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Weld Bead Performance Assessment using Image Processing during Destructive Testing by Multivision Technique through NDT methods for MS ASTM A 106 B grade material

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Abstract

Pulsed Gas Metal Arc Welding (P-GMAW) is extensively used in high hi-tech industries for fabrication of materials to gain better productivity and quality. Grade B MS ASTM A 106 is carbon steel material can be easily welded by all types of fusion welding processes for high temperature service. P-GMAW achieves coalescence of metals by melting constantly fed current-carrying wire. This process needs consistent, high-quality welding procedures to accomplishexcellent quality of weld and attractive looking. This requires due to continuous control metal transfer that is essential in P-GMAW for thin metal work pieces. In this paper welding process parameters considered are viz., Current, Gas Flow Rate (GFR) and Wire Feed Rate (WFR). For performance assessment of a weld bead the output variables considered are Ultimate Tensile Strength (UTS, N/mm2), Yield Strength (YS, N/mm2) and % of elongation. Trials have been conducted based on Taguchi's L_{27} standard orthogonal array.This paper establishes how NDT methods and image processing technique could be applied to MS ASTM A 106 B grade material weld bead for assessment of mechanical properties during destructive testing. Using image processing by multivision techniques for different loading conditions, image features like area and height of weld bead have been extracted.For quality inspection and process monitoring, vision techniques play a significant role. Though vision technology pixel processing and edge recognition are improved consistently and reliably achieved. From the established trend and study conducted it is evident that multivision technique and NDT methods are capable of quantifying the parameters associated with performance of wed bead joints. The trend established using image processing features correlating well with traditional measurement.

Keywords: Multivision, NDT, P-GMAW, Destructive test.

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1. Introduction

Pulsed Gas Metal Arc Welding (P-GMAW) is a leadingfabrication process in advanced and High technology manufacturing industries. The current is periodically modulated between a relatively low base current and high peak current, in pulse current gas metal arc welding process. With precise control of arc dynamics, P-GMAW can be used fora high deposition rate, a fast-follow process and fast-fill process at high travel speeds. A variation of the spray transfer mode, pulse-spray is based on the principles of spray transfer but uses a pulsing current to melt the filler wire and allow one small molten droplet to fall with each pulse. The pulses allow the average current to be lower, decreasing the overall heat input and thereby decreasing the size of the weld pool and heat-affected zone while making it possible to weld thin work pieces.P-GMAW introduces additional parameters such as pulse duration (Tp), pulse frequency (f), peak current (Ip), background current (Ib) and background time (Tb) shown in Fig. 1. The appropriate selection of pulse parameters provides required droplet velocity and control over weld pool to achieve desired geometrical characteristics of weld joint. To increase the productivity and lower the cost in today’s welding inspection. Weld beads are usually subjected to destructive tests such as tensile, toughness, bend and test hardness for assessing the suitability of weldjoint for a particular application. It is highly desirable to increase the accuracy of automatic weld defect detection in X radiography fornon-destructive testing and evaluation.

