Effect of filler metal on mechanical properties and corrosion behavior of dissimilar metals welds

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Abstract

This work purposes to investigate the microstructure and the mechanical behavior of dissimilar metals weld between 2205 duplex stainless steel (UNS 31803) and high strength low alloy steel API X52. The joining was produced by shielded metal arc welding process using two different filler metals, the duplex E2209 and austenitic E309 grade.

The microstructures of the dissimilar welded joints have been investigated by optical microscopy, scanning electron microscopy and energy-dispersive spectroscopy (EDS). The EDS analysis performed at the API X52/weld metal interface showed an evident gradient of Cr and Ni between fusion and type II boundaries, where the highest Nano hardness value was recorded.

Keywords: Dissimilar metals welding; 2205 duplex stainless steel; API X52 HSLA steel; Heat-affected zone.

1. Introduction

Dissimilar metal welding (DMW) is a joining technique most often used where a transition in mechanical properties and/or performance in service are required [1]. Currently, dissimilar material joining is inevitable in engineering industries; it is particularly applied between stainless steel to carbon or low alloy steels which are widely used in pressure vessels, boilers, heat exchangers of power generation industry and petrochemical plants [2,3].

The joining of dissimilar materials is generally more challenging than that of similar materials, due to various factors such as the differences in chemical compositions, physical and mechanical properties of the base metals welded. These differences cause a serious complication in selection of filler metals which is compatible to both base metals [4,5].

During dissimilar welding, some problems and difficulties may occur, such as the formation of brittle intermetallic phases caused by the carbon migration from the higher carbon-containing alloy to the relatively lower carbon alloy steel. This carbon migration causes loss in strength of ferritic material adjacent to the weld interface and an increase in hardness of the weld metal (carbon-enriched zone) [6-7].

2. Experimental material and procedure

The parent metals used in this study are 2205 duplex stainless steel (2205 DSS) and high strength low alloy steel API X52. The materials were received in tubes form of 152.4 mm diameter and 12mm in wall thickness. The chemical composition of base and weld metals is given in Table 1.

Table 1: Chemical composition of base and filler metals

Elements		C	Si	P	Cr	Ni	Mn	Mo	N
Base	SAF 2205	0.029	0.46	0.002	21.58	5.27	1.7	2.98	0.19
metals	API X52	0.14	0.24	0.017	0.058	0.041	1.2	0.014	-
Filler	E2209	0.03	0.90	0.026	21.8	6.8	1.0	3.1	0.15
metals	E309	0.04	0.56	0.03	19.9	9.8	1.4	0.8	-

A single V groove is prepared with an angle of 60°. The schematic of the welded joint is shown in figure 1. The welding parameters used were voltage: 22-28 V; current: 80-110A and welding speed: 70-90 mm min^{-1}.

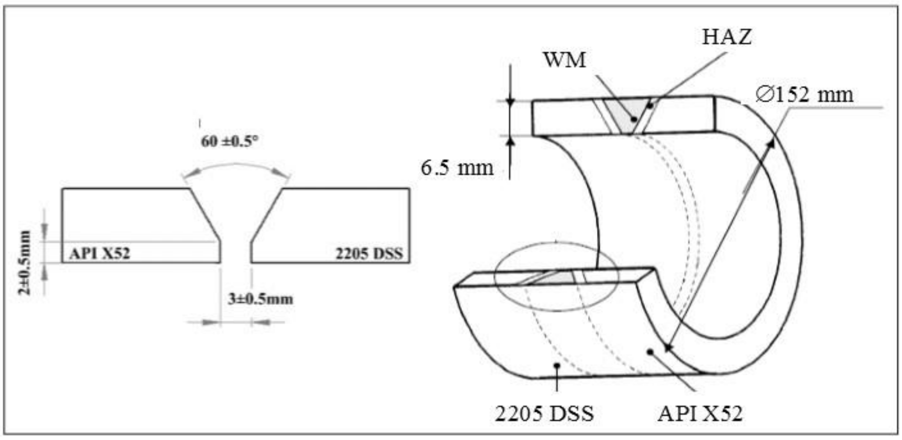

Fig.1: Single V groove welded joint

Metallographic sections transverse to the welding direction were prepared for optical metallography using standard techniques for mechanical polishing. The etching of X52 steel was carried out with

