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Effect of electrode type on the characteristics of AISI 316 Stainless Steel

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Abstract. In the present investigation, the microstructural and mechanical characteristics of welded AISI 316 austenitic stainless steels (SS) plates were studied. AISI 316 SS plates were joined using shielded metal arc welding (SMAW). different electrodes, typically, E316L-16 and E312-17 (according to AWS) have been used in welding. Tensile and hardness tests were employed at room temperature to highlight the changes in mechanical behavior of welded joints. Both macro- and microstructure examinations have been used to evaluate the effect of electrode material on phases and grains structure of the welded joints. The comparison study leads to that the AISI 316 SS specimens, welded using E316L-16 electrodes, exhibited a higher joint efficiency than those welded using E312-17 electrodes.

KEYWORDS: Stainless Steel, Microstructure, SMAW, Mechanical Properties, Electrode Material.

1. Introduction

AISI 316 stainless steels (SS) are brilliant member in family of alloys that have magnificent corrosion resistance and brilliant mechanical behaviors. Austenitic stainless steels are metallurgically simple alloys. They are either 100% austenite or austenite with a small amount of ferrite (see Table 1). This is not the ferrite to be found in carbon steel but a high temperature form known as delta (δ) - ferrite. Unlike carbon and low alloy steels the austenitic stainless steels undergo no phase changes as they cool from high temperatures. They have good strength, ductility, and machinability among alloys from higher temperatures to lower the one [1,2]. Austenitic stainless-steel presents combination mechanical behavior which makes them a demand at industrial application. It also has good formability and machinability with good strength and weldability. Typical applications for austenitic stainless steels include cooking utensils, containers and pipework in the food industry, storage vessels, pipes and tanks for corrosive liquids, architecture, mining, chemical and pharmaceutical equipment.

Shielded metal arc welding (SMAW) known as Stick welding or Manual metal arc welding uses a metallic consumable electrode of a proper composition for generating arc between itself and the parent work piece. The molten electrode metal fills the weld gap and joins the work pieces. This is the most popular welding process capable to produce a great variety of welds.[3,4]

2. EXPERIMENTAL PROCEDURES

The chemical compositions AISI 316 austenitic stainless-steel base materials are shown in Table 1.The material was received in form local market as rolled plates and then cut into plates having dimensions of (50 mm width × 600 mm length and 10 mm thickness), the plates have been prepared and machined by milling machine to make a chamfer in one side, Preparing two plates beside each other to get single V-groove with an angle of 60^{o} before welding as shown in Fig. 1. Similar joints AISI 316 austenitic stainless-steel plates (i.e. 316-316) were joined by employing SMAW technique using welding voltage about 30 Volts, DC constant welding current of 100 Ampere with reverse polarity. Four passes required to complete the welding joint with an average welding speed of 8 mm/sec. The AISI 316 SS plates were welded using E312-17 and E316L-16 AWS electrodes. The two types of electrodes which selected from Esab handbook where most suitable selection of electrodes for the base metal.

All electrodes have 3.2 mm diameter. Showed also in table 1 the chemical compositions of the different electrodes used in the present study.

Table 1. Chemical composition of AISI 316 and electrode materials (wt.-%)

	Elements (wt.-%)													
	C	Cu	Mo	Mn	Ni	Cr	Nb	W	V	Si	P	S	N	Fe
Base Alloy AISI 316	0.08	0.31	2.07	1.32	10.42	16.49	0.02	0.05	0.10	-	-	-	-	Bal.
Electrode E316L-16	0.02	0.05	2.8	0.6	11.6	18.6	-	-	-	0.61	0.03	0.01	-	Bal.
Electrode E312-17	0.14	0.05	0.07	0.9	10.1	29.1	-	-	-	0.64	0.02	0.007	0.07	Bal.