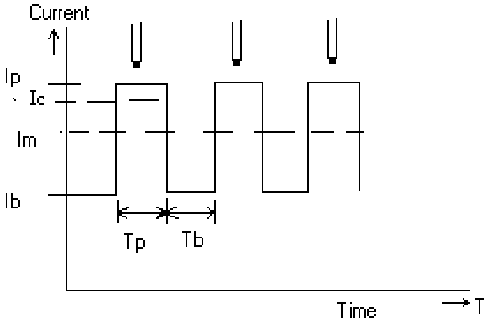


Fig.1. Pulsed current waveform

Some of the research work has proposed a machine vision method for weld defect segmentation using the Least Probability Weighted Background Group (LPWBG), an improved version of Otsu’s method. The least non-zero probability value of gray-levels of the whole image has been considered as a weighted parameter of the background group of Otsu’s within-class criterion. They determined that the resulting threshold value will always lie at the left bottom side of the unimodal distribution, especially when the defects are smaller than the background area. The results reveal that the proposed method provides satisfactory segmentation results over the others [1]. Some researchers have discussed the application of computer vision technology for real-time seam tracking in robotic Gas Tungsten Arc Welding (GTAW) and Gas Metal Arc Welding (GMAW).The key aspect in using vision techniques to track welding seams is to acquire clear real-time weld images and to process them accurately. This is directly related to the precision of seam tracking. By analyzing the features of weld images, a new and improved edge detection algorithm was proposed to detect the edges in weld images for more accurately extract the seam and pool characteristic parameters. The image processing precision was verified through the experiments. Results showed that the precision of this vision based tracking technology can be controlled to be within ±0.17 mm and ±0.3 mm in robotic GTAW and GMAW respectively [2]. Investigation has made on the cryogenic tensile properties and fracture behavior of FSW and post-weld heat-treated joints of 32Mn-7Cr-1Mo-0.3N steel. Cryogenic brittle fracture, which occurred in the as-welded joint, is related to the residual particles that contain tungsten in the joint band structure. Post-weld water toughening resulted in the cryogenic intergranular brittleness of the joint, which is related to the non-equilibrium segregation of solute atoms during the post-weld water toughening. Annealing at 550^0C for 30 min can effectively inhibit the cryogenic intergranular brittleness of the post-weld water-toughened joint. The YS, UTSand uniform elongation of the annealed joint are approximately 95%, 87%, and 94% of the corresponding data of the base metal [3]. To identify and classify different kinds of surface defects generally encountered during the FSW using Universal Testing Machine (UTM) according to ASTM Standards. Image processing method is used to perform processing process using digital image processing techniques. The defects on the surface of the weld are identified using image pyramid and image reconstruction algorithms. Further, using these algorithms the defects can be classified into voids, grooves, cracks, key-hole and flash with the help of unique features of each kind of defect. Vertical intensity plot and the area plot of the defect blobs are represented for the proper localization and analysis of severity of defects [4]. Some of the researchers have tested the welded sample of SS304L by various NDT techniques such as magnetic particle inspection, liquid penetrate test and ultrasonic flaw detection. In ultrasonic testing, two discontinuities were detected. In the liquid penetrant test, no surface defects were found. In magnetic particle inspection, linear surface defects were found. The results show that liquid penetrant testing is more sensitive in detection of surface defect and magnetic inspection is sensitive in sub surface defects. Finally ultrasonic method is more sensitive in detection of internal defects [5].In the present study high resolution digital camera is used to capture the images while conducting the destructive test for the welded specimens by operations on an image, in order to get an enhanced image to extract some useful information from it.

2. Selection of work material, EdgePreparationandExperimental work

The present study has been carried out with MS ASTM A 106 B grade pipe material for high-temperature service having excellent weld ability by all standard fusion welding methods, with filler metals The .material finds its applications most in refineries and plants where gasses or fluids are transported at high temperatures and pressures. The chemical composition of the material is shown in Table.1.

Table.1. Chemical composition of MS ASTM A 106 material.

C	Mn	P	S	Si	Cr	Cu	Mo	Ni	V
0.30	0.27-0.93	0.35	0.035	0.01	0.40	0.40	0.15	0.04	0.08

Experiments were conducted using Pulsed Current Lorch welding machine by DC electrode positive power supply. Test pieces of size outer diameter of 22 mm, inner diameter of 19 and thickness of 3mm having length 300 mm were cut in to length of each 150 mm. Initially an edge preparation is made of 45^o degree shown in Fig. 2 and tack welded. Copper coated mild steel electrode of 1.2 mm diameter was used for welding. Argon (85%) and CO2 (15%) gas mixture were used for shielding. Welding speed 5 rpm has been kept constant for all trials. By varying the initial parameters, single pass welding was performed on work material. The trials were conducted based on Taguchi's L_{27} orthogonal array. The pipe material prepared according to the dimensions as shown in Fig. 2. The edge preparation is made for the work material is depicted in Fig. 3.

