to read radiographic images. With the help of image processing, a semi-automated system consisted of manipulated images can be evaluated easier, faster and more accurate by an expert and/or non-expert.

There are several approaches making inspections on radiographic images using different image processing and computer vision methods such as fuzzy clustering methods, multiclass methods using geometric texture features, neural networks, morphological watershed segmentation technique and so on [3-5]. In this paper, implementation of flaw detection in radiographic weld images using morphological approach discussed [6].

II. METHOD

Segmentation is necessary to detect flaws in weld images. To segment weld images, a boundary-based approach used. Method simply involves two pieces. First we find edges in radiographic image and then apply morphological operations dilation and erosion respectively.

A. Edge Detection

There are many edge detection methods which can be used for detect edges in images [7,8]. Canny edge detection is widely used method for detecting edges with very good signal to noise ratio [9]. Aim in using Canny operator is catching all important edges. Canny edge detection presents downgrade multiple edges to a single edge. Canny edge detection steps listed below respectively.

- Convolution with the Gaussian filter
- Finding the intensity gradient of the image
- Non-maximum suppression
- Double threshold
- Edge tracking by hysteresis

Fig. 1 Original image of incomplete penetration. [10]

MathWorks MATLAB's "edge" function used to obtain edge detected images [11]. Double threshold is the key point for catching all important edges and ignore others. Several assumptions are applied to detect threshold values adaptively. For higher threshold values Otsu, k-mean etc. and for low threshold their factors applied. Unfortunately, none of these assumptions succeeded to signalize proper edges for all images. Consequently, threshold values given by hand with trial and error.

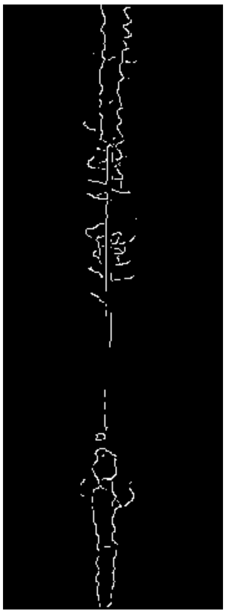


Fig. 2 Edge detected image of lack of penetration.

B. Morphological Processing

Output image is in the form of contours has discontinuities due to crack edges. First dilation and then eroding operations applied to the output image. [12-13] This process also known as closing.

For dilation operation MathWorks MATLAB's "imdilate" function used from its image processing toolbox [14].

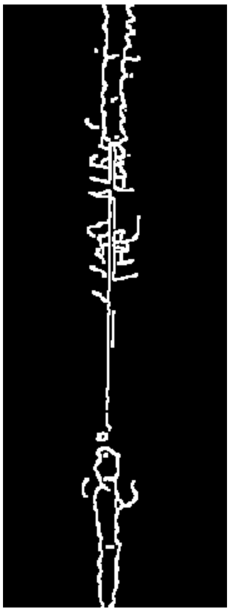


Fig. 3 Dilated image of incomplete penetration.

For erosion operation MathWorks MATLAB's "imerode" function used from its image processing toolbox [15].

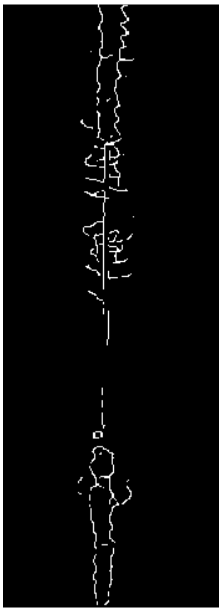


Fig. 4 Eroded image of incomplete penetration.

C. Superimposition

After dilation and erosion operations had a closed binary image. For all white pixels in this binary image we manipulate the original image as making these pixels white. Superimposed image gives us a much easier to read image comparing with the original image.

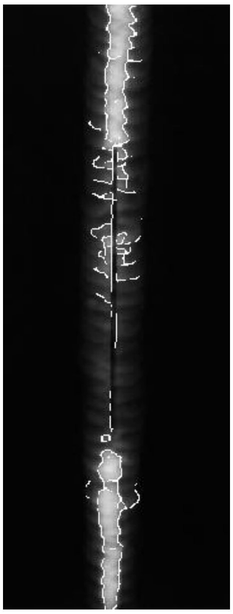


Fig. 5 Superimposed image of incomplete penetration.

