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Evaluation of Parameters Effect on Microstructure and Mechanical Properties in TIG Welding of A105 to A106 Steels

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Abstract. Welding parameters such as current intensity, voltage, number of passes can affect the mechanical properties of the weld. In this paper the effect of these parameters on structure and mechanical properties of welded A105 and A106 steels has been evaluated. According to the mechanical and microstructure test results, increasing in welding pass number causes reduction in grain size and increasing in average hardness of HAZ. Also inter pass slag inclusion defect occurred in high number of passes.

Introduction

A105 and A106 steels are the low carbon steels which are used in pipes and fittings in the oil and gas industries. Although from the point of view of their composition, these two types of steels are closes to each other but the application of A105 steel is to manufacturing the forged parts such as different types of fittings and A106 steel in manufacturing of seamless tubes. Different types of welding methods are used to join these two types of steels. The mechanical properties of the weld metal in these steels depend on the type of welding process and its parameters. For example increasing welding current intensity causes increasing in heat input which leads to grain growth in HAZ and then reduces mechanical properties of weldments.A105 and A106parts joined together with TIG method by changing current intensity and pass numbers, then macro and microscopic evaluations, hardness, tensile, impact and bending tests accomplished.

Experimental procedure

The 4" A106 steel pipes and A105 steel flanges were used for welding. The joint design implemented to weld was in the shape of single-V and the root gap and root face values, respectively, were as shown schematically in Fig.1.

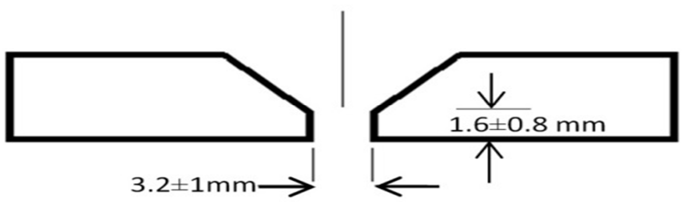


Fig. 1. Joint design for welding A106 pipes to A105 connections/connectors

TIG method was used for the welding of samples and parameters which changed during welding were current intensity (60, 80 and 100 amp) and the number of weld passes (three and five passes).

Results and discussion

The effect of current intensity illustrated as stereomicroscope images in Fig .2.as shown in low current sample S1 (60amp), insufficient penetration welding, defect has seen in the weld root zone due to the reduced heat input and low temperature to melt filler metal, while in the samples of S2(80amp) and S3(100amp) are free of defects.

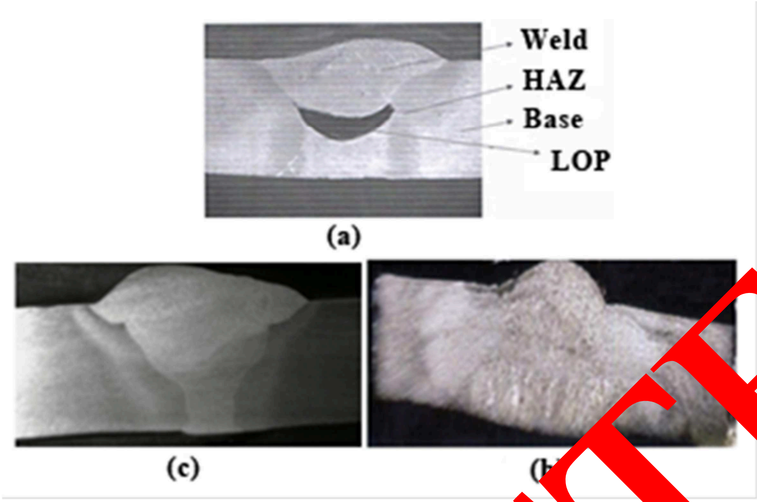


Fig. 2. Macroscopic Images of welded samples in different current
(a) S1 (60 amp), (b) S2 (80 amp), (c) S3 (100 amp)

Tensile test results of welded samples in two positions (6 and 12) with 80 and 100 amp shown in fig.3 for the welded sample under the 60 amp current intensity the tensile test has not been carried out due to the failure to investigate the macroscopic defects due to the lack of penetration defect.