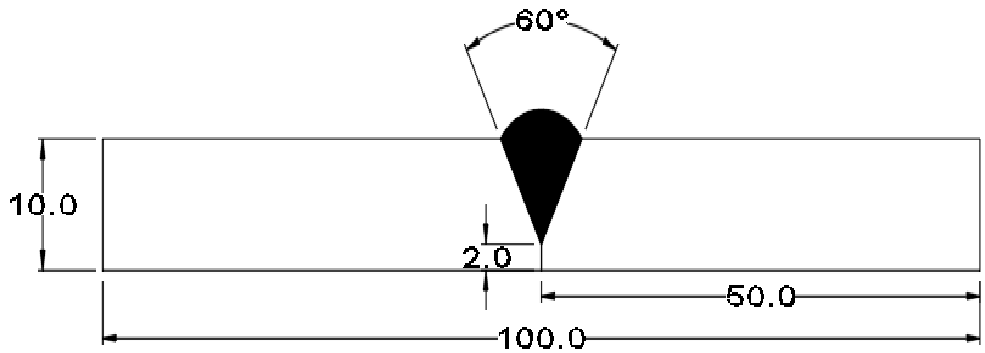

Figure 1. The welded joint configurations (dimensions in mm).

After welding process, the welded plates machined by milling machine to smoothing the welding surface then cutting samples by using laser cutting machine to prepared samples to the mechanical testing.

The tensile properties of AISI 316 SS welded joints were examined at room temperature. The tensile tests were performed using Shimadzu universal testing machine having maximum load of 200 kN. The tensile specimens were machined from the transverse sections. The crosshead speed during tensile tests is kept constant at 5 mm/min. Tensile specimens have total length of 85mm and gauge length of 50 mm and 6×8 mm^2 cross-section as shown in figure2.

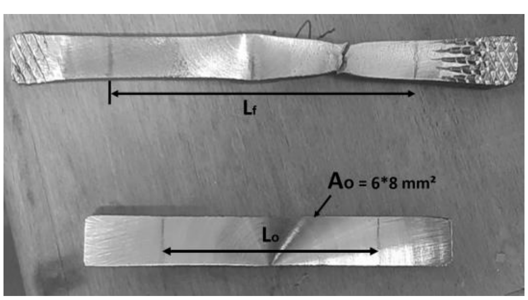

figure2 Tensile samples before and after tensile test

The welded regions were subjected to Rockwell hardness tests (HRA), which has diamond cone indentor with 120 degree. Hardness calculation was performed in the National Institute of Standard using a Rockwell Hardness Tester (Wolpert Wilson, Germany) ,according to the ASTM E18-20 standard at the thickness of all samples along the cross-section transverse to the welding direction with an internal spacing of 1 mm under a load of 60 kgf for a loading time of 15 secs.

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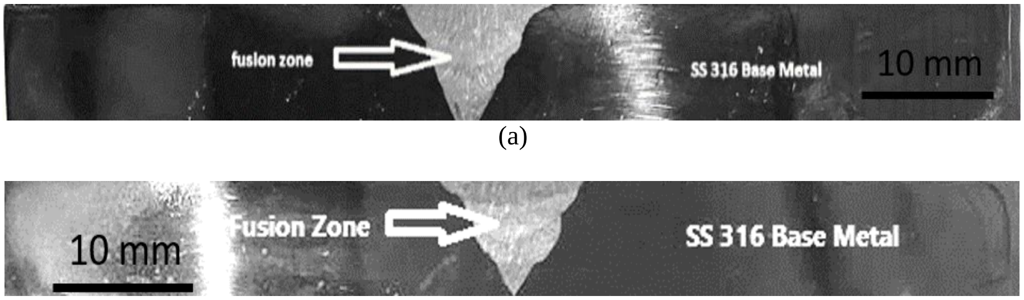
Specimens were ground under water on a Metasery Grinder 2000 polishing/grinding machine using silicon carbide abrasive discs of increasing fineness then polished using 0.1 μm alumina suspension. both macro- and microstructural examinations have been performed using a Kern Optical Metallurgical Microscope. Both micro- and macro-etching have been carried out using a V2A etching solution (100 ml of distilled water, 10 ml of nitric acid, 100 ml of hydrochloric acid) at ambient temperature.