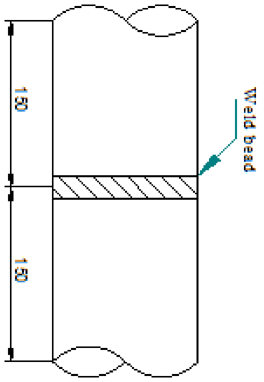


Fig. 2. Tensile Test Specimen

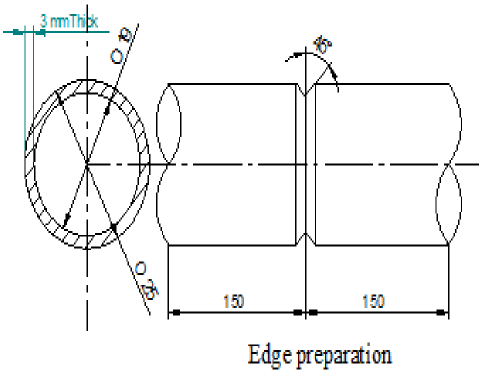


Fig. 3. Edge Preparation

The working ranges for the process parameters were selected from the American Welding Society (AWS) handbook. Control factors and their levels for optimization of welding process parameters are tabulated in Table.2. Based on the Taghuchi’s optimization, optimized weld parameters have been set then joining processes was performed on welding machine is as shown in Fig. 4.

Table. 2. Control factors and levels.

Welding parameters	Level 1	Level 2	Level 3
Current, amp	60	65	70
Gas Flow Rate (GFR) ltrs/min	15	16	17
Wire Feed Rate (WFR) mm/min	120	125	130

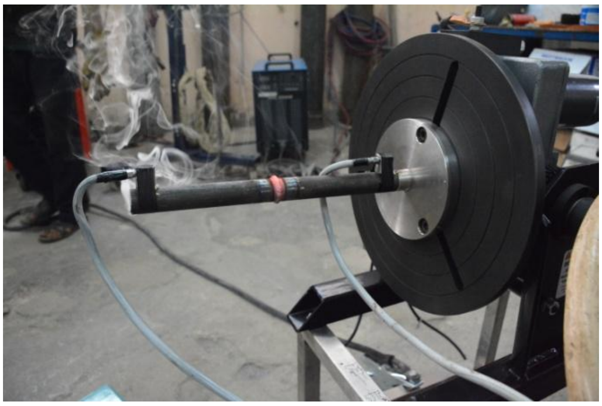


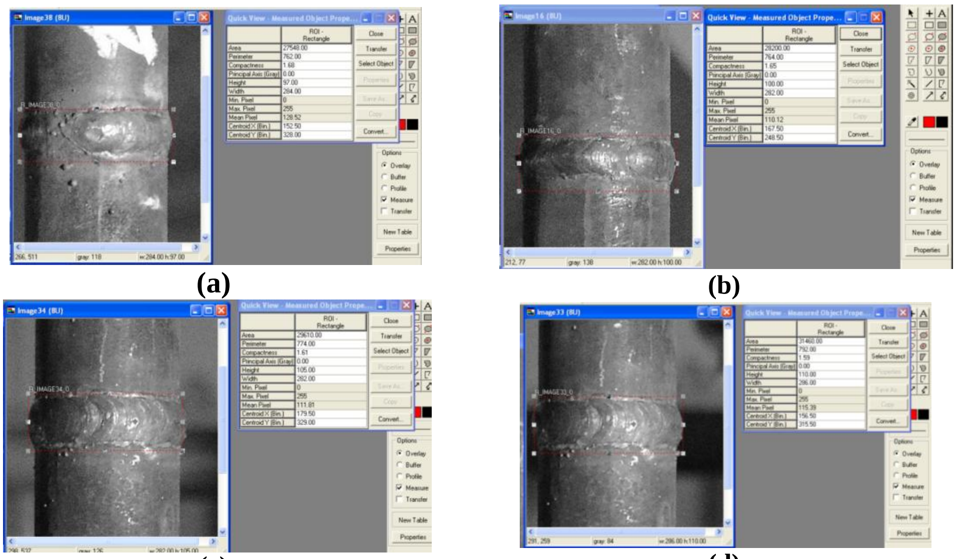
Fig. 4. Welding Experimental Setup

Fig. 5.Tensile Experimental Setup

Ultimate Tensile Strength and weld bead strength of the weld bead is the objectives. For the calculation of the responses i.e., tensile test were performed using Advanced Universal Testing Machine (UTM) as shown in Fig.5, model number; AI UTS-1000 KN. Machine vision system was used to capture images for initial and final weld bead at different loading condition while carrying out the trials on UTM. Captured images will be processed through image processing software. Then trends will be established.