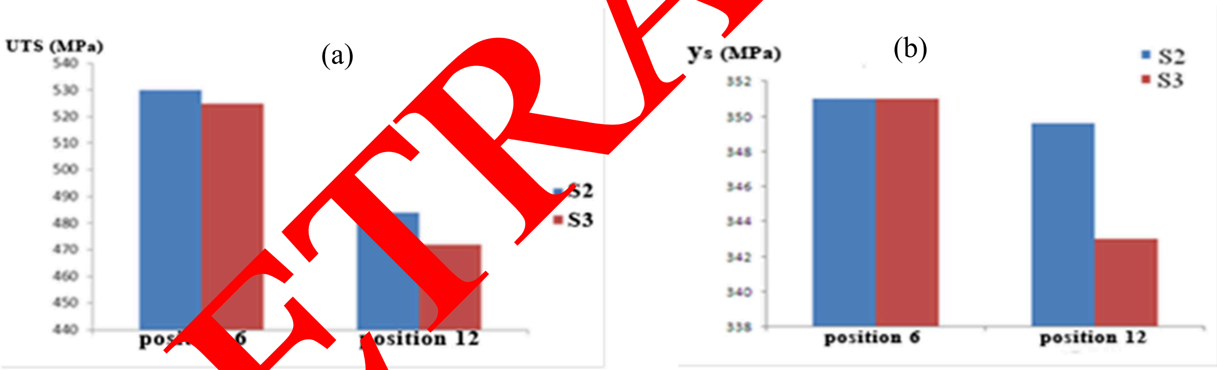


Fig. 3. (a) the yield stress and (b) the ultimate strength of welded samples in the currents intensities of 80 mA (S2) and 100 mA (S3) in positions 6 and 12

Considering the results in Fig.3, the yield stress and ultimate strength of welded samples with the 80 amp at both positions (6 and 12) is higher value in comparison with the 100 amp. as shown in Fig.4. Due to the increase of heat input with increasing of current from 80 to100am, the grain size of the HAZ in the S3 increased then hardness decreased from 149 in S2 to 141HV in S3.

It is expected that the tensile features of weld in this sample would be less than the 80 amp sample as can be seen from tensile test results.

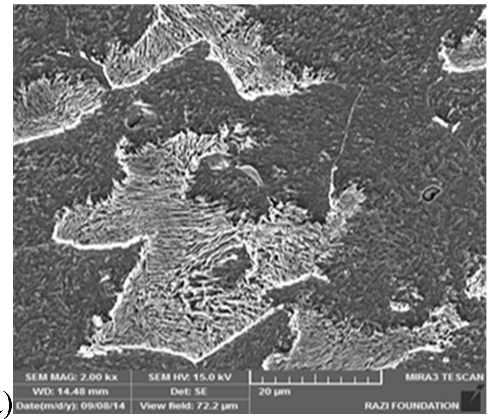
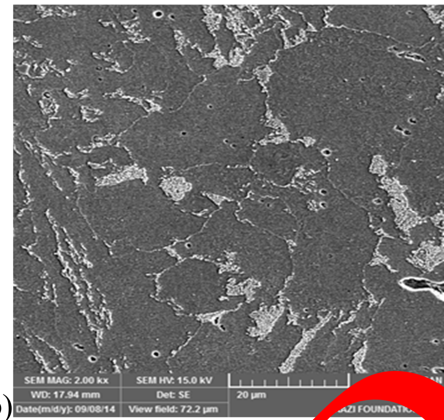
(a) 
(b) 

Fig. 4. SEM image of the HAZ (a)S3(100amp) and (b) S2(80 amp) –mag.2[illegible]

Impact test results of welded samples with the current intensities of 80 and 100 amp are shown in Fig. 5. It is observed that the welded sample under the current intensity of 80 amp shows higher impact resistance.

