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Detection of Cracks in Friction Stir Weld of AA7075-AA2024 Using Morphological Edge Based Segmentation Techniques

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Abstract

Friction stir welding (FSW) is a new and promising welding process that can produce low-cost and high-quality joints of heat-treatable aluminum alloys because it does not need consumable filler materials and can eliminate some welding defects. Even though the friction stir welded metals are also subjected to fracture. To investigate the fracture it is necessary to find the defect sites. Existing methods of finding the defect sites are expensive one. The purpose of this paper is to find the non-destructive method to detect defects in welding with fewer expenses. The technique used in this experimental is that a web camera is rotated at 360 degree over the surface of the work metal and the captured pictures are analyzed using MATLAB to find the defects along with histogram diagrams. The experimental results shows that other testing processes like XRD, ultra sonic inspection and other NDT methods are more time consuming and expendable one. But this present method is not yet used or practiced. It is non expendable one and can be used to save time and money.
Keywords: Friction Stir Welding, MAT LAB, Cracks, clustering, thresholding, Otsu's method, k- clustering, defects.

1. Introduction

The present world is the speed of light to reach the innovative ideas and being dependent on the care of expenditure. Hence many kinds of non expendable ideas in manufacturing sector has been in circulation since last two decades and one of which is FSW.

In recent times, focus has been on developing fast, efficient processes that are environment friendly to join two dissimilar materials. The spotlight has been turned on Friction stir welding as a joining technology capable of providing welds that do not have defects normally associated with fusion welding processes [1-3]. Friction stir welding (FSW) is a fairly recent technique that utilizes a non consumable rotating welding tool to generate frictional heat and plastic deformation at the welding location, thereby affecting the formation of a joint while the material is in the solid state.

Figure.1 shows the schematic drawing of friction stir welding representing all the relevant parameters of the process.

The principal advantages of FSW, being a solid-state process they have low distortion, absence of melt-related defects and high joint strength, even in those alloys that are considered non weld able by conventional techniques. Furthermore, friction stir welded joints are characterized by the absence of filler-induced problems/defects, since the technique requires no filler, and by the low hydrogen contents in the joints, an important consideration in welding steels and other alloys susceptible to hydrogen damage [4-6].

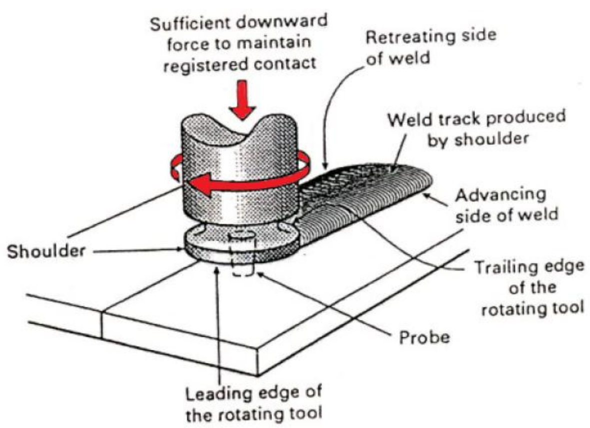

Figure 1. Schematic illustration of Friction Stir Welding

FSW can be used to produce butt, corner, lap, T, spot, fillet and hem joints, as well as to weld hollow objects, such as tanks and tubes / pipes, stock with different thicknesses, tapered sections and parts with three dimensional contours.

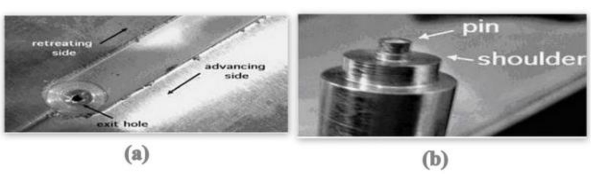

Figure.2. (a) Mode of weld (b) Tool profile for FSW

Figure.2 (a) gives the idea of advancing and retreating sides in the traverse direction of welding. The AS is the side where the velocity vectors of tool rotation and traverse direction are similar and the side where the velocity vectors are opposite is referred as RS. Figure.2 (b) shows the tool with threaded cylindrical nib or probe pin.

