A comparative study on the Effect of Electrode on Microstructure and Mechanical Properties of Dissimilar welds of 316L Austenitic and 430 Ferritic Stainless steel

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Abstract: This paper aims to study the different welding processes such as Shielded metal arc welding process (SMAW) and Gas metal arc welding process (GMAW) which is used to weld dissimilar stainless steel 316L austenitic stainless steel(ASS) and 430 Ferritic stainless steel (FSS) having 3mm thickness with single pass. Microstructures were observed by means of optical microscope with Villella's reagent. The austenitic and ferritic grain boundaries were observed and the grain growth and the interface boundaries were observed in the weld zone, interface zone and heat affected zone in both the welding processes. The results of tensile and impact tests revealed that GMAW has higher tensile strength than SMAW. The hardness test revealed that in SMAW weld zone the hardness is higher than GMAW.

1. Introduction

The different welding is famous in different ventures like chemical, petrochemical and shipbuilding industries [1,2]. These industries are using 316L austenitic stainless steel which contain nickel which increases the mechanical and corrosion properties of the material. But the cost of nickel is increasing day by day, so industries are looking for alternative material which will increase strength and corrosion. These industries are using ferritic stainless steel as an alternative which increases strength and corrosion. The 430 ferritic stainless steel (FSS) shows low weldability and grain development in the weld zone (WZ) and heat impacted zone (HAZ) because of the shortfall of stage change. Therefore, for sound joint of austenitic and ferritic stainless steel, selection of fillers and welding processes is the important criteria. The studies based on 316L ASS and 430 FSS shows that the two dissimilar joints can be welded by different types of fillers and welding processes. Sara Aguilar et.al [3] welded 316L ASS and 430 FSS by means of SMAW by using E309L and E2209-16 electrode. They found that, the tensile strength is similar, but microhardness varies in the fusion zone of the weld due to the difference in delta-ferrite of the fillers. A.M. Barrios et. al [4] welded 430 and 316L by GMAW using two different shielding gas mixtures composed of 97Ar-3N2 and 80Ar-19He-1O2. The weld joints are compared with the samples immersed in a hydrochloric acid solution for 24 and 72 hours with non-immersed samples. They found that, the yield strength and percentage elongation changes with respect to immersion time as ultimate strength remains unchanged. The microhardness and corrosion are highest in 430FSS heat affected zone (HAZ) side as the intergranular and pitting corrosion increases with respect to immersion time. D.Jeraldnavinsavio et.al [5] welded 316L and 430 by TIG process by utilizing ER310 and ER2594 fillers and observed that the rigidity is most noteworthy for ER2594 but the micro hardness values are similar for both the joints. From the above studies, it has been noted that 316L ASS and 430 FSS can be welded by different welding processes but the comparison between the GMAW and SMAW with 309L filler have not been studied yet and this is the area of study.

Experimental Work

1.1 Sample Preparation

Two plates of 316L ASS and 430 FSS of 100 mm length,75 mm width and 3 mm thickness were welded with SMAW and GMAW process. Compound organization (wt%) of the BM and fillers is given in table 1. The plates were sliced through wire cut Electrical Discharge Machine (EDM) for the various samples for mechanical and microstructural testing. Single pass SMAW and GMAW with ER309L filler was used. Single butt joint with root hole of 1.2 mm was performed at a steady current of 90 A. Argon gas is utilized as a protecting gas with a stream pace of 15 l/min. Trial set-up of SMAW and GMAW as displayed in fig.1.Table 2 shows welding boundaries with various filler materials. The intensity input (HI) is determined as

$$HI = \eta \times \frac{V \times I}{w} \quad KJ/mm \ldots\ldots\ldots\ldots\ldots\ldots \text{eq.1}$$

Where, η-effectiveness of GMAW as 0.7, V-voltage in volts (V), I-welding current in amperes (A) and w-welding speed in mm/s [8]

Table 1: Chemical Composition (wt %) of base metal and filler materials

Materials	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Fe
AISI 316L ASS	0.028	0.454	1.101	0.036	0.0012	16.470	2.103	10.021	0.002	0.178	0.281	Bal
AISI 430 FSS	0.030	0.170	0.78	0.032	0.0047	16.00	0.0079	0.13	0.0011	0.0098	0.0145	Bal
ER 316L Filler	0.029	0.405	1.13	-	-	17.13	2.062	10.185	-	-	0.3	Bal