3. Processing of weld bead Images using Machine Vision (MV)

In high technology industries, the use of machine vision in the visualization of weld bead status is fairly wide spread. In the present study an attempt is made to utilize vision system to monitor weld bead status during destructive testing. A series of images have been acquired using vision system during destructive for non- optimized condition were depicted in Fig. 6 (a) to (d). Since the material is less ductile in nature, it can sustain lesser load on weld bead joint and fracture occurred at a weld bead with a load of 60 KN.



(a)

	ROI - Rectangle
Area	27548.00
Perimeter	762.00
Compactness	1.68
Principal Axis (Gray)	0.00
Height	97.00
Width	284.00
Min. Pixel	0
Max. Pixel	255
Mean Pixel	128.52
Centroid X (Bin.)	152.50
Centroid Y (Bin.)	328.00

(b)

	ROI - Rectangle
Area	28200.00
Perimeter	764.00
Compactness	1.65
Principal Axis (Gray)	0.00
Height	100.00
Width	282.00
Min. Pixel	0
Max. Pixel	255
Mean Pixel	110.12
Centroid X (Bin.)	167.50
Centroid Y (Bin.)	248.50

(c)

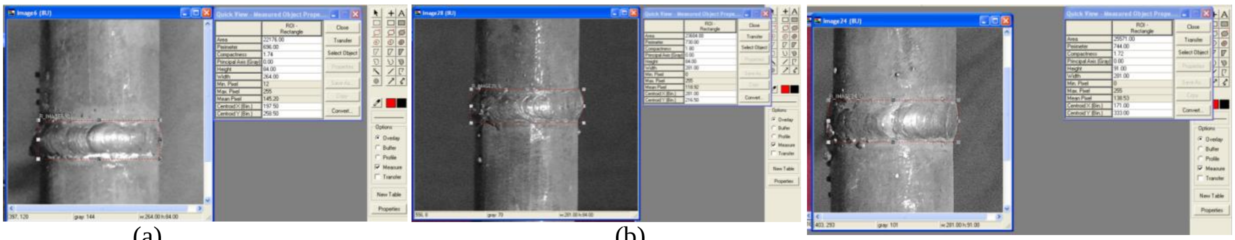
	ROI - Rectangle
Area	29610.00
Perimeter	774.00
Compactness	1.61
Principal Axis (Gray)	0.00
Height	105.00
Width	282.00
Min. Pixel	0
Max. Pixel	255
Mean Pixel	111.81
Centroid X (Bin.)	179.50
Centroid Y (Bin.)	329.00

(d)

	ROI - Rectangle
Area	31460.00
Perimeter	792.00
Compactness	1.59
Principal Axis (Gray)	0.00
Height	110.00
Width	286.00
Min. Pixel	0
Max. Pixel	255
Mean Pixel	115.39
Centroid X (Bin.)	156.50
Centroid Y (Bin.)	315.50

Fig. 6. Weld bead images acquired under different loading conditions for non-optimized parameters

The weld bead area and height of the final image is having31460 pixels and 110 pixels of respectively. Fig. 7 (a) to (e) shows the weld bead image at a load of initial, 20KN, 40KN, 60KN and final weld bead. For optimized condition, the weld bead joint is to sustain the higher load up to 80KN and with this load the specimen gets fracture/fail. The weld bead area and height of the final image is having 25145 pixels and 93 pixels respectively.For a strong weld bead joint, area and height of the weld bead values decreases along with % of elongation by increase inload.