Nital (100 mL of ethyl alcohol and 2 mL of nitric and the DSS was etched with a solution of Glycerigia, containing 10 ml HNO3, 20 ml glycerol and 30 ml HCl.
Microstructural investigation of the weldments was done using a ZEISS optical microscope and scanning electron microscope (JEOL JSM 6360). The ferrite and austenite volume fractions were estimated by automatic image analysis adapted to the optical microscope. Eenergy dispersive X-ray spectrometry (EDS) was employed to determine the distribution of alloying elements across the base and weld metals interfaces.
In order to study the mechanical behavior of the dissimilar metals welded joints, Nano hardness and impact tests were executed.

3. Results and discussion

3.1 Microstructure

The microstructures of API X52 and 2205 DSS steels base metals and are shown in Fig. 2a and Fig.2b respectively.

The DSS base metal (DSS BM) microstructure revealed an elongated grain structure, where austenite (γ) phase is distributed in the ferrite (δ) matrix with average amounts of 54% of ferrite and 46% of austenite.

While the microstructure of X52 base metal (X52 BM) consists of a rolled microstructure mainly formed by a ferritic matrix (light area), and pearlite phases (dark area).

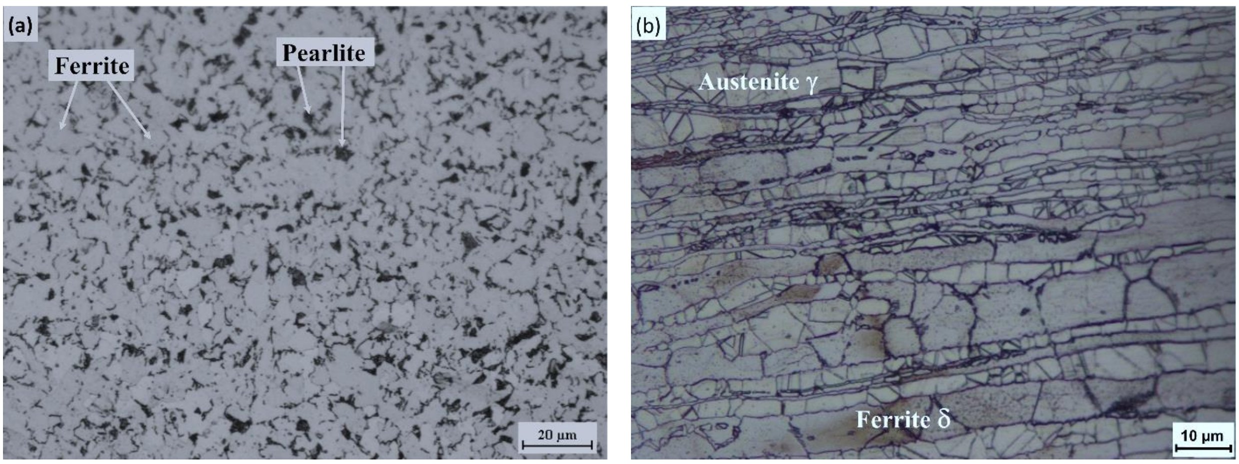

Fig. 2. Optical micrographs of base metals: (a) API X52 Low alloy steel, (b) 2205 Duplex stainless steel

The optical micrographs of the weld metals (E309 WM and E2209 WM) are shown in Fig. 3a and 3b respectively. Both of weld metals structures are composed of ferrite and austenite; a structure of an interdendritic ferrite in austenite matrix structure is found in the E309 weld metal, while widmanstätten austenite grains within a matrix of ferrite is observed in the micrograph of the E2209 weld metal.

