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Experimental Investigation on the effect of SMAW process on the IS 2062 grade E550 BR microstructure and Mechanical properties

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Abstract

The selection of the welding process is a significant step before fabricating welding structure. The integrity of the weld joint depends on the selection of the welding process, welding parameters along with thermal distribution across the welded section. The present study is to investigate the mechanical and microstructure in low carbon steel IS2062 grade E550 BR joints made using SMAW (shielded metal arc welding) technique. The formation of bainite and ferrite in the joint make it more brittle whereas mechanical properties increase significantly like toughness and hardness.

Keywords: SMAW, HAZ, IS2062 grade E550 BR Steel

1. Introduction

Welding is a fabrication process in which a permanent joint is made as an alternative of forging, casting, riveted and bolted joint. The welded joint formed by fusion of the joining process with or without application of mechanical pressure. There are numerous methods of heat supply for the fusion to the weld surface like electric arc or gas burning etc. SMAW process is a more acceptable welding process amongst FCAW (Fluxed cored arc welding), GMAW and SMAW (Modified short arc welding) for the fabrication of gas/liquid pipeline, boiler, pressure vessel or ship manufacturing etc. The affordable purchase cost, high welding speed, portability of equipment and excellent thermal diffusion in the heat affected zone make SMAW more useful although the dissolution of hydrogen gas in welded parts remain the causes of concern [1]. The reliability of the welding structure formed by GMAW responds differently. Balasubramania and

Guha [2] studied the welding parameters effect on toe cracking behavior. It was observed that the welded joints of ASTM 515 grade F formed by SMAW have better fatigue life than the FCAW welded joints. The formation of bainitic packets in FCAW joints reduces the fatigue life of the joint. The observation also shows that the Heat affected zone (HAZ) has better fatigue life in SMAW welded joints than FCAW (Flux cored arc welding) because of the low carbon martensite structure in FCAW joints. Higher heat input in FCAW causes rise in temperature of the heat affected zone compared to SMAW joints. The slower cooling rate of the heat affected area causes formation of the bainite [3]. The bainite formations cause poor fatigue properties.

In SMAW or shielded metal arc welding, the electric arc is made between the work piece and tip of a coated metal wire called the electrode. SMAW is sometimes called "stick" welding or manual welding. The temperature of the electric arc is over 6000° F., which is more than enough to melt metal. The coating of electrode makes the arc steadier, provides a shield of gas around the arc to keep oxygen and nitrogen in the air away from the molten metal and provides a flux for molten pool. The present study aims to investigate the mechanical and microstructure in low carbon steel IS2062 grade 550 BR joints made using SMAW (Shielded Metal Arc Welding) technique.

2. Experimental Set-up and Procedure

Experimental sample has been prepared using low carbon steel IS2062 grade E550 BR. The dimension of the experimental sample was 150 mm X 150 mm X 20 mm with V- type grooved at the welding edge as shown in Figure *1*. The experimental set-up of the experiment is shown in the Figure *2*. The experimental samples were joined using SMAW. The chemical composition of the experimental sample and the SMAW filler material is given in Table 1 and

Table *2*. The weld consumable was specified to be E7018 electrode of 4 mm diameter for deposition of all passes. Fig. xx specifies the detailed dimensions of the weld cross section for both samples and the deposition sketch for the SMAW processes. The chemical composition and mechanical properties of the weld consumables is given at Table 3 and Table *4*.

Table 1: The Chemical composition of the base metal used.

Grade Designation	*Quality*	*Ladle Analysis, Percent, Max*					*Carbon equivalent (CE), Max*	*Mode of Deoxidation*
		C	Mn	S	P	Si		
IS2062 E550	BR	0.22	1.65	0.02	0.025	0.50	0.54	Semi-killed/killed

Table 2: The mechanical properties of the metal used.

Grade Designation	*Quality*	*Tensile Strength Rm , Min MPa*	*Yield Stress ReH, Min MPa*			*Percentage Elongation A, Min at Gauge Length, Lo=5.65*	*Internal Bend Diameter Min*		*Charpy Impact Test*	
			<20	*20-40*	*>40*		*≤25*	*>25*	*Temp (°C)*	*Min (J)*
IS2062 E550	BR	650	550	530	520	12	3t	-	RT	15

Table 3: The chemical composition of the filler metal used.

Filler metal/ Chemical	C	Cr	Mn	Mo	Ni	P	Si	S	V
E7018	0.15	0.20	1.60	0.30	0.30	0.035	0.75	0.035	0.08

Table 4: The mechanical properties of the filler metal used.

