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Analysis of Mechanical and Microstructure Properties for FCAW Welded IS 2062 Steel Bead

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Abstract:- Production rate and excellent metal deposition rate makes Flux cored arc welding (FCAW) unique among all welding process. The application of FCAW in field of structure joining of high strength allow steel is large. The base metal consists of two 150 × 150 × 16 mm thick steel plates of grade IS2062 E 350 are chosen for the study. The weld metals made by repeated pass FCAW process were submitted to tensile, bending and charpy-V examination. The metallographic examination for samples removed transversally to the weld bead. For the experiment, optimum parameters were chosen. From this study, the result showed that the mechanical and microstructural propertied of weld bead are superior than the base metal.

Keywords:- *FCAW, HAZ, IS2062, E350 Steel, Microstructure.*

I. INTRODUCTION

FCAW are widely used in field of manufacturing of high strength low alloy steel. FCAW application are manufacturing and fabrication of energy pipeline, ship development, manufacturing of pressurized vessels is high. It has advantages such as high deposition rates, prevention from rust than other welding, simpler and more user-friendly than SMAW, skilled worker not required like GMAW, better manufacturing rate than SMAW with excellent appearance. [1]. FCAW uses flux-cored filler wire which undergoes continuous feed. The flux around the feed wire helps to protect weld pool from the atmosphere. Welding parameters and consumables have noticeable contribution on strength and performance. The current directly affect the weld penetration [1]. Mohamat et al. [2] investigates that higher welding current will leads to higher heat penetration and vice versa. It has observed that the weld bed hardness is higher in FCAW in case of base metals is mild steel.

The weld parameter like welding speed greatly affects the grain boundary of microstructure. The dimension of the grain boundary smaller and smaller with the increase of welding speed. The relation of hardness with voltage and current is inverse where hardness decreases with increase in voltage and current due to dimensional change in grain boundary. Palani et al. [3] experimental study suggest that the model developed gives reasonable idea about the geometry of weld bead with acceptable accuracy. From this current study, the result showed that, at the optimum welding parameter, the value of depth of penetration, HAZ, mechanical properties and microstructure of weld bead are superior than the base metal.

II. MATERIAL AND METHOD

The experimental two specimens consist of 150 × 150 × 16 mm steel plates of grade IS2062 E 350. The chemical percentage and mechanical characteristics of the specimen are shown in Table-1 and Table 2. All the samples were thoroughly prepared and any surface impurity removed with the help of acetone. For weld joining, single "V" (60°) notch shape is made represented in Figure 01. The set-up is shown in Figure 2. The testing facility includes the welding table, FCAW machine as well as the accessories of the set-up. The FCAW joining experiment was carry-out with the help of flux cored arc welding using electrode E71T1-1C of diameter of wire1.4mm in multi pass. The Fig.3 is the actual photograph of the welded joint of the IS 2062, 350BR after welding.

The FCAW welding parameters that are being used for joining the plates has been depicted in Table 3. The specimen development is as per the standard ASTM which is depicted in Figure 4. The tensile test performed at UTM machine of capacity 1000 kN. Whereas, for the impact toughness test, impact testing machine 300 J has been used. The impact testing machine is manually controlled. Vickers microhardness testing machine for hardness testing is also used. The condition is 05 kg load and 15 second dwell. Weld quality tested using optical microscopy. It has been assured that the surface of the specimen should be mirror polished and etched using Nital with dwell time 31 to 55 seconds. The evaluation of phase along with compositions analyzed with the help of using SEM and EDS machine.