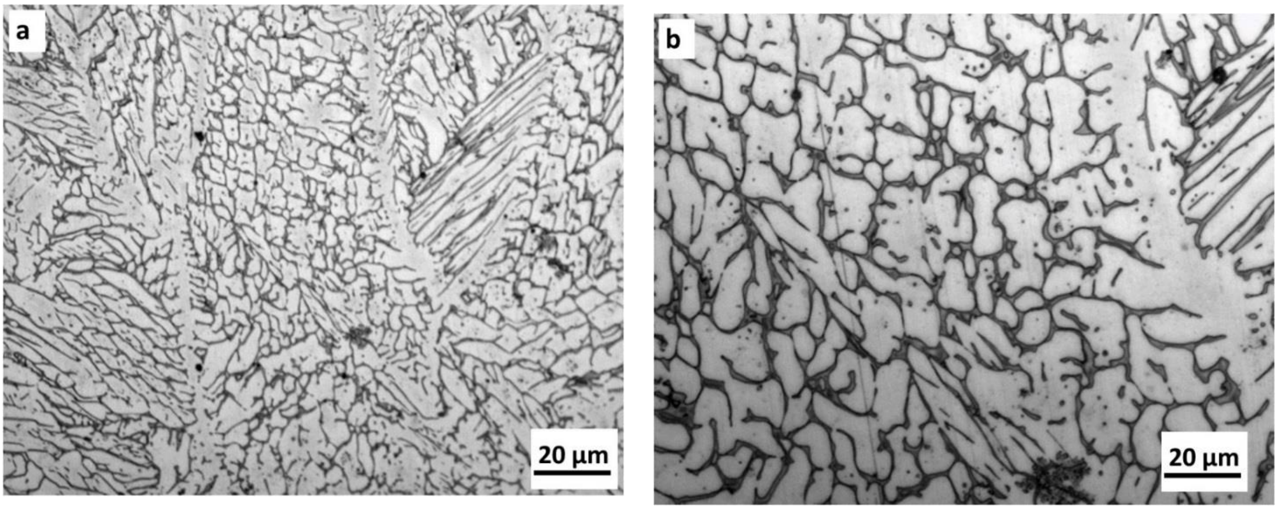

Fig.3. Optical micrographs of weld metals: (a) E2209WM, (b) E309 WM

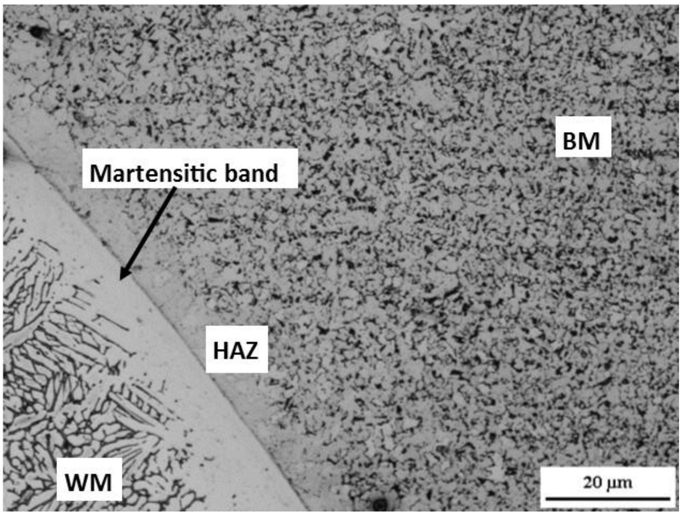

Fig. 4. Microstructure of the X52steel/weld

Because of the weld metal was richer in Cr which has a high affinity for carbon, a migration of carbon occurred during welding from the API X52 steel base metal into the weld metal. This result in the development of a narrow carbon depleted region (Fig. 4), about 10 µm in width. [8]. In the other hand, the metallographic exam reveals the presence of a hard narrow zone of about 20 µm between the fusion boundary and the type II boundary, called “Martensitic band” [9, 10] .