ER 309L Filler	0.037	0.185	1.68	0.018	0.005	23.45	0.75	12.6	4.0	-	-	Bal

Fig.1: Experimental set-up for Welding

Table 2: Welding parameters for SMAW and GMAW process

Parameters	GMAW	SMAW
Polarity	DCEN	DCEN
Arc Voltage	12 V	12 V
Welding Current	90 A	90 A
Welding Speed	1.90 mm/sec	1.84 mm/sec
Electrode diameter	1.5 mm	2.5 mm
Electrode Material	309L	309L
Root gap	1.2 mm	1.2 mm
Shielding gas	Argon	
Shielding gas flow rate (l/min)	16	16

1.2 Microstructural properties

Subsequent to welding, tests were cut with aspect of 10 x 10 x 3 (mm) to investigate the microstructure and microhardness. All weld tests were cleaned with silicon carbide cleaning paper with various coarseness sizes. To notice the microstructure of BM and WM the examples were electrochemically carved in Villela's reagent. Different welding locales were investigated and metallographic assessment were completed in Zeiss Axio optical magnifying instrument..

1.3 Mechanical properties

Hardness test is acted in Vicker's hardness test set up by taking a consistent heap of 500 gm for 10 seconds. Tractable properties like yield strength, extreme elasticity and rate extension of the joints are surveyed utilizing widespread testing machine (UTM). V indent Charpy influence test was performed at room temperature having an example size of 3 x 10 x 55 (mm). Three samples were taken for each test and average value is taken for each test for data reproducibility.

2. Results and discussion

3.1 Microstructural Examination:

Fig1. 430 Base metal

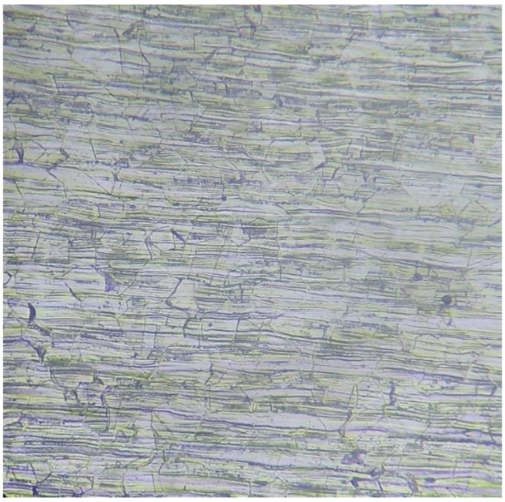


Fig2. 316L Base metal

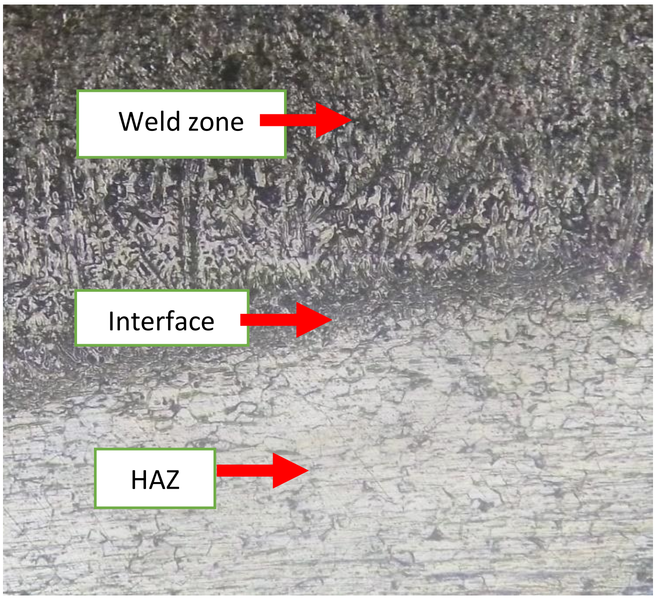


fig3. (a)

