Automatic Laser Welding Defect Detection and Classification using Sobel-Contour Shape Detection

M.A.A. Halim[1], N.I.R. Ruhaiyem[2], E.R.I. Fauzi[3], M.S.C. Jamil[4], A.S.A. Mohamed[1]
[1,2]*School of Computer Sciences, Universiti Sains Malaysia,*
11800, Penang, Malaysia.
[3,4]*School of Mechanical Engineering, Universiti Sains Malaysia,*
Engineering Campus, Nibong Tebal, 14300 Penang.
sufril@usm.my

***Abstract*—This paper describes a detection of common defects in laser welding of structural aluminum alloy. To overcome these problems, a technique has been proposed to detect defects automatically and effectively using the image segmentation technique. Although, this technique has been well developed, it does suffer from several disadvantages of radiographic images taken to be poor in quality, as well as the microscopic size of the defects together with poor orientation relatively to the small size and thickness of the evaluated parts. Using image segmentation algorithm allows the defects to be automatically inspected and measured within the welded surface such as cracks, porosity and foreign inclusions, which may be weakening the welded parts. This paper proposes a system to automatically identifies and classifies the faults from the welding process by using the existing image segmentation algorithms. The output of the developed system produces a measured analysis which can be then used to describe the mechanical properties of welded part of the alloy such as its tensile and force. The benefits of this project will improve the welding process to reduce faults and defects for both constructing and manufacturing fields.**

***Index Terms*—Automatic Laser Welding; Classification; Defect Detection; Sobel-Contour Shape.**

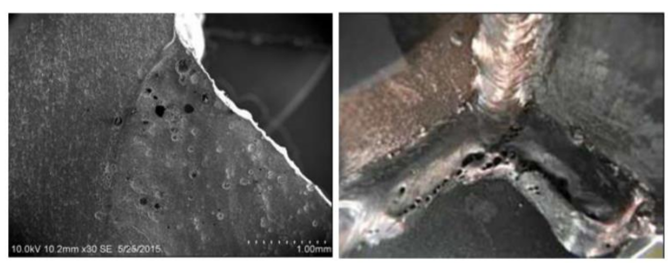
I. INTRODUCTION

Welding is the most important process in manufacturing industry particularly using the steel alloy. The use of laser welding for aluminum is gaining its popularity due to its cheaper construction material, and with the use of laser benefits in terms of higher temperature of heat applied and capable of welding at greater precision. Despite that, due to the high temperature and various welding situations, the process using the aluminum al-low is naturally complicated and nonlinear, making it prone to a number of defects, such as porosity, undercuts, surface holes, and solidification cracking which are often found in laser welds [3,16].

Furthermore, welding the structure of aluminum alloy may contain more defects compare to other types of steel alloy. This is because aluminum alloy composes of different material composition compared to other steel alloys, and usually purposely hardened to match the strength of steel alloy, which can lead to its natural weakening states at the welded areas. Furthermore, cracks and porosities are some of the problems in laser welding usually found in most welded materials [10,16].

Cracks happen when applying stress and tension to the welded area while porosities happen when there are gasses trapped within the solidify welded area thus weakening the strength of the welded structure. The process of identifying these faults require many steps and ingest higher attention which is time consuming and very hard to be done. However, current technology enables images to be taken at microscopic level with high resolution, and with the use of image processing technique, image segmentation can be used to automatically extract and classify these faults and measuring them [3,6,7,16].

Figure 1a shows an example of welding defect using the Scanning Electron Microscope (SEM) taken at the School of Mechanical Engineering, USM. The welded interface with porosities and slags usually occur when the gas used is not enough or the surface contained contaminants, and thus weakening the strength of the welded area (see figure 1b).



(a) (b)

Figure 1: (a) An example of welding defect. (b) welded interface with porosities and slags.

In order to solve this problem, several methods are used to detect defects based on image segmentation. Image processing is a method to process an image into digital form. So, in order to get some useful information from it, some operations must be performed on it. Because of fast growing technologies nowadays, this application is very useful in various aspects of a business and manufacturing industry. There are several purpose of image processing such as image sharpening and restoration that will create a better image and visualization to observe the objects that are not visible, image recognition that will distinguish the objects in an image, and so on. Meanwhile, the purpose of image segmentation is to divide the image into regions with different characteristics and extract its features into the related goals [1]. There are many different ways to perform image segmentation such as thresholding methods, color-based segmentation, trans-form methods, and texture methods.