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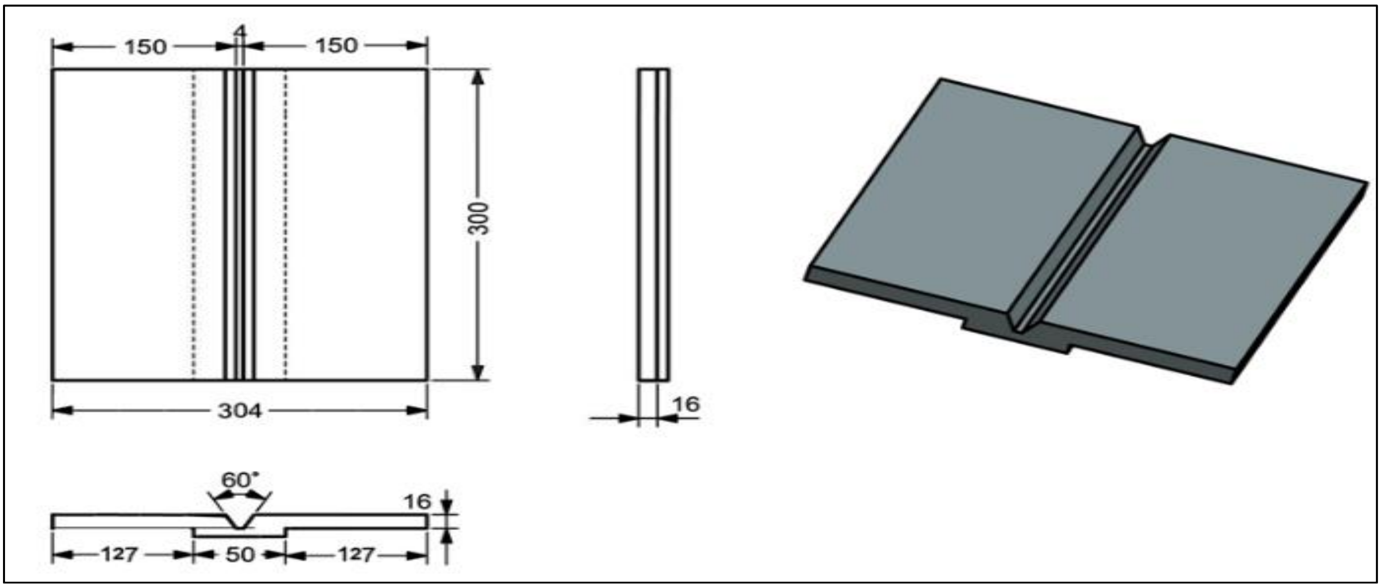

Fig 1: Base Metal Plate for FCAW Welding with Groove

Table 1: The Chemical Compositions (%) of IS2062 E350

Carbon equivalent (CE), Max	**0.47**	
Mode of Deoxidation	**Semi-killed/killed**	
Ladle Analysis, Percentage, Max	P	0.20
	Mn	1.50
	S	0.045
	P	0.045
	Si	0.45

Table 2: The Mechanical Properties of IS2062E350 Base Metal Used

Tensile Strength Rm, Min MPa	**Yield Stress ReH, Min MPa**		**Percentage Elongation, Min at Gauge Length, Lo=5.65**	**Internal Bend Diameter Min**		**Charpy Impact Test**	
490	< 20	350	22	2t	-	Temp (°C)	Min (J)
	20 - 40	330				RT	27
	> 40	320					


Fig 2: Experimental Setup of FCAW

Table: 3: Chemical Composition of the filler wire

Contents	**Electrode for FCAW (E71T-1C) Max**
Ni	0.50
Cr	0.20
P	0.03
Cr	0.20
C	0.12
Mo	0.30
V	0.08
Si	0.90
S	0.03

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Fig 3: FCAW Welded Specimen

Table 4: Welding Parameters used for FCAW Process

Pass	Voltage (V)	Current (A)	Wire Speed (inch/min)	Gas flow (LPM)
7	25	150-180	3.57-5.86	14-28

Table 5: Chemical Composition of Bead

C	Si	S	Mn	P
0.19	0.32	0.023	0.80	0.024

III. RESULT AND DISCUSSION

In this section, experimental testing result has been discussed as analyzed below:

A. *Chemical Composition of Weld Bead*

Welding is performed and the weld bed examined and it is observed as shown in Table 5 that the manganese composite was 0.80 percent. The composition of manganese indicates that the brittleness of the steel has lowered whereas the impact has increased.

B. *Tensile Test*

The ASTM standard has been used to obtain tensile data. The transverse tensile data obtained using specimen as shown in Figure 4. The tensile test specimen outline as per ASTM E8 standards. The actual sample for tensile test as standards is shown in figure 5 (a.). The tensile test had conducted on UTM having capacity of 1000 kN. The FCAW welded joint maximum observed yield strength is 607 MPa. The ultimate tensile strength of FCAW is being observed 640 MPa. The test specimen rupture in tensile is shown in Figure 5(b.). Figure 6 illustrates the load to displacement curve. The failure of FCAW joint occurred during the tensile testing in subcritical interface zone. The transition region leads to the formation of soft zone which finally leads to the tensile failure.

It has been analyzed from above experimental result that rupture observed in the base metal. It signifies that the weld bead and HAZ have higher strength than the base metal.