(a)

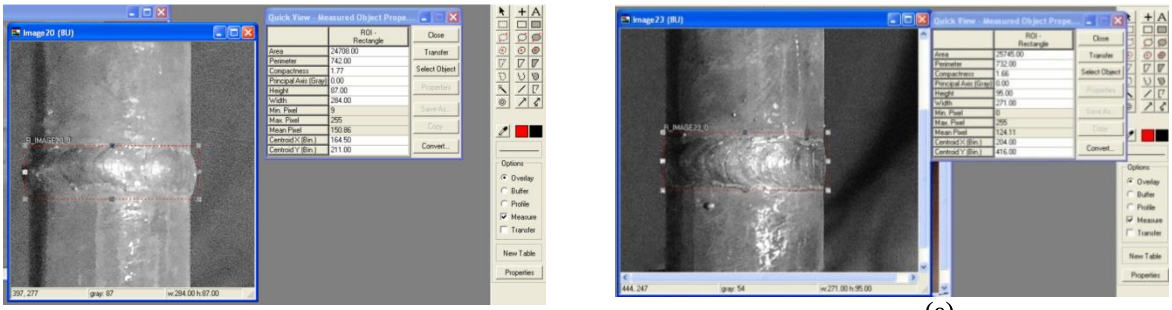
	ROI - Rectangle
Area	22176.00
Perimeter	696.00
Compactness	1.74
Principal Axis (Gray)	0.00
Height	84.00
Width	264.00
Min. Pixel	12
Max. Pixel	255
Mean Pixel	145.20
Centroid X (Bin.)	197.50
Centroid Y (Bin.)	258.50

(b)

	ROI - Rectangle
Area	23604.00
Perimeter	730.00
Compactness	1.80
Principal Axis (Gray)	0.00
Height	84.00
Width	281.00
Min. Pixel	0
Max. Pixel	255
Mean Pixel	118.92
Centroid X (Bin.)	201.00
Centroid Y (Bin.)	216.50

(c)

	ROI - Rectangle
Area	25571.00
Perimeter	744.00
Compactness	1.72
Principal Axis (Gray)	0.00
Height	91.00
Width	281.00
Min. Pixel	0
Max. Pixel	255
Mean Pixel	138.53
Centroid X (Bin.)	171.00
Centroid Y (Bin.)	333.00



	ROI - Rectangle
Area	24708.00
Perimeter	742.00
Compactness	1.77
Principal Axis (Gray)	0.00
Height	87.00
Width	284.00
Min. Pixel	9
Max. Pixel	255
Mean Pixel	150.86
Centroid X (Bin.)	164.50
Centroid Y (Bin.)	211.00

(d)

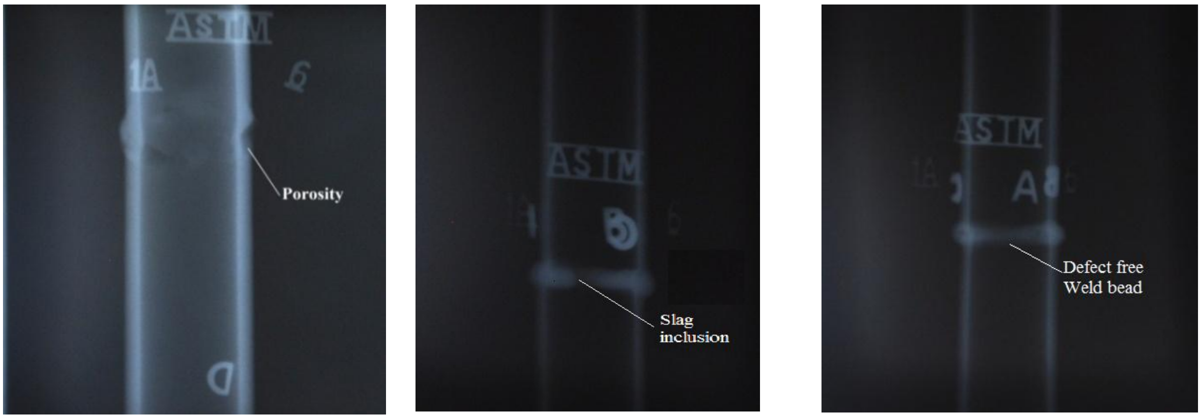
	ROI - Rectangle
Area	25745.00
Perimeter	732.00
Compactness	1.66
Principal Axis (Gray)	0.00
Height	95.00
Width	271.00
Min. Pixel	0
Max. Pixel	255
Mean Pixel	124.11
Centroid X (Bin.)	204.00
Centroid Y (Bin.)	416.00