II. RELATED WORKS

Due to fault detection found in the steel alloy several problems have been heavily researched and developed [4,5,11,14,15]. The motivation of the proposed system is to overcome the problem arises from the defect detection found in the hardened aluminum alloy which is very new in the construction and manufacturing industries. After the system is develop completely, it can be implement in the manufacturing industry and helps the engineers to detect any faults found visually and classify them. The results are then further validated with the conventional method of testing such as tensile and strength tests. This will ease the burden of having a train eyes to manually calculate and measure the faults and can effectively provide an automatic visual inspection at microscopic level.

This existing work proposes an algorithm which can detect defects in industrial pipe. A method has been introduced to automatically detect defects in industrial pipes based on image processing [13]. This paper pro-posed algorithm that consist of three steps. At first, the converting of the RGB image pipe into a grayscale image and extracts the edges by using So-bel gradient method, after eliminating the unused objects based on their size. Next, the method will extract the dimensions of the pipe. Lastly, the algorithm will detect and identifies the defects such as holes and cracks on the pipe which is based on their characteristics [13]. Table 1 shows some of the comparisons of the existing algorithm used in measuring faults using other types of alloy.

Table 1
Comparisons of algorithm used to detect faults

Paper Title	Measure	Method Used	Type of Materials
An algorithm to Detect and Identify Defects of Industrial Pipes Using Image Processing [13]	Holes and Crack	Sobel gradient method	Industrial Pipes
Defect Detection of Steel Surface Using Entropy Segmentation [12]	Water droplet, blister, and scratch	Histogram Thresholding method	Steel surface

III. METHODOLOGY

This paper proposes a hybrid pre-processing and processing algorithm using the Sobel-Contour Detection Algorithm. The aim is to detect water droplet, blister and scratch defect on the steel surface. In order to deal with these problems, special pre-processing methods like illumination compensation method and determine the position of defect by using local entropy, background subtraction, histogram thresholding, morphology and edge detection [12]. Each of the existing work has the similarities and also the differences in features. However, all of the existing work have limitation and also weaknesses. Therefore, the proposed system will provide suitable features which are going to overcome the problems.

The Segmentation processes are the part an image is partitioned into regions. In this paper, we introduce a method of combining both edge and shape detection. By using the image segmentation algorithm technique, 2d images are converted to grayscale [4] from the images and analyzed to automatically to detect and isolate the defects found right after the welding process.

The 2d grayscale image will then be used to detect cracks of the outer surface and specimens are to be cut into smaller parts which will then be captured again using SEM to detect anomalies of the inner surface. An effective and Sobel edge detection technique is used to perform image edge detection [9,15] on the image which provides a comprehensive environment for data analysis, and contour shape detection to match with the template for data visualization [2]. The development process is listed out in Figure 2 showing the flowchart of each process.

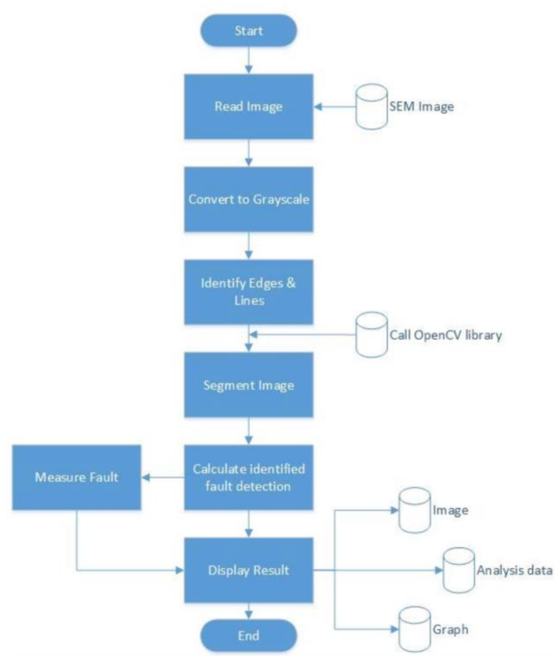


Figure 2: Flowchart of each process of the detection algorithm

The algorithm starts with the reading of SEM image. The image which displays fault in the aluminum alloy is going to be processed one at a time. After the image is being read and stored, it is going to be converted into 2d grayscale image. This process is important because it helps the system to analyze the image correctly using the contour shapes detection to identify features such as porosities and cracks. Next, the edges and lines of the image are processed using Sobel operator [9,15] and features are extracted based on the template matching using standard Sum of Absolute Difference (SAD) [2] giving a hybrid solution of Sobel-Contour Shape Detection as shown in equation (1), where (*MxN*) is the size of the fault template, i and j are the size of the windows size depending on the size of the radius of faults and the lengths of the cracks, (Gx and Gy) are the gradient components of the input image measured at every rotation of 90 ^{O}and lastly T represents the template containing the sample shape of faults and I is the target image to look for the faults.

$$|G|_S = \sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left(|G|_{x(i,j)} - |G|_{y(i,j)}\right)^T - \left(|G|_{x(i,j)} - |G|_{y(i,j)}\right)^I \quad (1)$$

In general, these image segmentation process contributes part of the fault detection process typically used in a welding process. Figure 3 shows an example of SEM image processed using Sobel operator to segment and build the edges and lines around the image. The size of the tested SEM image is x14 microns and these are taken after the grinding and polishing process.