	Yield Point ReH (Mpa)	Tensile Strength Rm(Mpa)	Elongation A5(%)
Standard	≥375	490-660	≥22

Figure 1:Experimental sample with V-type groove before welding.

Figure 2: SMAW set-up in the laboratory.

Table 5: Welding parameters used for SMAW process.

Pass number	Filler/electrode	size	AMP DCEP	Volts DCEP	Speed mm/min	HI kJ/mm
1	E7018	4	128.5	26.2	333	0.61
2	E8010	4	132.9	27	341	0.63
3	E8010	4	134.2	27.8	294	0.76
4	E8010	4	141.1	27.2	283.	0.81
5	E8010	4	139.5	26.8	277.8	0.81
6	E8010	4	144.9	26.4	324.6	0.71
7	E8010	4	143	27.2	282	0.83
8	E8010	4	144.5	27.4	288	0.82
9	E8010	4	144.7	27.8	321.2	0.75
10	E8010	4	143.8	28.1	294	0.82
11	E8010	4	144.1	26.1	289.6	0.78
12	E8010	4	143	26.4	294	0.77
13	E8010	4	141.4	27	283.5	0.81
14	E8010	4	141.5	27.8	289.6	0.82
15	E8010	4	142.8	26.2	279	0.80

16	E8010	4	143.2	27.5	287	0.82
17	E8010	4	139.8	26.4	279.8	0.79
18	E8010	4	142.3	27.4	286.8	0.82
19	E8010	4	138.8	27.4	280.4	0.81
20	E8010	4	143.6	27.5	306	0.77
21	E8010	4	142	27.3	287.3	0.81
22	E8010	4	141.9	26.5	289	0.78
23	E8010	4	134	27.2	283	0.77
24	E8010	4	140.7	26.6	288.5	0.78
25	E8010	4	143.5	26.7	295	0.78

3. Result and Discussion

The welding process, including the energy input and the resulted thermal distribution along with th**e** thickness of parent metal control the cooling rate of the weld joint fusion zone and the extend of the HAZ. The cooling rate experienced by the weldment controls the microstructure and residual stresses [4]. Both microstructure and residual stress are indicators for expected hardness of weld metal.

3.1 *Chemical composition of weld bead*

Table 6:The Chemical composition (% by mass) of the weld bead

C	Mn	S	P	Si
0.19	0.80	0.23	0.024	0.32

Each pass of weld and HAZ were clearly visible. The wider welded joint of SMAW had wider arc column and uniform passes. The development of columnar structure becomes more pronounced with the passes of the welding. With the each passes of the head addition became more effective through the top surface. The anisotropy in mechanical properties of welding beds affects the uniformity of the alloy distribution in the welding beds. The micro segregation of alloy may affect the mechanical properties and development of crack may occurs during the service period.

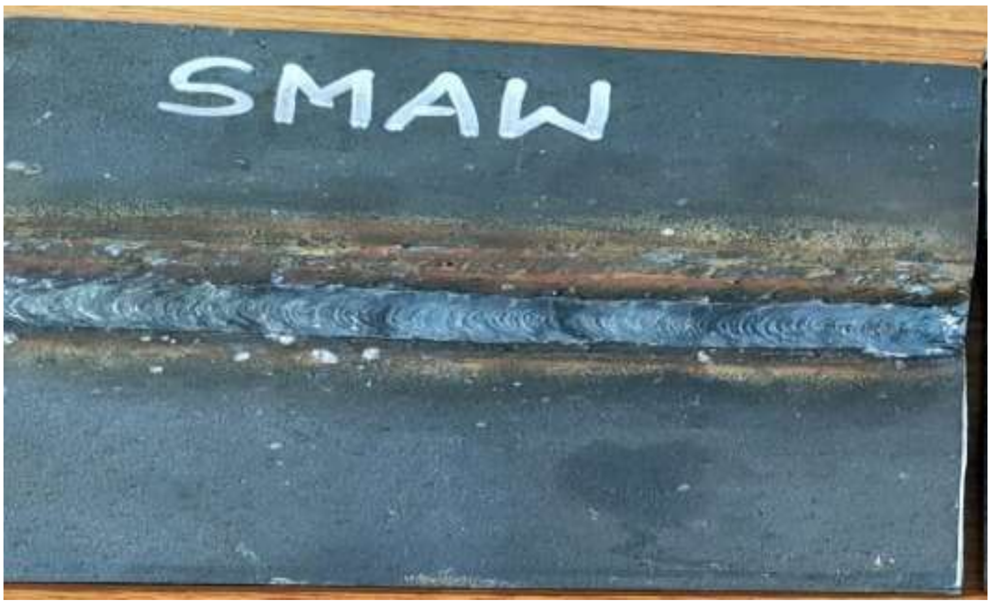

Figure 3: IS2062 grade E550 BR joints made using SMAW.