The objective of this paper is about the inspection machined components with non expendable methods. The various testing methods includes destructive and non destructive are expendable at present scenario. Thus technique is one of among which, but non expendable one and user friendly.

In this technique the crack in weld boundaries are find out by applying the canny operator [7] after selecting an appropriate threshold value. The boundaries are then fixed using a morphological image processing approach i.e. dilating few similar boundaries and eroding some irrelevant boundaries decided on the basis of pixel characteristics. The cracks detected by this method are categorized according to their properties. This method gives excellent outcome for materials with contrast between the weld and the plate, in case of Incomplete penetration , Lack of Fusion are identified. Weaving Faults are identified very clearly. Slag lines are identified. many extra edges are also obtained which points the error in illumination when image is captured. Some information regarding Lack of Fusion is missing. In case of Weaving Fault some information is missing at the corner of the image.

The defects can be detected by various techniques. One of the well known Techniques for detection of defect is segmentation. Segmentation is a process in which regions or features sharing similar characteristics are identified and grouped together. Image segmentation is based on thresholding, clustering, edge detection, region detection or combinations of any of these techniques. By reviewing related research literature, It found that segmentation algorithms of thresholding, clustering and edge detection could be applied in welding detection [8]. Therefore, thresholding, clustering and edge detection are chosen to do the further application research. According to Jawad Nagi et al and Syed Khaleel Ahmed et al, the system was evaluated in MATLAB using an image database of 25 face images, containing five subjects and each subject having 5 images with different facial expressions. After training for approximately 850 epochs the system achieved a recognition rate of 81.36% for 10 consecutive trials. For this research work it is collected as three testing images from every category, especially in pore, crack, incomplete penetration and incomplete fusion. Procedure followed as Applying thresholding, clustering and edge detection to segment three groups of sampling variable images based on image processing toolbox MATLAB. Throughout subjective evaluation, we choose the representative algorithm of these three methods of image segmentation, histogram and thresholding. If the histogram of an image includes some peaks; we can separate it into a number of modes. Each mode is expected to correspond to a region, and there exists a threshold at the valley between any two adjacent modes. The midpoint method finds an appropriate threshold value in an iterative fashion.

1.1. Segmentation by thresholding:

Thresholding is the simplest segmentation method. In the technique of thresholding, the pixels are partitioned depending on their intensity value.

Global thresholding, using an appropriate threshold T is written as:

$$g(x,y) = \begin{cases} 1, & if\ f(x,y) > T \\ 0, & if\ f(x,y) \le T \end{cases}$$

In Variable thresholding, if T can change over the image, there are two cases:

(i) Local or regional thresholding, if T depends on a neighborhood of (x,y)

(ii) adaptive thresholding, if T is a function of (x,y).

Multiple thresholding:

$$g(x,y) = \begin{cases} a, & if \quad f(x,y) > T_2 \\ b, & if \quad T_1 < f(x,y) \le T_2 \\ c, & if \quad f(x,y) \le T_1 \end{cases}$$

(2)

Global Thresholding algorithm:

1. Initial estimate of T
2. Segmentation using T:
   - G1, pixels brighter than T;
   - G2, pixels darker than (or equal to) T.
3. Computation of the average intensities m1 and m2 of G1 and G2.
4. New threshold value:
   - Tnew = m1 + m2/ 2
5. If |T − Tnew| > ΔT, back to step 2, otherwise stop.