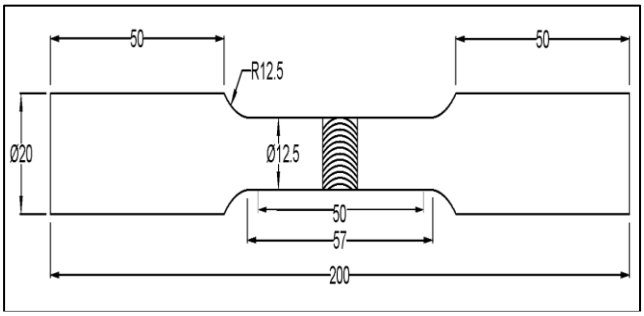

Fig 4: Tensile Specimen Preparation as Per ASTM E8 Standards


(a.)


(b.)

Fig 5: Tensile Test Specimen (a.) before and (b.) after the Tensile Test

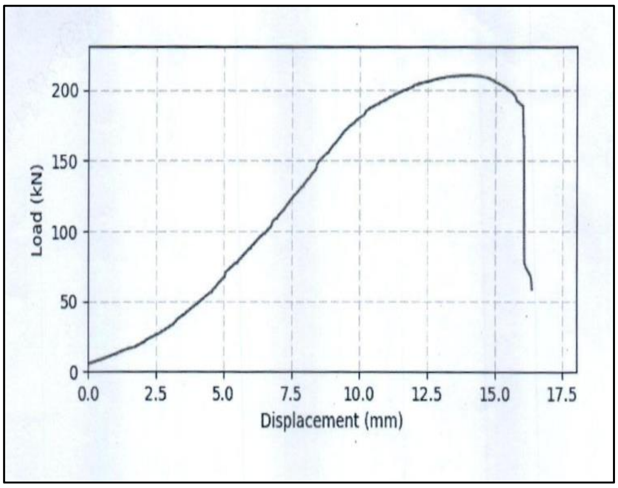

Fig 6: The Load to Displacement Curve for Welded Joints

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Fig 7: Notch Specimen after the Impact Test

C. Toughness Test

Charpy V notch is made on the specimen. To evaluate Charpy impact test on welded joint three specimen were prepared at room temperature and then tested as shown in Figure 7. Notches made in such a way that it would lies under the weld zone. Impact toughness is relatively higher than base metal impact strengths and observed 180 J.

It is observed that the higher Charpy impact strength values at the weld zone compared to the base metal. This phenomenon can occur due to several factors:

- Microstructural Changes: The welding process alter the microstructure in the HAZ and weld metal. Rapid cooling leads to the formation of finer grains and a more refined microstructure, which can enhance toughness.
- Alloying Elements: The filler material used in FCAW contain alloying elements that improve the toughness of the weld metal. These elements can enhance the ductility and impact resistance of the weld zone.
- Residual Stresses: Welding can introduce residual stresses that influence the impact properties. These stresses can help in improving the impact resistance of the weld zone.
- Welding Parameters: The parameters set during the welding process, such as heat input, travel speed, and voltage, can significantly impact the mechanical properties of the weld. Optimized parameters result a stronger and tougher weld.

D. Bending Test

Non-destructive test (NDT) is widely used for the defects test but when it comes to find out about small defects then it’s sometimes difficult to obtain accurate information. The ultrasonic tests are widely used as NDT. Despite the fact of accuracy of ultrasonic test, performance bending test has been carried out to acquire more robust data.

In this present work, bending test were performed and the result obtained from all three specimen were analyzed satisfactory. The bending sample is shown in Figure 8. It is also observed after analyzing tension test that the fracture always developed in the base metal, so it is concluded that along the fusion line, welding joint is free from discontinuity.

The bend test on all three specimens were conducted as per standard. ASME section IX followed to check. The weld joint being checked from face to root to get information about soundness of weld. All the sample cleared test which shows, weld joint integrity.