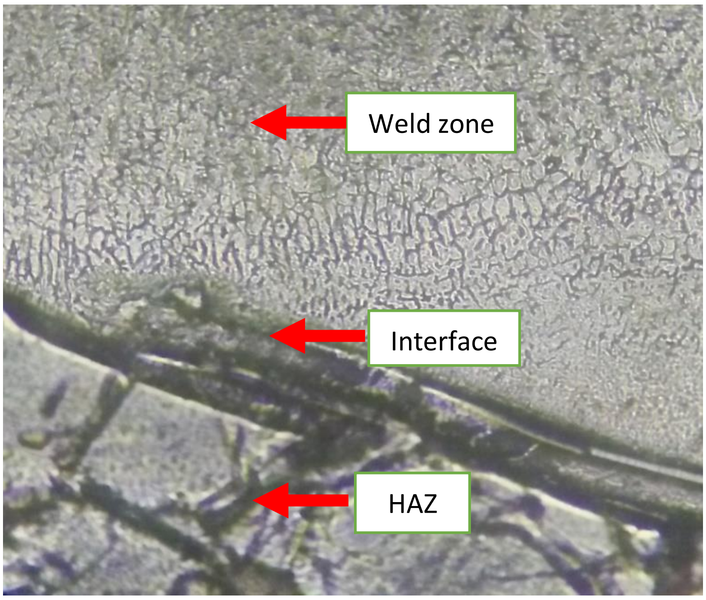


fig3. (b)

Fig3. (a) 430 heat affected zone and Fig3. (b) 316L heat affected zone of SMAW

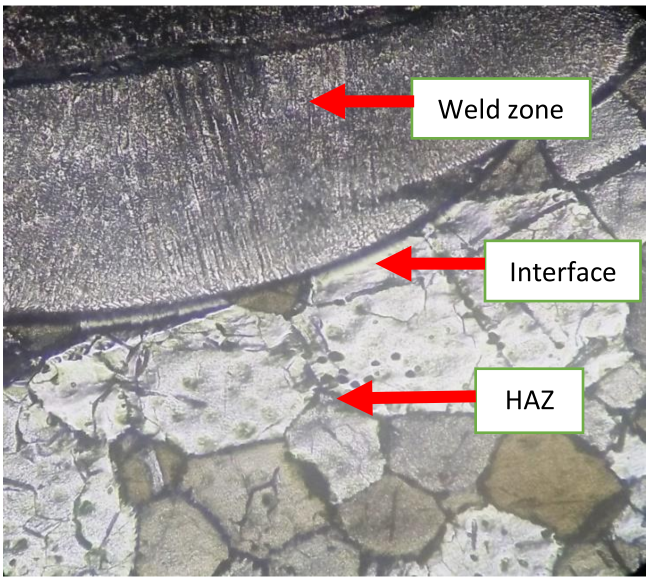


fig4. (a)