The Energy-dispersive spectrometric (EDS) method used for the analysis of the selected welded joint area. The chemical analysis of the selected area shows the presence of the Mn, Cr and Si particles etc as shown in the figure Figure 4.

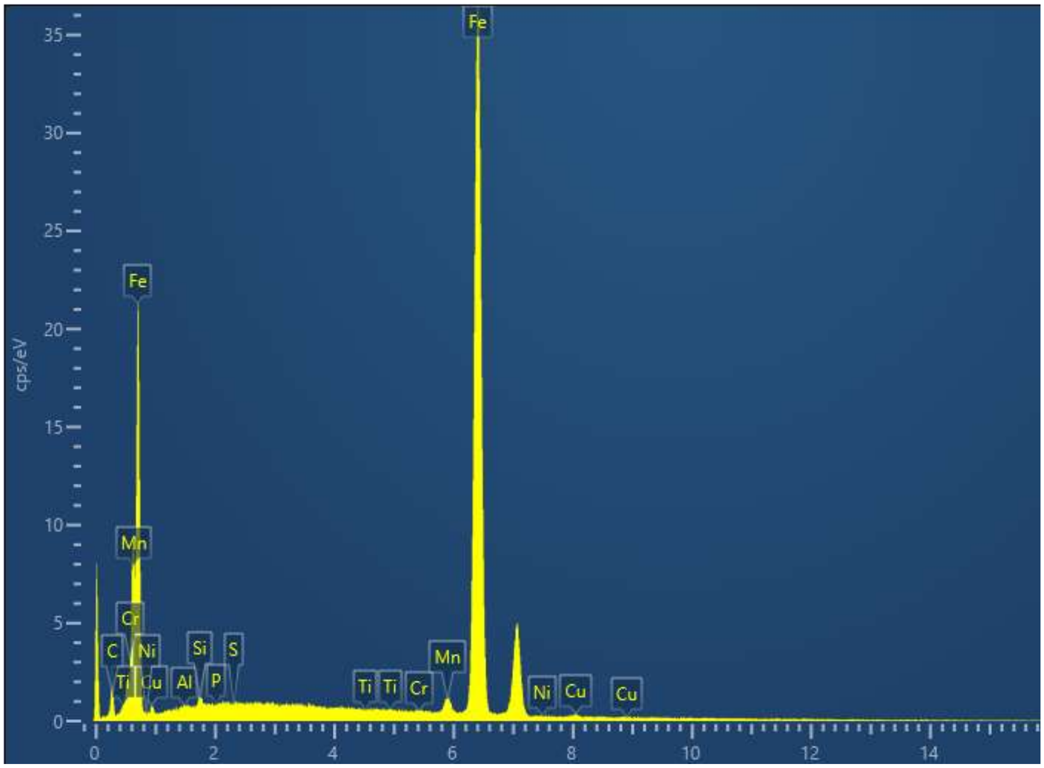

Figure 4: Energy-dispersive spectrometric (EDS) of particles in the grain boundatry.

3.1 Microstructure Analysis

The Figure 3 shows, the microstructure of the SMAW. The grain interior is being observed by energy dispersive X-ray spectroscope (EDS). The effects of the welding process greatly affect the microstructure, residual stresses and hardness [5] and [6]. The present study includes these were investigated. Different morphologies of ferrite including polygonal ferrites precipitates of carbide are detectable. Coarse carbide precipitates of average size were observed less than the average particle size of base metal.

The root pass microstructures are basically acicular because of the heat received from the subsequent passes of welding. Microstructure of ferrite morphologies and few bainite were also observed as it can be seen in Figure *5* and Figure *6*.

The repeated pass of welding and wider arc column in SMAW adds the heat to its previous pass which brings the effect of some tempering due to reheating. The reheating leads to the reduce the grain size with increase in uniformity for SMAW.

The grain size has significantly affected the mechanical properties of the steel [7]. The measurable increase in hardness, yield strength, fatigue strength along with the impact strength observed with reduction in grain size. As IS2062 Grade E550 BR is a structure material so the fatigue strength and tensile strength play significant role in the selection of the material that is why this material is broadly used in the construction of structure [8]. Yield strength has greatly depended on the size of grain compare to tensile strength [9]. High yield strength of IS2060 Grade E550 BR welded joint by SMAW due to it fine grain size.