As can be seen in Fig. 5a, the EDS line scanning performed at the X52 steel-weld metal interface reveals a clear concentration gradient of alloying elements (Cr, Ni and Mo). Close the fusion line, the chromium content decreased significantly, more greatly than that of Nickel. These gradients are generated by the diffusion of carbon, the dilution and the rapid cooling of the weld fusion. The EDS profile taken across the WM-DSS interface did not show much variation in the chemical composition (Fig. 5b).

(a) (b)

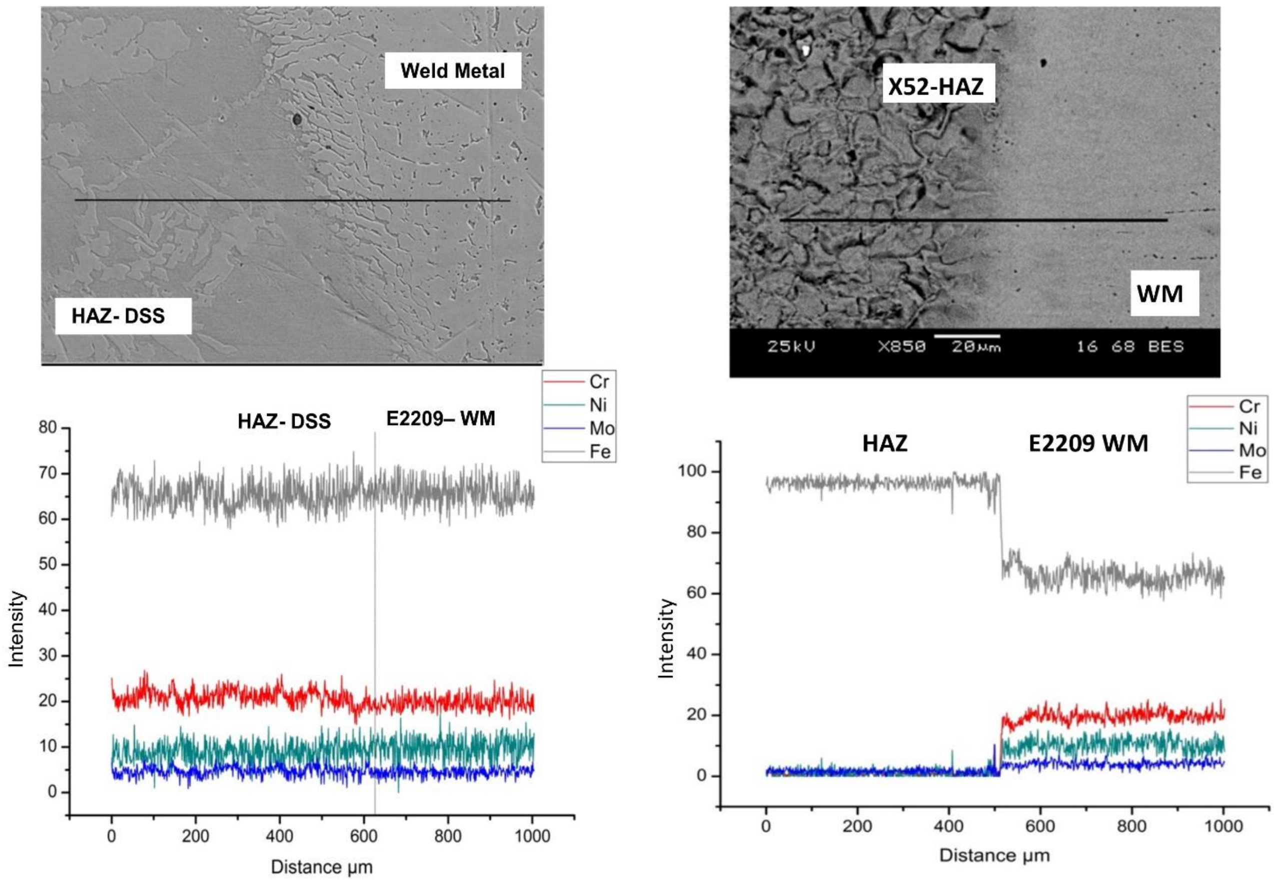

Fig. EDS line scan-showing variation of alloying elements across the interface: (a) DSS HAZ-WM interface, (b) X52 HAZ-WM interface;