1.2.Otsu's method of clustering:

- Otsu's method is aimed in finding the optimal value for the global threshold.
- It is based on the interclass variance maximization.
- M x N image histogram:
  - L intensity levels, [0, …, L-1];
  - n_i # pixels of intensity i;

$$MN = \sum_{i=0}^{L-1} n_i$$

- Normalised histogram

$$p_i = \frac{n_i}{MN}$$

$$\sum_{i=0}^{L-1} p_i = 1, \quad p_i \ge 0$$

- Using k, 0 < k < L-1, as threshold, T = k:
  - Two classes: C1 (pixels in [0,k]) and C2 (pixels in [k+1,L-1]) (1)
  - $P_1 = P(C_1) = \sum_{i=0}^{k} p_i$, probability of the class C1
  - $P_2 = P(C_2) = \sum_{i=k+1}^{L-1} p_i = 1 - P_1$, probability of the class C2
  - m_1, mean intensity of the pixels in C1:

$$m_1 = \sum_{i=0}^{k} i.P(i|C_1)$$

$$= \sum_{i=0}^{k} \frac{P(C_1|i)P(i)}{P(C_1)}$$

$$= \frac{1}{P_1} \sum_{i=0}^{k} i.P_i$$

Where $P(C_1|i) = 1, P(i) = P_i \, e \, P(C_1) = P_1$.

- Similarly, m_2, mean intensity of the pixels in C_2

$$m_2 = \frac{1}{P_2} \sum_{i=k+1}^{L-1} i.P_i$$

- Mean global intensity, m_G

$$m_G = \sum_{i=0}^{L-1} i.P_i$$

- While the mean intensity up to the k level, m:

$$m = \sum_{i=0}^{k} i.P_i$$

- Hence

$$P_1 m_1 + P_2 m_2 = m_G$$

$$P_1 + P_2 = 1$$

- The global variance σ_G^2:

$$\sigma_G^2 = \sum_{i=0}^{L-1} (i - m_G)^2 . P_i$$

- The between-class variance, σ_B, can be defined as:

$$\sigma_B^2 = P_1 (m_1 - m_G)^2 + P_2 (m_2 - m_G)^2$$
$$= P_1 P_2 (m_1 - m_2)^2$$
$$= \frac{(m_G P_1 - m)^2}{P_1 (1 - P_1)} X$$

- The goodness of the choice T = k can be estimated as the ratio η

$$\eta = \frac{\sigma_B^2}{\sigma_G^2}$$

- The quanities re quired for the computation of η, can be obtained from the histogram

- Hence, for each value of k, η(k) can be computed as:

$$\eta(k) = \frac{\sigma_B^2(k)}{\sigma_G^2}$$

where

$$\sigma_B^2(k) = \frac{(m_G P_1(k) - m(k))^2}{P_1(k)(1 - P_1(k))}$$

- The optimal threshold value, k* , satisfies:

$$\sigma_B^2(k^*) = \max_{0<k<L-1} \sigma_B^2(k)$$

1.3. Algorithm

The algorithm is outlined below:
1. Apply a reasonable initial threshold value.
2. Compute the mean of the pixel values below and above this threshold, respectively.
3. Compute the mean of the two means and use this value as the new threshold value. Continue until the difference between two consecutive threshold values are smaller than a preset minimum.

1.4. Histograms

The histogram for different images are drawn below using the algorithms in mat lab with the help of these histogram we can easily threshold it to give the crack spot easily. There are different methods to threshold the histogram.

1.5. K-Means Clustering

In K-Means algorithm data vectors are grouped into predefined number of clusters. At the beginning the centroids of the predefined clusters are initialized randomly. The dimensions of the centroids are same as the dimension of the data vectors. Each pixel is assigned to the cluster based on the closeness, which is determined by the Euclidian distance measure. After all the pixels are clustered, the mean of each cluster is recalculated. This process is repeated until no significant changes result for each cluster mean or for some fixed number of iterations.

The algorithm is composed of following steps:
1. Place K points into the space represented by the objects that are being clustered. These points represent initial group centroids.
2. Assign each object to the group that has the closest centroid.
3. When all objects have been assigned, recalculate the positions of the K centroids. Repeat Steps 2 and until the centroids no longer move. This reduces a separation of the objects into groups from which the metric to be minimized can be calculated.
In K-means algorithm, we firstly initiate cluster centers and then decide the number of iteration by a lot of tries to get the good quality of segmentation.