III. RESULTS

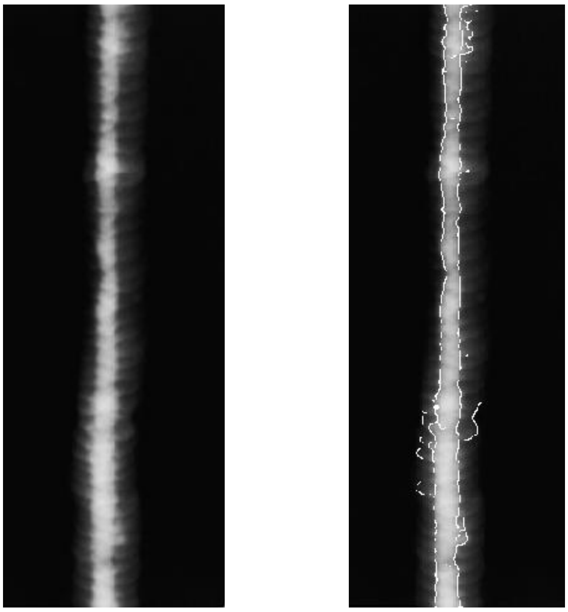
In RS Anand and P Kumar's work, type of flaws and their segmented image appearances are shown in Table 1.

TABLE I. CATEGORY OF DEFECTS IN SEGMENTED RADIOGRAPHIC IMAGES

No.	***Segmented image appearance***	***Type of flaw***
1	Thin line along the edge of weld. Line may be wavy and diffuse depending upon the orientation of defect with respect to the X-ray beam	Lack of fusion
2	Edge line in the middle of weld	Incomplete penetration
3	Line more or less interrupted, parallel to the edges of weld	Slag line
4	Irregular contour of any shape and size	Slag inclusion
5	Fine line, straight or wandering in direction	Cracks
6	Line sometimes broad and diffused along the edge of weld	Undercuts
7	Rounded contours having dark shadows	Porosity (gas cavities)

According to this categorization there are several images processed. Some of them are shown in below. It's possible to increment of number of these categories in radiographic testing. But this seven are sufficient for most of welding processes.

Results according to RS Anand and P Kumar's categorization are accurate. Nevertheless, even in real life some radiographic images are fuzzy to decide its flaw type. In these type of defects results may be specious.

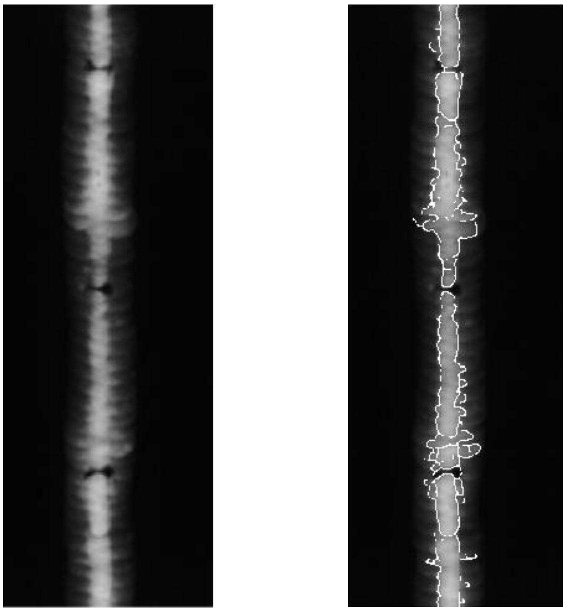


(a) (b)