3. RESULTS AND DISCUSSION

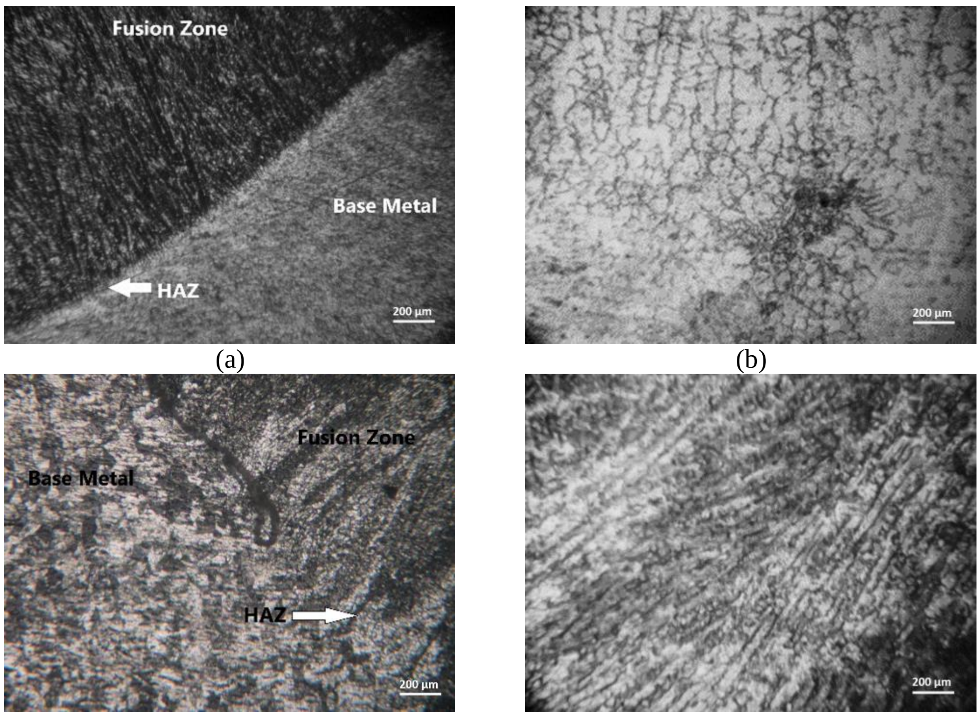
3.1. Macro- and Microstructural Examinations.

Figure 3 shows typical macrographs of AISI 316 stainless steel specimens welded using different electrodes. The fusion zones are been viewed in the macrographs. full penetration was observed. There are no imperfections in welded joints such as cracks, voids…etc[5]. Figures 4 show micrographs of the microstructure of the AISI 316 stainless steels welded regions. AISI 316 stainless steels, the fusion zones (FZ) exhibited microstructure consists of ferrite structure (dark) in austenitic matrix (light). However, in this figure was also observed at locations where the ferrite content was higher. Some coarse columnar grains in the seam center was observed as shown in figure 4.b and 4.d. Coarse long grains were observed along the heat decremental direction, in the near fusion zone of the seam as shown in figure 4.a and 4.c[6].



(b)

Figure 3. Typical photographs of the macrostructure (a) using E312-17; (b) using E316L-16 electrodes.