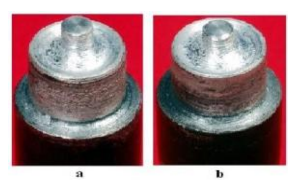

Figure 3. Tool pin profiles (a) Straight cylindrical threaded (ST) (b) taper cylindrical threaded (TT)

2. Experimental Work

The friction stir welding is completed using two pin profiles ST and TT (Figure 3) and weldment is made as shown in Figure 4.

Figure 4. Typical cross section of the weld (600rpm, 30mm/min, 2.5kN, TT tool) shows the NZ,TMAZ and HAZ.

For the identification of crack the experimental setup can be made in a small prototype by placing the friction stir welded butt joint piece in a cuboids where a sliding mechanism undergoes at the top rectangular surface of the cuboids attached with a web camera of 8 mega pixels to capture the pictures of the weld. Thus the images are stored in the memory retrieved to the computer where we use the tool called mat lab to detect the defects in the welded portion.

This research work is carried out using the software MATLAB. **MATLAB** is a numerical computing environment and fourth-generation programming language which is developed by Math Works. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and FORTRAN. Here the various histograms, bar chart and curves are plotted to the images describing that the defects is present or not. Similarly we can use the same technique in the industry to find cracks, cored holes, and all other defects in metal works easily. It is a time saving, and non expendable process.

2.1.Determination of size of crack:

Length of the crack= Difference between starting point and ending point pixel of crack in the image

Size of the crack = (length of the crack * width of the crack)

The algorithm for finding the threshold value is outlined below:

- Apply a reasonable initial threshold value.
- Compute the mean of the pixel values below and above this threshold, respectively.
- Compute the mean of the two means and use this value as the new threshold value.
- Continue until the difference between two consecutive threshold values are smaller than a preset minimum.

3. Result and discussion

This experimental study is to research on the application of image segmentation in photoreceptor ray film of the ray inspection of welding. We take sampling as the method of data collection and then do data analysis by MATLAB. Figure 5 represents the MATLAB images after evaluation for welded plates of respective weld speeds 600, 800, 1000 and 1200 r.p.m.. We observe the Mean Squared Error (MSE), Signal to Noise Ratio (SNR), Peak Signal to Noise Ratio (PSNR) and Mean absolute error (MAE) of the images using Otsu' method and Fuzzy K-means clustering as on Table 1. Clustering Interpretation rules satisfied with Gray scale based K-clustering.

Clustering Interpretation rules:

1. MSE and MAE: the smaller, the better.
2. SNR and PSNR: the larger, the better.

Table 1. Evaluated values for K - clustering and C - clustering

Otsu's Method based k-clustering				
Case	MSE	SNR	PSNR	MAE
1	6518.60	46.86	8.26	68.24
2	7820.70	28.46	18.85	88.64
3	1400.40	22.84	29.42	90.46
4	1920.60	20.86	39.64	92.68

Gray Scale based C-means clustering				
Case	MSE	SNR	PSNR	MAE
1	4218.44	48.76	14.42	36.24
2	2022.44	32.76	56.72	18.22
3	1247.44	28.46	58.62	15.62
4	1548.62	26.72	68.66	12.86

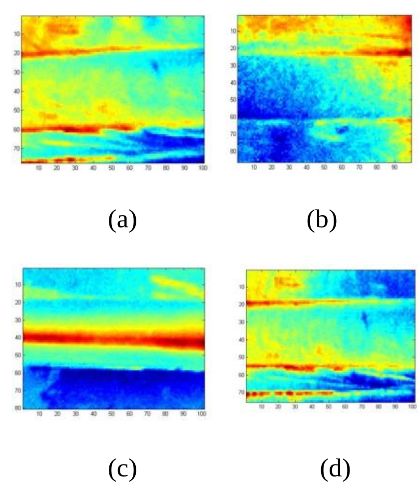

Figure 5. Surface texture of the welded parts at different speeds using MAT LAB

[(a) 600rpm, 30mm/min, 2.5kN, TT tool,
(b) 800rpm, 30mm/min, 2.5kN, TT tool,
(c) 1000rpm, 30mm/min, 2.5kN, TT tool and
(d)1200rpm, 30mm/min, 2.5kN, TT tool]