The SMAW welded joint observation shows that the presence of coarsed ferrites along with the pearlite microstructure. The presence of these indicates that the SMAW slow cooling leads to the formation of pearlite and ferrite. The low carbon presence in the welded joint in the IS2062 grade E550 BR, make it more suitable for the structural formation. The welded joint microstructure shows the distribution of the carbide precipitates as shown in the figure Figure 7.

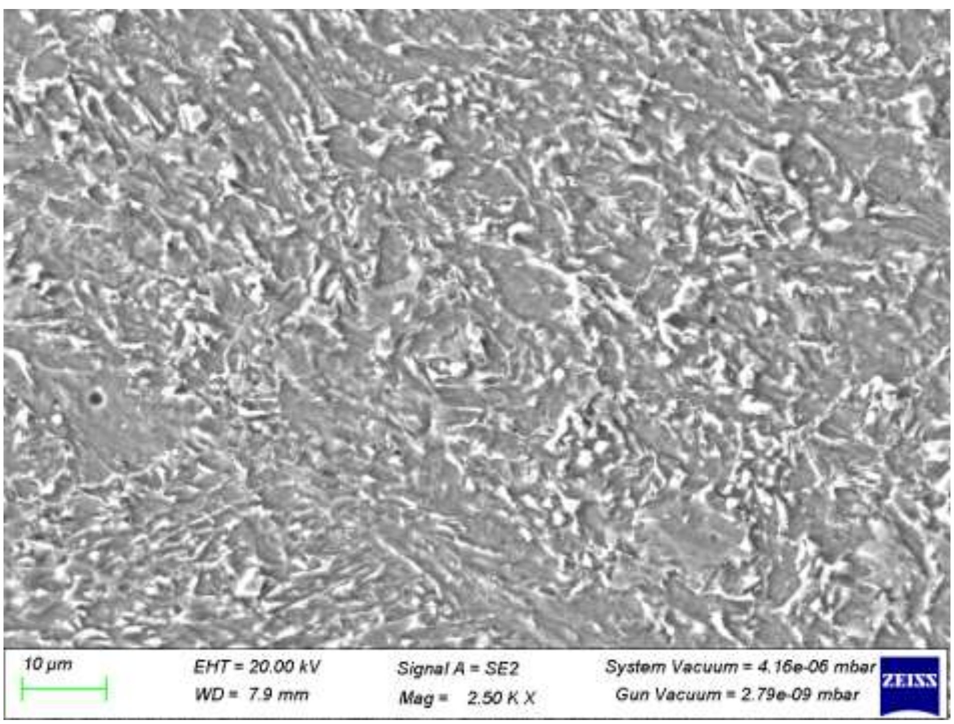

Figure 5: Microstructure of SMAW welded joint.

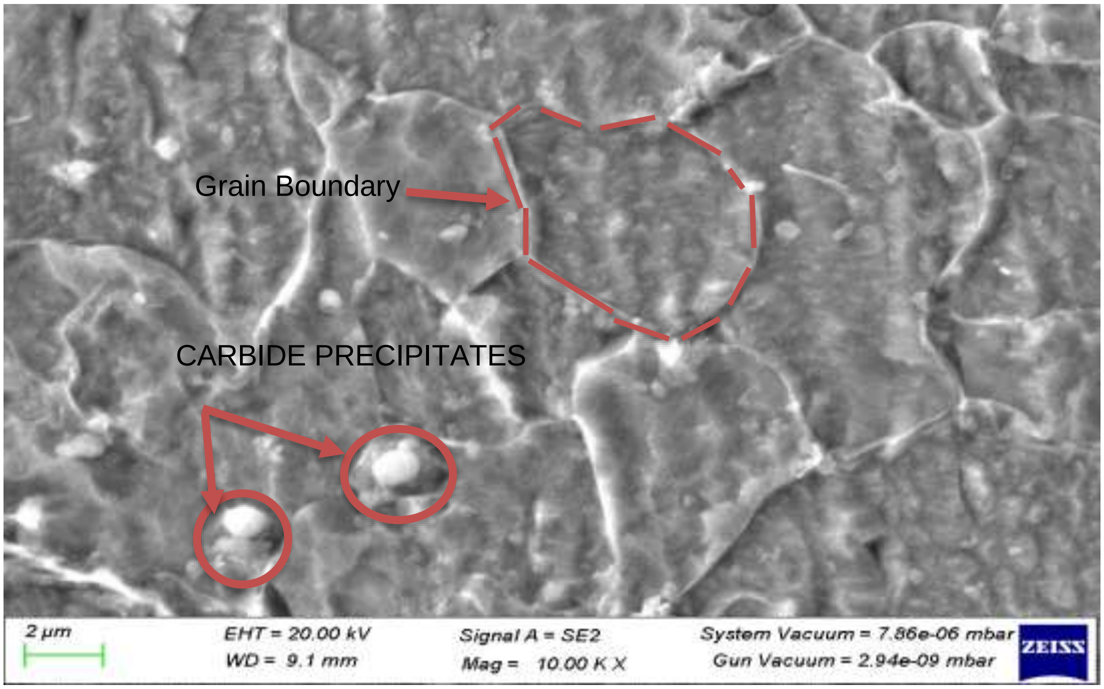

Figure 6: Presence of Grain boundary and Carbide.