3.2 Mechanical properties

Figure 8 shows the load-depth relationships for the different zone of the dissimilar weld joint in the X52 steel side. It can be seen clearly, that the nano-hardness in the narrow zone between the fusion boundary and type II boundary is higher (9.1GPa) than that in the HAZ of the X52 steel (2.8GPa) . This can be explained by the formation of harder micro- constituents in this region, caused by the carbon migration from the X52 steel side into the weld metal.

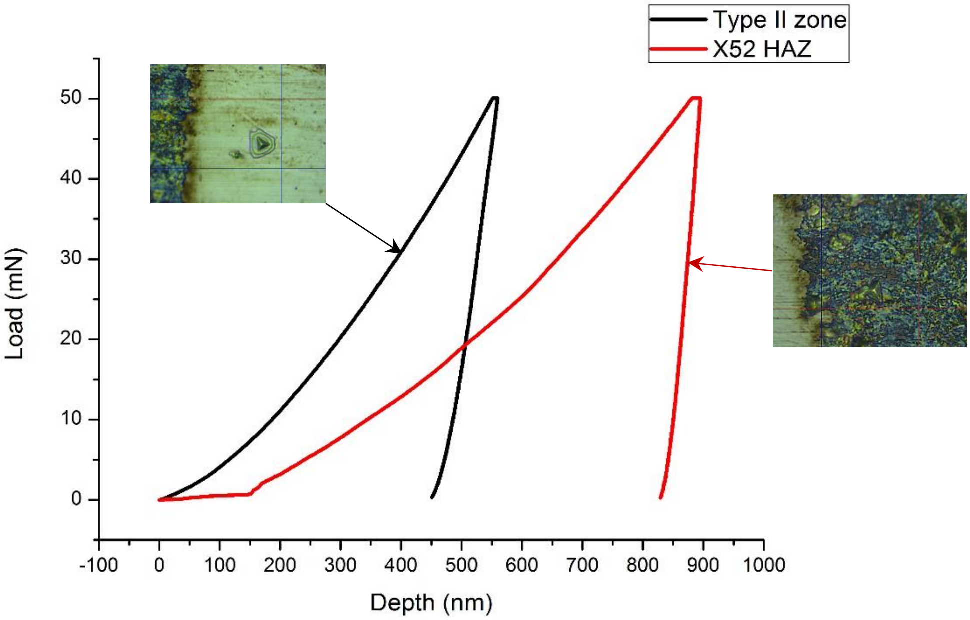

Fig. 8. Load-depth curves for X52 HAZ and Type II zone

The weld metals specimens reveal a ductile fracture mode, where a large number of dimples can be observed. More fine dimples are distributed in E309 WM compared to E2209 WM (Fig.9).