(e)

Fig. 7. Weld bead images acquired under different loading conditions for optimized parameters

4. Results and discussions

The tension test carried out by applying gradual loading on specimens to failure. Tensile properties of the weld bead namely UTS, YS and percentage of elongation in weld bead area can be obtained by direct and indirect method. To ascertain weld bead joint defects and to validate optimized welding condition, NDT method i.e X- radiography was performed as per ASME sec V Art 2. Since the work material is circular in nature (pipe), X- radiography images have been taken over a welded joint by Double Wall Single Image (DWSI) superimposition technique. Fig.8 (a) and (b) demonstrates the X–ray images having porosity and slag inclusion defected weld bead for non–optimized conditions.Porosity and slag inclusion occurs due to gas gets trapped in welded zone and longer arcdue to non–optimized conditions. The result of direct method is as shown in Fig.9. During the test, the tensile load and the elongation of a weld bead were monitored by acquiring series of weld bead images for different loading condition. Hence Machine vision is capable of monitoring the weld bead status during destructive testing efficiently.



(a) (b) (c)

Fig. 8: X- Ray images (a) Porosity (b) Slag inclusion (c) Optimized welding condition

Fig.8. (c) shows the x- ray image for optimized condition. The image shows the condition of the filler metal around the welded joint. The joint shows up bright white because it is thicker than rest of the material. From the X- radiography film, the weld bead joint is assessed.There is no welding defects are found with the optimized condition and the tensile values like UTS and YS found maximumof363 N/mm2 and of 335 N/mm2 respectively

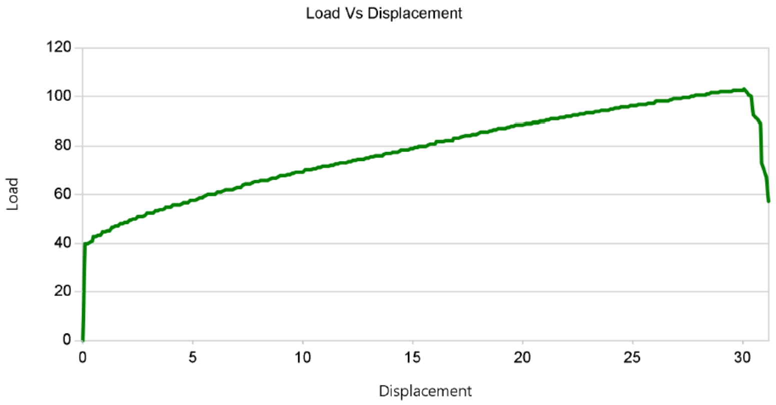


Fig.9.Trend obtained by UTM machine

5. Conclusion

Automated testing of weld bead using machine vision is being applied in the present research.A few P-GMAW welded specimens were prepared by using the optimized welding parameters as per the trials based on the design of experiments, to conduct mechanical testing which includes tensile test, it was observed that there was no fracture in the weldment whereas fractures were originates in the base metals. To determine the tensile strength of the welded joint the samples were prepared as per ASTM standards. Tensile test was carried out by holding the specimen in UTM and applying an increasing load on to the specimen till it fractures. During the test, the tensile load and the elongation of a weld bead were monitored by acquiring series of weld bead images for different loading condition. As the load increases weld bead area increases and follows the trend obtained by traditional method. Similar trends were obtained for other features. Hence machine vision is capable of monitoring the weld bead status during destructive testing efficiently. NDT testing like X- Radiography carried out for optimized and Non –optimized weld bead gives additional information regarding defects in the weld beads.

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