Fig. 6

(a) Original image of undertcut defects

(b) Segmented image of undercut defects

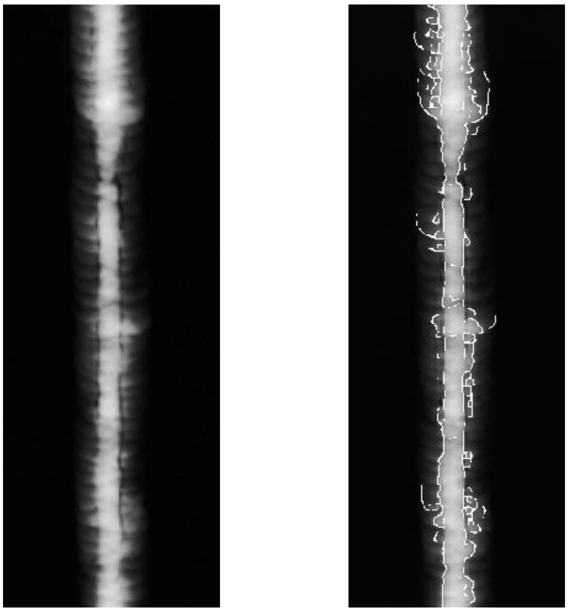


(a) (b)

Fig. 7

(a) Original image of slag inclusion defects

(b) Segmented image of slag inclusion defects

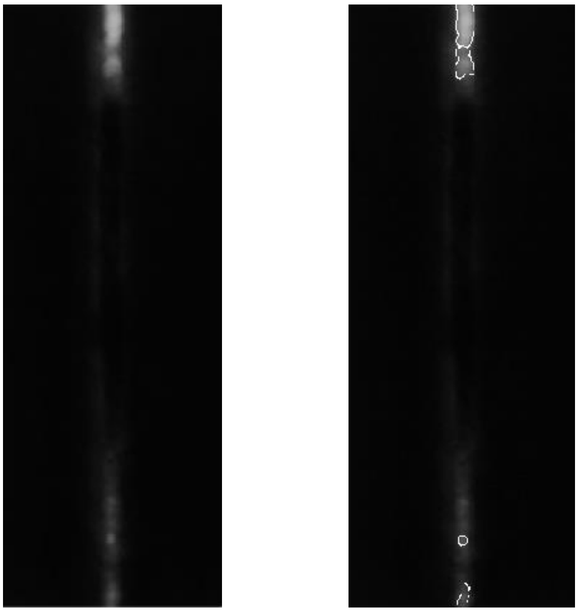


(a) (b)

Fig. 7

(a) Original image of slag line defects

(b) Segmented image of slag line defects

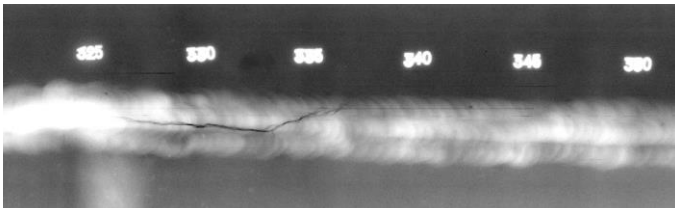


(a) (b)

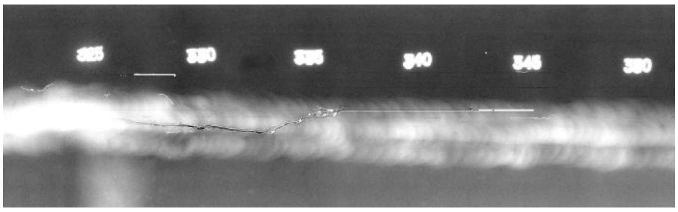
Fig. 7

(a) Original image of gas cavities defects

(b) Segmented image of gas cavities defects



(a)



(b)

Fig. 8

(a) Original image of crack

(b) Segmented image of crack

IV. CONCLUSION

RS Anand and P Kumar’s flaw detection in radiographic weld images using morphological approach paper implemented successfully. Method simply divided into three parts: First, Canny edge detector applied to original radiographic weld image. Second, morphological operations called dilation and erosion applied to the output image respectively. Finally, with white pixels of output binary image superimposed with original image.

After these image processing operations output images evaluated in according to Table 1. Many images gathered from internet. Some are from the paper. All outputs are correct. Even some images are still fuzzy to decide it's helpful for the future quality control of welding processes.

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