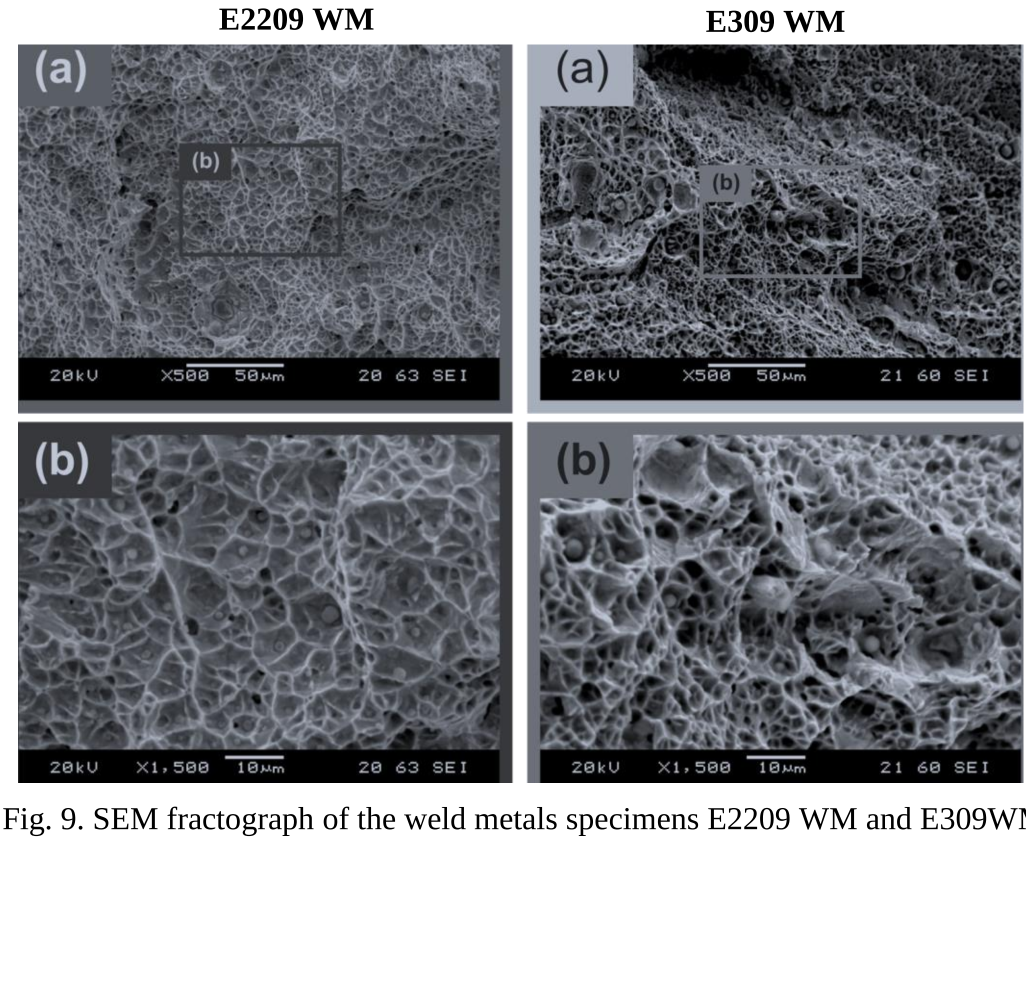

Fig. 9. SEM fractograph of the weld metals specimens E2209 WM and E309WM

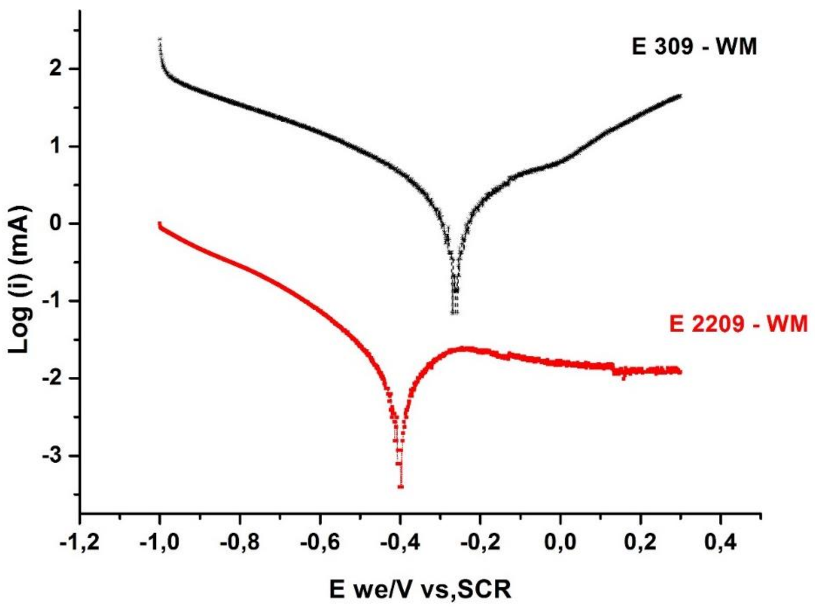

Fig. 10 Potentiodynamic polarization curves of weld metals in 3.5% H2SO4 solution at room temperature