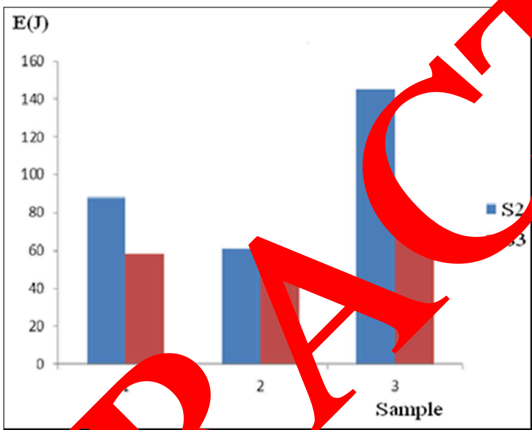
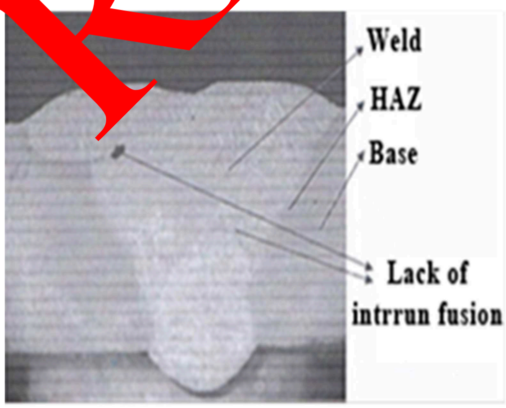


Fig. 5. Comparative graph of [illegible] welded samples S2(80 amp) and s3(100 amp)

Passes number effect

Macroscopic feature of S4 sample prepared by stereomicroscope with 10X has been shown in Fig. 6(a). The sample is welded with the current intensity 80 amps and 5 passes. SEM image of this sample has been shown in fig 6(b). Entire welding conditions of this sample were same as S2 sample and the only difference of these two samples is in the weld passes. As it is observed, increase of weld pass number from 3 passes to 5 passes, has caused the remaining of slags across the passes. This defect can cause the decrease of strength and resistance against impact.

(a) 

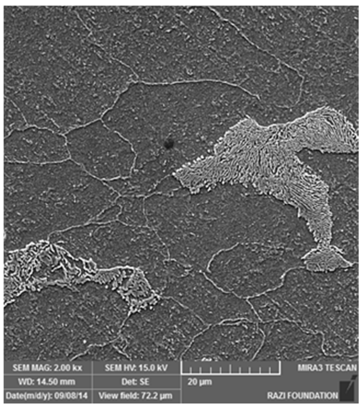
(b) 

Fig. 6. (a) Stereo microscopic image of S4 (80amp-5pass) and (b) SEM image of the HAZ in S4-mag2.00kv

The hardness profile of two samples of S2, S4 has been compared with each other in fig.7.

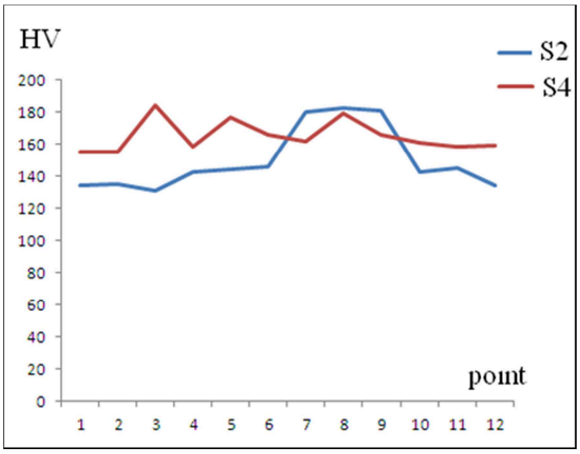
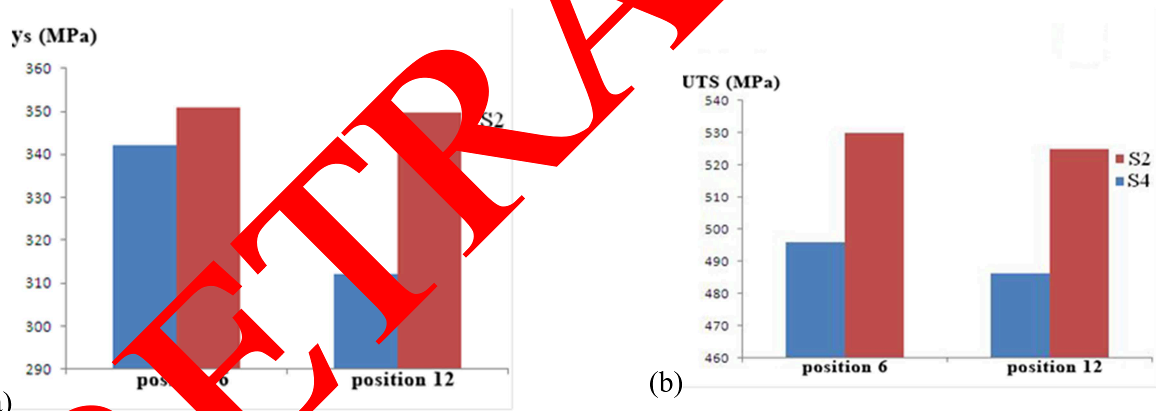