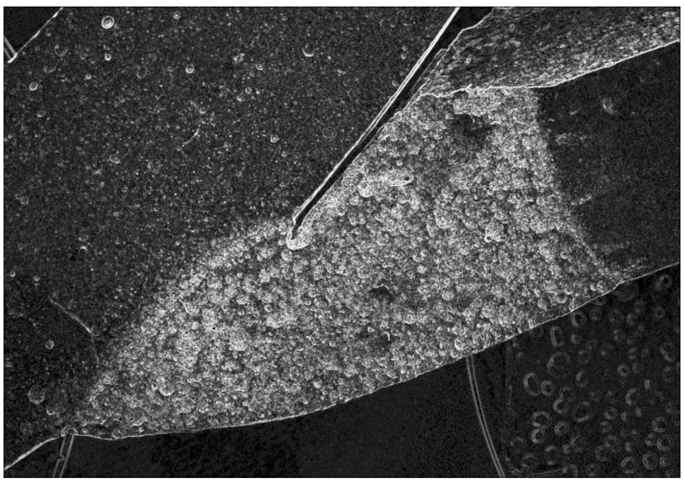


Figure 3: An example of SEM image used with the size of x14 microns with Sobel operator implemented to show the edges and lines

Next, the markers are placed on the image indicating the faults detected by using SAD algorithm to match with the template samples containing the various sizes and shapes to be detected (see Figure 4).

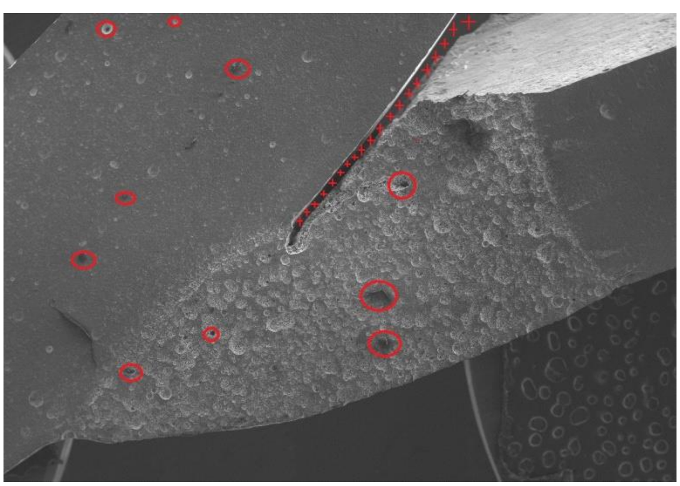


Figure 4: An example of SEM image used with the size of x14 microns

Figure 5 shows the general steps taken the whole process of welding. Generally, for analyzing the faults are done before the hardness test. Therefore, for this system, it will help to automatically trace faults in the welded materials and measure the strength of the welded materials by looking at the ratio of the number of porosities and cracks over the initial strength of the materials.

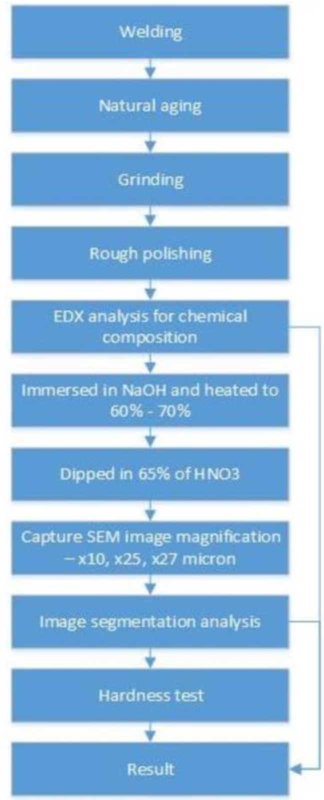


Figure 5: Steps taken for identifying the faults

IV. CONCLUSION

The main significant of the project is to better analyze the fault found in aluminum welded materials. This will benefit the manufacturing industry and simultaneously saves time and costs of using trained eyes by manual inspection. In addition, the algorithm can represent a visual form of inspection and the data analyzed can be used into something meaningful to the engineers to compliment their method of measuring the aluminum alloy's strength and durability.