We collect all the data from the MATLAB, shown in the Table 1. According to above evaluation criteria, it is found that Fuzzy K-means clustering gives better performance than Otsu's method. We apply Gray scale based Fuzzy K-means clustering to image segmentation in welding detection.

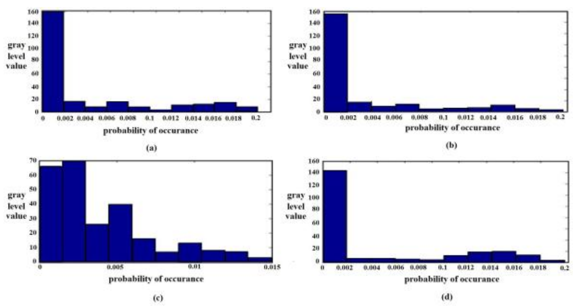

Figure 6. Histogram of surface texture for different weld rotational speed
[(a) 600rpm, 30mm/min, 2.5kN, TT tool,
(b) 800rpm, 30mm/min, 2.5kN, TT tool,
(c) 1000rpm, 30mm/min, 2.5kN, TT tool and
(d)1200rpm, 30mm/min, 2.5kN, TT tool]

Figure 6 shows the segmented result using Histogram thresholding and the others will be shown in related appendix files. Histogram thresholding is based on selecting the middle gray value as the threshold value between the two peaks. If the histogram of an image includes some peaks, we can separate it into a number of modes. Each mode is expected to correspond to a region, and there exists a threshold at the valley between any two adjacent modes. The midpoint method finds an appropriate threshold value in an iterative fashion.

The Figure 6. shows the segmented result using Histogram thresholding. Histogram thresholding is based on selecting the middle gray value as the threshold value between the two peaks.

From Figure 6c it is found out that there are two classic peaks in gray-scale histogram diagram. Then we could select the middle gray value between them. It is encouraged to test the appropriate middle gray value. Finally, by comparison of values of 45 and 65, it is clear that segmented image with threshold value of 65 is better.

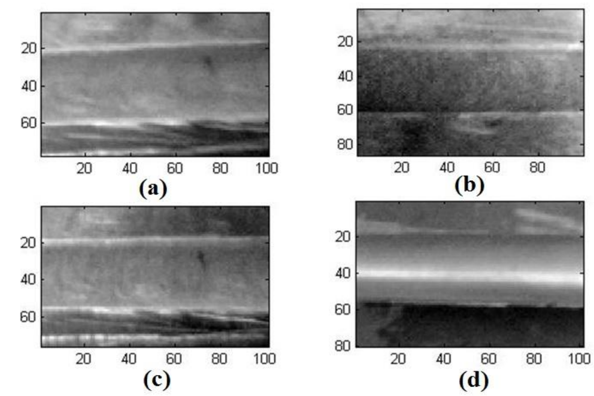

Figure 7. Gray scale image of surface texture for different weld rotational speed
[(a) 600rpm, 30mm/min, 2.5kN, TT tool,
(b) 800rpm, 30mm/min, 2.5kN, TT tool,
(c) 1000rpm, 30mm/min, 2.5kN, TT tool and
(d)1200rpm, 30mm/min, 2.5kN, TT tool]

Figure 7 represents gray scale image for the respective weld speed. Data analysis contains subjective evaluation on application of image segmentation. It is proposed to select the gray scale as application solution based on MATLAB data from Table 1.