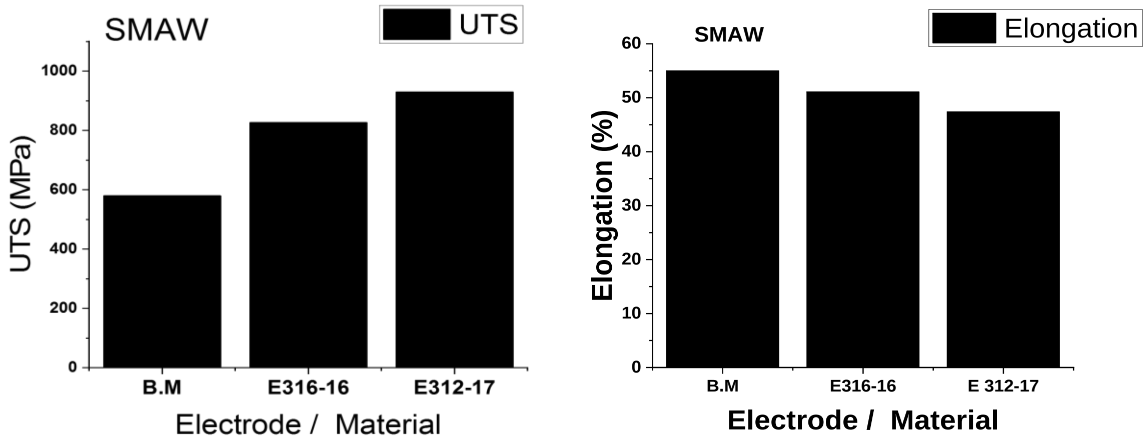


(c) (d)

Figure 4. Micrographs of the microstructure of AISI 316 SS welded using (a,b) E312-17 and (c,d) E316L-16 electrodes (×50).

3.2. Tensile strength property of the Weldments.

Figures 5.a and 5.b showed the variation of the mechanical characteristics with the electrode material for the welded AISI 316 specimens. In all cases, the welded joints showed higher tensile strength and less elongation percentage than the stainless-steel base alloys. For AISI 316 stainless steel, joints welded using E312-17 electrodes has a highest strength and lowest elongation %, but in the other hand welded spacemen using E316-16 electrodes have moderated tensile strength and percentage of elongation.



(a) (b)

Figure 5 Tensile test results (a) shows Ultimate tensile strength of SMAW samples, (b) shows Elongation of SMAW specimens

3.3. Hardness values of the Welded Regions.

Figure 6 shows the hardness profiles at the middle-height of the cross-section of the welded regions for AISI 316 stainless-steels. Generally, the fusion zones have more hardness values in middle of fusion zone and tends to decrease with a little change along the specimens. This may be due to the presence of elements of electrodes and difference in size of grains with the presence of ferrite structure in the internal structure of the welds AISI 316 SS, the regions welded using E316L-16 electrodes exhibited lower hardness than those welded using the E312-17 electrodes.

After reaching peak value, the hardness decreases in the HAZ. the HAZ, adjacent to the fusion boundary, showed fine grains size which motivates high hardness attitude, whereas the HAZ adjacent to the base metal showed grained structure with coursed which resulted lower hardness. The areas that are adjacent to the weld/fusion zone, experiences relatively faster cooling rate and hence has finer grained microstructure, whereas the area adjoining the base metal undergoes slower cooling rate. In general, it is observed from the hardness measurements that the hardness follows a decreasing trend in the order of weld metal, HAZ and base metal [7].

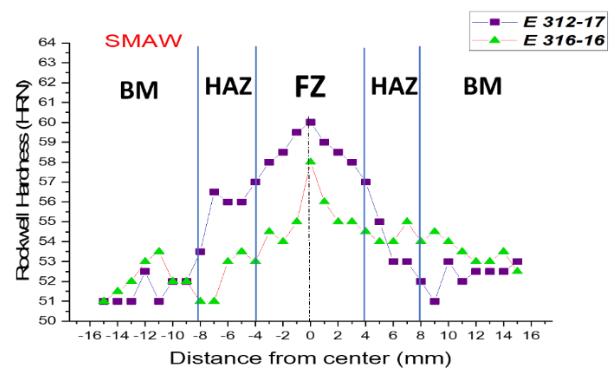


Figure 6. Hardness distribution in the welded regions for AISI 316 SS specimens
welded using E312-17 and E316L-16 electrodes.

4. CONCLUSIONS

The conclusions from the present work:

- the welded joints showed higher tensile strength and lower elongation percentage when compared with the stainless-steel base alloys. For AISI 316 stainless steel, joints welded using E312-17 electrodes exhibited slightly higher strength and lower elongation % than those welded using E316-16 electrodes.
- The relation between the UTS and Elongation % is inverse relationship.
- AISI 316 SS, the regions welded using E316L-16 electrodes exhibited lower hardness than those welded using the E312-17 electrodes, results obviously showed the hardness follows a decreasing trend in the order of weld metal, HAZ and base metal.

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