The use of hardened aluminum alloy for welding is new for the construction and manufacturing domain. The algorithm used for developing this system is unique as it helps to solve the manufacturing problems of using hardened aluminum alloy materials and automatically detect and measure the faults and defects after the welding process. This will enhance the overall simplicity and effectiveness of the system. There are several capabilities can be found upon developing the system. One of them is it can detect errors in every image captured and analyze it by displaying the result using the deployed algorithm. This will improve the accuracy of the errors found compare to the manual detection by the trained eyes of the engineers.

One of the limitation of the system is poor image quality due to wrong technique in capturing picture. This will lead to false detection of the image. There is another possible limitation is the time taken when analyzing the image provided. The algorithm used can increase the overall simplicity of the program. This study leads to understanding defect which can be analyze using image processing algorithm. This process can overcome the limitation of manual detection by the engineers. This will give the accurate result when calculating the defect. It will improve the efficiency and simplicity of the program.

In work of future, several improvements are worth to be mentioned, different algorithm technique and method should be study, as it can improve the accuracy of the result.

ACKNOWLEDGMENT

The authors acknowledge the support from University Science Malaysia (USM) and Ministry of Higher Education Malaysia through FRGS research grant (203.PMEKANIK.6071331).

REFERENCES

[1] Li, C.-T, and Chiao, R. "Multiresolution Genetic Clustering Algorithm for Texture Segmentation", Image and Vision Computing, (2003): 21 (11) pp. 955-966.

[2] I. E. Richardson "H.264 and MPEG-4 Video Compression: Video Coding for Next-generation Multimedia". Wiley:(2003).

[3] R. Nejatpour, A.A. Sadabad, "Automated Weld Defects Detection Using Image Processing and CAD Methods", ASME International Mechanical Engineering Congress and Exposition (2008)

[4] K. Parvati, B. S. Prakasa Rao, and M. Mariya Das, "Image Segmentation Using Gray-Scale Morphology and Marker-Controlled Watershed Transformation", Discrete Dynamics in Nature and Society, (2008): pp 8

[5] K. Singh, A. Singh, "A Study Of Image Segmentation Algorithms For Different Types Of Images", IJCSI International Journal of Computer Science (2010): 7(5).

[6] A. Bala, "An Improved Watershed Image Segmentation Technique using MATLAB", International Journal of Scientific & Engineering Research (2012): 3(6)

[7] J. Shen, "Application of Image Segmentation In Inspection Of Welding – Practical research in MATLAB", University Of Boras (2012).

[8] R. Dass, P.S. Devi "Image Segmentation Techniques ", IJECT (2012): 3(1)

[9] A. Chaudhary, T. Gulati, "SEGMENTING DIGITAL IMAGES USING EDGE DETECTION", International Journal of Application of Innovation in Engineering & Management (2013): 2(5)

[10] "WELDER'S Visual Inspection" HANDBOOK (2013): pp. 32-33

[11] D. Narsimhachary, "Effect of Laser Welding Parameters on 6061 Aluminium Alloy", Department Of metallurgical And Materials Engineering, National Institute Of Technology Rourkela, Odisha-769008 (2014).

[12] G. K. Nand, N.N. Neogi, "Defect Detection of Steel Surface Using Entropy Segmentation", Department of Electrical And Electronic Engineering, Birla Institute, Mesra, Ranchi-835215, Annual IEEE India Conference (2014).

[13] M. A. Alam, M. M. N. Ali, M.A.A. Syed, N. Sorif, M. A. Rahaman, "An Algorithm to Detect and Identify Defects of Industrial Pipes Using Image Processing", Department of Electrical and Electronic Engineering, International Islamic University Chittagong (IIUC), Chittagong, Bangladesh (2014).

[14] R. Cogranne, "Statistical detection of defects in radiographic images using an adaptive parametric model", Signal Processing. (2014). 96(B): Pages 173–189 (8)

[15] S. Madani, M. Azizi "Detection of Weld Defects in Radiography Films Using Image Processing". (2015).(9)

[16] M.S. Che Jamil, E.R. Imam Fauzi, C.S. Juinn, M.A. Sheikh, "Laser Bending of Pre-stressed Thin-Walled Nickel Microtubes" Journal of Optics & Laser Technology (2015) 73: 105-117.