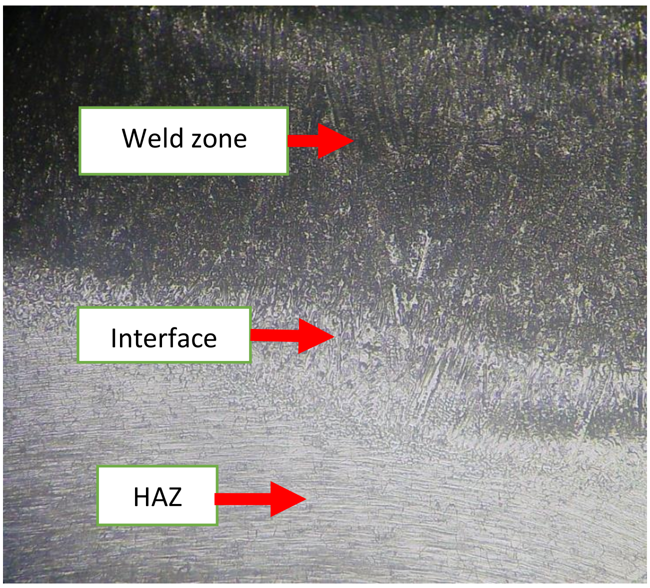


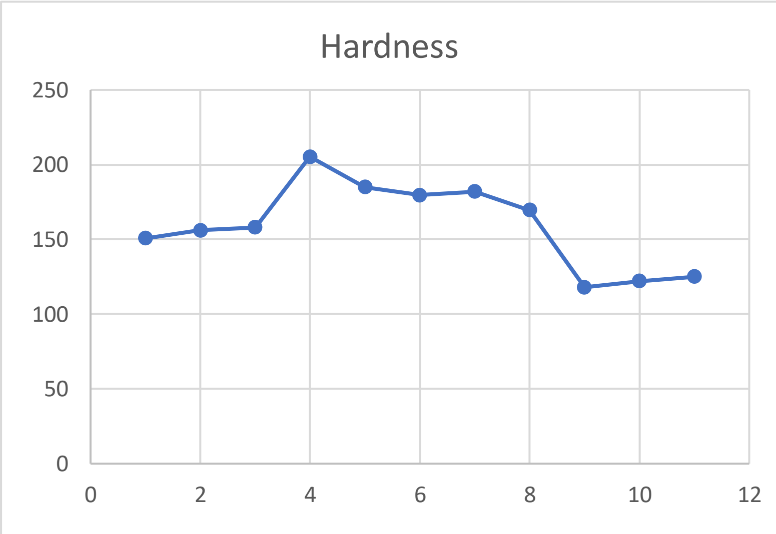
fig4. (b)

Fig4. (a) 430 heat affected zone and Fig4. (b) 316L heat affected zone of GMAW

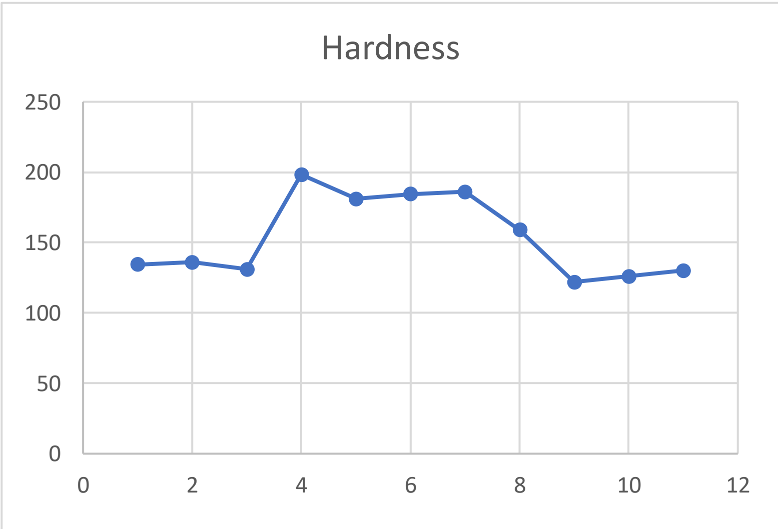
Optical magnifying lens with Villella's reagent was used to see the microstructures of the welds. The austenitic and ferritic grain limits were noticed and the grain development and the point of interaction limits were seen in the weld zone, interface zone and intensity impacted zone in both the welding processes [6].

3.2 Micro-hardness Test

It was observed that the hardness of SMAW weld zone is greater than the GMAW weld zone due to the higher grain boundaries in SMAW [7-9].