Figure 10 shows clearly that E309 WM exhibits higher corrosion resistance in 3.5% H_2SO_4 solution than E2209 WM one. This can be explained by the high ferrite content in E2209 WM compared to E309 WM.

4. Conclusion

The investigations on dissimilar welding between 2205 DSS and API X52 HSLA steel by SMAW using two different filler metals reach the following conclusions:A type II boundary is formed in the dissimilar weld metals between 2205 DSS and API X52 HSLA steel, for both weldments performed with E2209 and E309 electrodes.

A highest value of Nano hardness is recorded in the narrow zone between the fusion boundary and type II boundary, which is attributed to the presence of micro-harder micro-constituents in this region. Both the weld metals specimens reveal a ductile fracture mode.

Corrosion resistance behavior of the weld metal produced by E309 electrode is better than that produced by E2209 electrode.

References

[1] J. Lippold and D. Kotecki, *Welding Metallurgy and Weldability of Stainless Steels*. 2005.

[2] K. D. Ramkumar, N. Arivazhagan, and S. Narayanan, “Comparative assessment on microstructure and mechanical properties of continuous and pulse-current GTA welds of AISI 304 and Monel 400,” *Met. Mater.*, vol. 52, pp. 287–298, 2014.

[3] J. Wang, M. X. Lu, L. Zhang, W. Chang, L. N. Xu, and L. H. Hu, “Effect of welding process on the microstructure and properties of dissimilar weld joints between low alloy steel and duplex stainless steel,” *Int. J. Miner. Metall. Mater.*, vol. 19, no. 6, pp. 518–524, 2012.

[4] M. Jafarzadegan, a Abdollah-Zadeh, a H. Feng, T. Saeid, J. Shen, and H. Assadi, “Microstructure and Mechanical Properties of a Dissimilar Friction Stir Weld between Austenitic Stainless Steel and Low Carbon Steel,” *J. Mater. Sci. Technol.*, vol. 29, no. 4, pp. 367–372, 2013.

[5] R. Kaçar and O. Baylan, “An investigation of microstructure/property relationships in dissimilar welds between martensitic and austenitic stainless steels,” *Mater. Des.*, vol. 25, no. 4, pp. 317–329, 2004.

[6] C. Pan and Z. Zhang, “Characteristics of the weld interface in dissimilar austentic-pearlitic steel welds,” *Mater. Charact.*, vol. 33, no. 2, pp. 87–92, 1994.

[7] T. Vigraman, R. Narayanasamy, and D. Ravindran, “Microstructure and mechanical property evaluation of diffusion-bonded joints made between SAE 2205 steel and AISI 1035 steel,” *Mater. Des.*, vol. 35, pp. 156–169, 2012.

[8] A. Eghlimi ,M. Shamanian, M. Eskandarian, A. Abolian, M. Nezakat , J. A. Szpuna, "Evaluation of microstructure and texture across the welded interface of super duplex stainless steel and high strength low alloy steel", Surface & Coatings Technology 264,150–162, 2015.

[9] B. I. Mendoza, “Dissimilar Welding of Superduplex Stainless Steel/HSLA Steel for Offshore Applications Joined by GTAW,” *Engineering*, vol. 02, no. 07, pp. 520–528, 2010.

[10] P. B. Srinivasan, V. Muthupandi, W. Dietzel, and V. Sivan, “An assessment of impact strength and corrosion behaviour of shielded metal arc welded dissimilar weldments between UNS 31803 and IS 2062 steels,” *Mater. Des.*, vol. 27, no. 3, pp. 182–191, 2006