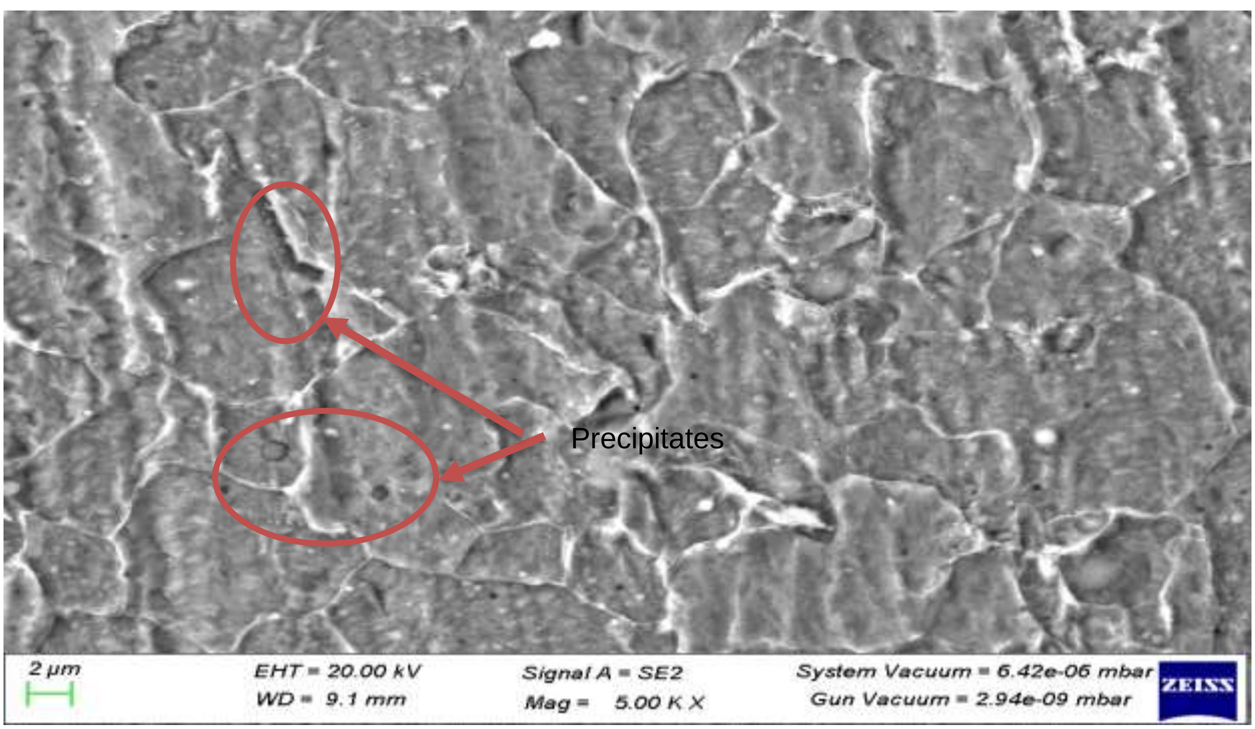

Figure 7: Precipitates in the welded joint of IS2062 grade E550 BR using SMAW.

4. Conclusion

The present investigation is to study the effects of the welding process on the microstructure and mechanical properties high-strength low-carbon steel IS 2062 grade E550 BR were investigated. The key findings of this experimental study were:

a. The SMAW welded fusion zone and HAZ area were observed larger. Larger fusion zone and HAZ leads to slow cooling. The slow cooling prevented the thermal stress.
b. The repeated pass of welding and wider arc column in SMAW adds the heat to its previous pass which brings the effect of some tempering due to reheating. The reheating leads to the reduce the grain size with increase in uniformity for SMAW.
c. The formation of bainite and ferrite in the joint make it more brittle whereas mechanical properties increase significantly like toughness and hardness. IS 2062 grade E550 BR welding using SMAW was observed highly usable welding process for the structure development.

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