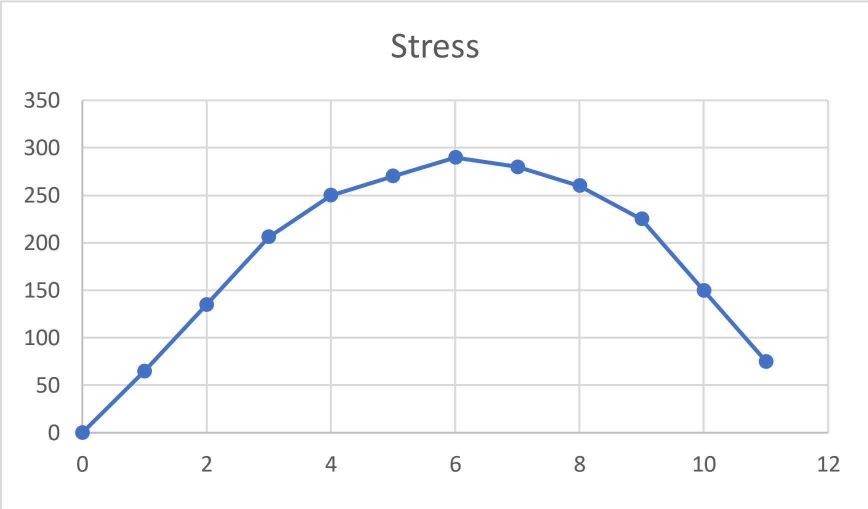
SMAW



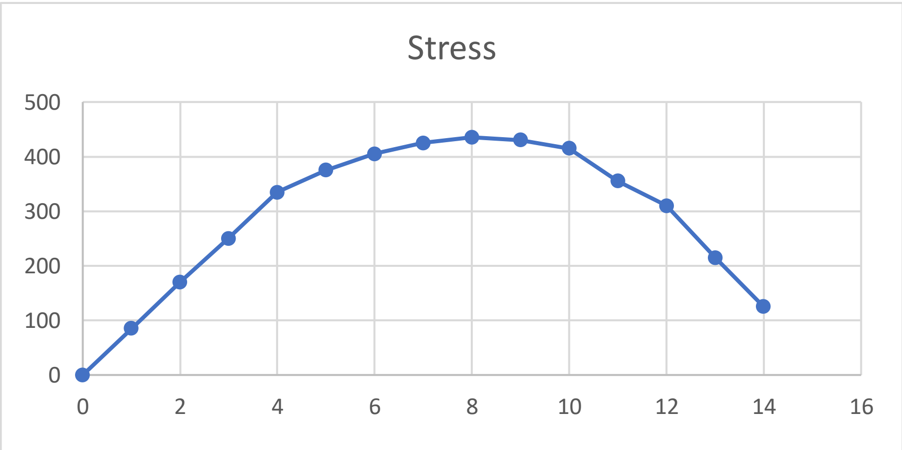
GMAW

3.3 Tensile test:

The tensile test reports show that the GMAW has more strength than the SMAW because of welding speed is higher in GMAW than SMAW [10-12].

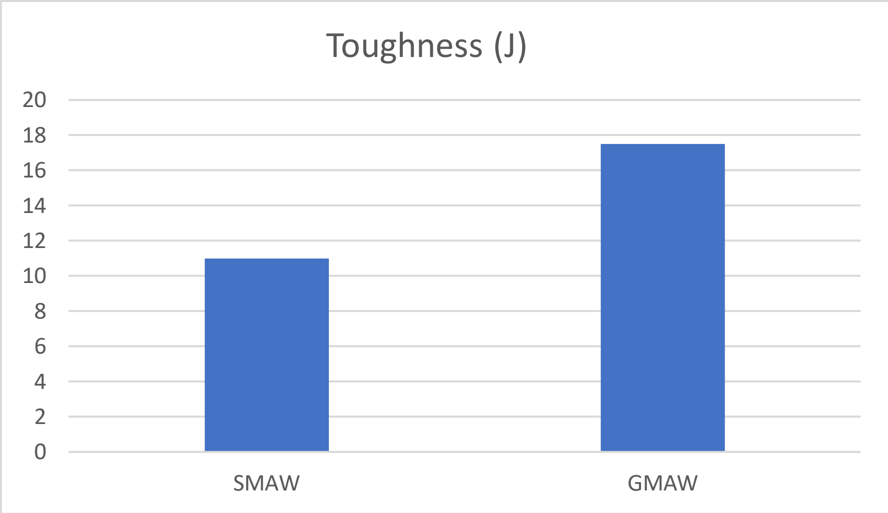


SMAW



GMAW

3.4 Impact test: In the impact test the hardness of the GMAW was found to be greater than SMAW because welding speed increases in GMAW as compared to SMAW [13-14]



3.Conclusions:

1. The microstructural study reveals that the austenitic and ferritic grain boundaries were observed and the grain growth were observed in the weld zone.

2. The tensile strength in GMAW is higher as compared to SMAW because the welding speed is higher in GMAW.

3. The toughness value of the dissimilar weld joint is higher in GMAW as compared with SMAW due to the increase in welding speed in GMAW.

4. The hardness value in weld zone or heat affected zone is larger in SMAW as compared to GMAW due to the higher grain growth or boundaries in SMAW.

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