Fig. 7. Hardness changes in S2 and S4 samples

Comparison of the hardness values of welded sample with 5 passes (S4) and sample welded with 3 passes (S2) indicates that the increasing welding passes from 3 to 5 caused to increase the average hardness values from 149 to 165.34 Vickers. By reducing the number of welding passes, due to increasing of heat-input and also prolongation of welding time and duration of solidification, the HAZ is, consequently, causes the decrease of hardness. As seen in Figure 7. In addition of being higher of S4 hardness of different points compared to S2, in the welded samples in 5 passes the hardness difference on different points is lesser that results from the input temperature decrease in passes. From the Comparison of microscopic structure images in fig.6.(b) with fig.4.(b) is clear that the HAZ grain size in the S4(80amps-5pass) (S2) is smaller than in S2(80amps- 3 passes). In Fig .8. The yield strength and ultimate strength of welded samples in 3 passes (S2) and 5 passes (S4) have been compared with each other in positions 6 and 12.



(a) (b)

Fig. 8. Yield strength (a) and ultimate strength (b) of welded samples in 3 passes of (S2) and 5 passes of (S4) in positions 6 and 12

Comparison of welded sample Strength in 5 passes (S4) with welded strength sample in 3 passes (S2) indicates that the increase in pass welding of 3 to 5 is decreased yield strength from 351 to 342 Mpa and of ultimate strength from 530 to 495. The reason for this decrease is the likely increase of defects in the weld passes that the sample of these defects has been shown in the form of remaining slag between passes as showed in Fig.6.

In Fig.9. the results of impact test samples welded in 3 passes (S2) and 5 pass (S4) are compared with each other.

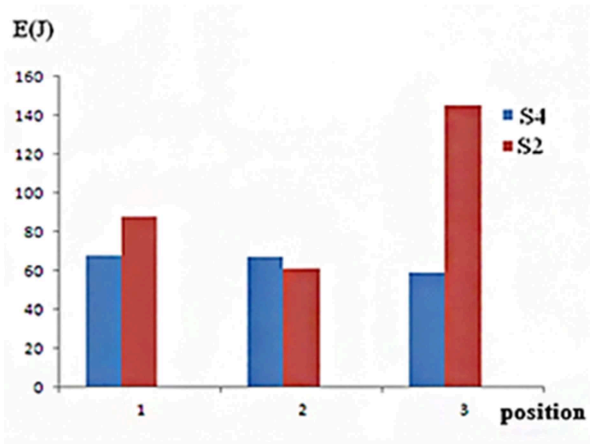


Fig. 9. Impact test results for samples (S2) welded in 3 passes, and (S4) 5 passes

The comparison of resistance to impact for samples welded in 5 passes (S4) and 3 passes (S2) with similar conditions of current intensity, welding speed, temperature and all effective parameters indicate that the increase of weld passes from 3 to 5 decreases the absorbed energy from 88 to 67 Jules in sample 1 and from 145 to 52.1 Jules in sample 3. Considering the microscopic study of this sample with stereoscope in which entrails/waste have been observed, the same matter can be a reason for decreasing the amount of resistance to impact.

Summary

1- In the joint welding of A105 to A106 steels, based on the macroscopic evaluations and mechanical testing results, current intensity of 80amps was selected as appropriate current intensity among the 60, 80 and 100 amps, hardness in this current intensity was 149 Vickers, the ultimate tensile strength is 530 MPa and impact resistance is 140 J.

2- The decrease in current intensity causes the LOP defect (Lack of penetration) in weld root, and increasing current intensity, causes the loss in mechanical properties of joint.

3- Appropriate Number of passes in joint welding of A105 to A106 steel is three Passes. The increase of passes numbers from 3 to 5 causes the developing of inclusion defect in welding and reducing the mechanical properties such as resistance to impact and strength. (Increasing pass number from 3 to 5 causes a decrease in absorbed energy from 88 to 67 joules in position 1 and from 145 to 52.1 J in position 3).

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