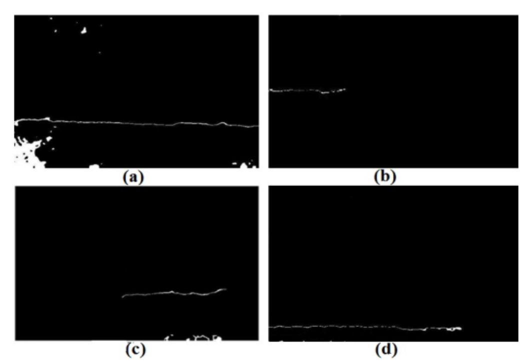

Figure 8. Surface cracks identified through image clustering for different weld rotational speed
[(a) 600rpm, 30mm/min, 2.5kN, TT tool,
(b) 800rpm, 30mm/min, 2.5kN, TT tool,

(c) 1000rpm, 30mm/min, 2.5kN, TT tool and
(d)1200rpm, 30mm/min, 2.5kN, TT tool]

Gray-scale based K-clustering of image segmentation performs well, which can exposure pixels in terms of gray value level so that it can show the hierarchical position of related defects by gray value.

These images clearly describe about the different surface texture of the welded parts at different speeds. The histogram can be plotted using these images. These are captured at different crack occurring spots. So that it is easy to find defect. Through crack size calculation, the crack sizes are identified less on the weld speed of 800 r.p.m. and 1000 r.p.m. Also MATLAB stress distribution colour code is being more uniform for Figure 8 b and c.

4. Conclusions

It can be found that the K-clustering method is better than histogram thresholding in ray detection of welding because it has higher quality in index during our evaluation. It is true that histogram thresholding has the limitation when the grey-scale histogram meets more two peaks which waste time test appropriate threshold. However, K-clustering method is fast and simply to set the appropriate threshold. So combatively speaking, K-clustering method is more suitable to be applied in welding crack detection.

Thus the crack defects in the welded portion are detected using the tool. This method is not yet used or practiced. It is non expandable one and can be used to save time and money. If it is to be in experimented the faster rate of growth in quality high production and defect free component releases will increase leading to greater productivity sales. Other testing processes like NDT (Non Destructive Testing), ultra sonic inspection are more time consuming and expandable one. If the further development is made in this the technique we achieve vast growth in the field of detection of cracks and defects in metal pieces or the components used in machineries.

5. References

[1] Terry Khalid., *"An outsider looks at friction stir welding"*, Report #ANM-112N-05, (2005).
[2] P. L. Threadgill., *"Terminology in friction stir welding"*, Science and Technology of Welding and Joining, Vol 12 , No 4357, 360,(2007).
[3] R.Nandan, T. DebRoy, H.K.D.H. Bhadeshia., *"Recent advances in friction-stir welding – Process, weldment structure and properties"*, Progress in Materials Science, 53, 980–1023, (2008).
[4] R.S. Mishra, Z.Y. Ma., *"Friction stir welding and processing"*, Materials Science and Engineering, R 50, 1–78, (2005).
[5] Y.D.Sato & H.Kokawa., "*Friction stir welding (FSW) process"*, Welding International, 17 (11), 852-853, (2003).
[6] M.Kumagai., "*Recent technological developments in welding of Aluminium and its alloys"*, Welding International, 17 (3), 173-181, (2003).
[7] V.Sridevi and N.Nirmala, "*Inspection Of Welding Images Using Image Segmentation Techniques"*, International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 3, (2013) .
[8] Wu Xiaomeng, "*Detection of Weld Line Defect for Oil-gas Pipeline Based on X-rays Image Processing"*, Proceedings of the 2009 International Symposium on Web Information Systems and Applications, pp. 273-275, (2009).
[9] Jawad Nagi, Syed Khaleel Ahmed, "*A MATLAB based Face Recognition System using Image Processing and Neural Networks"*, 4th International Colloquium on Signal Processing and its Applications, Kuala Lumpur, Malaysia, (2008).