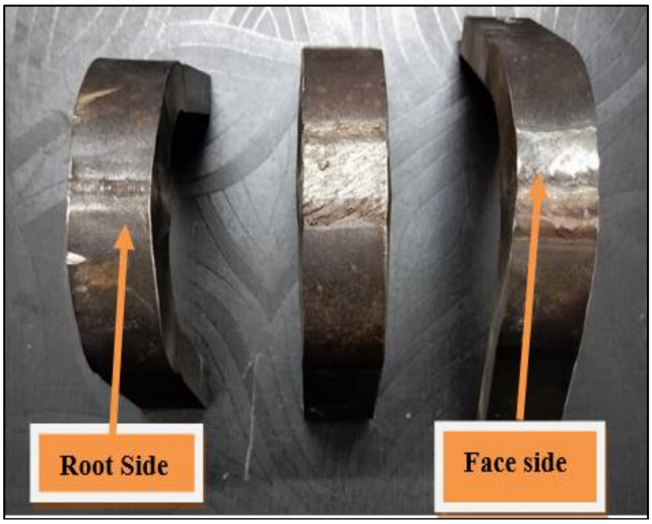

Fig 8: Welded Sample after Bending

E. Microstructural Observation

The welded metal piece was cut perpendicularly. The sample were prepared using wire cut EDM. Cutting were performed along welding direction. Post cutting, grinding and polished were performed. The testing material were given sighing using 2% or 10% nital [4-6]. The heat affected zone (HAZ) is examined on the etched section by optical microscopy as shown in Fig. 9. Various microstructural of weld zone, HAZ and base metal are shown in Fig. 10, 11 and 12. It has been observed that finer grain came in existence along fusion zone than parent metal which increase strength and toughness of weld zone. The EDAX spectrum of the inclusions of weld joint is shown in Fig.13.

IV. CONCLUSION

The microstructure is affected by welding process of IS 2062 E 350 steel has been examined. The key finding of this experimental are:

- The formation of finer grain structures and the presence of martensite and bainite in the HAZ contributed to higher yield and ultimate tensile strength.
- FCAW welds exhibited better toughness due to finer grain sizes in weld and HAZ.
- Higher cooling rate during flux core arc welding process has affected previous austenite grain size. Which rendering a less in size prior austenite grain and add more nucleation sites. i.e. bainite and ferrite improving mechanical properties such as strength and toughness.

Fig 9: Optical Micrograph of FCAW Welded Joint

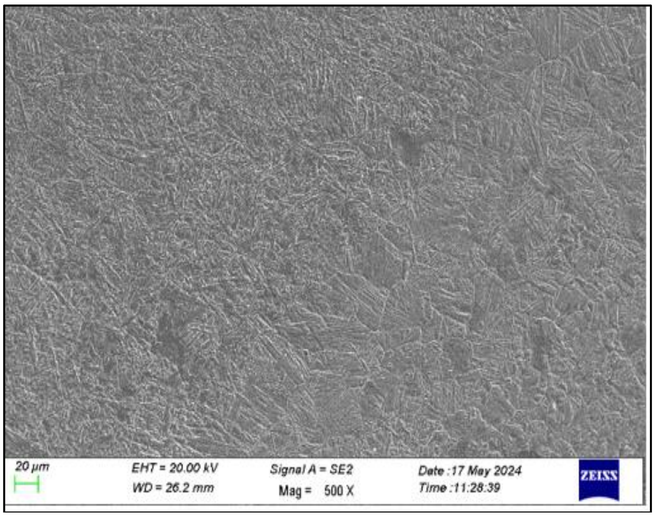

Fig 10: Microstructure of at the Interference of Base Metal and Weld Region

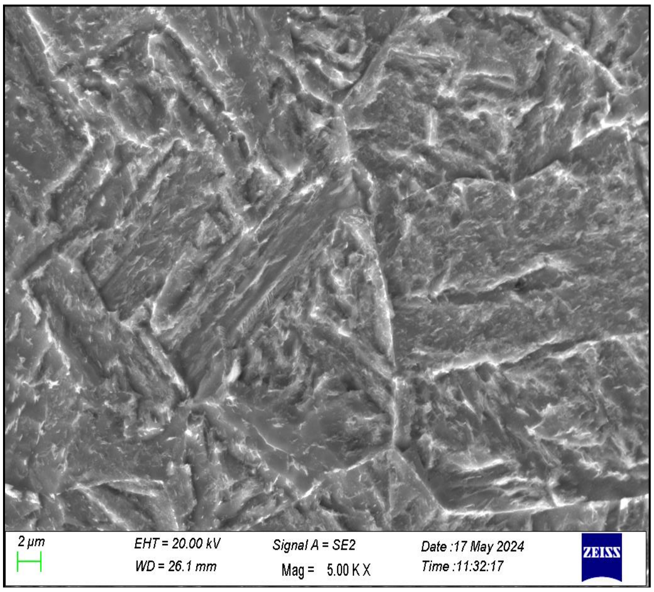

Fig 11: Microstructure of the Weld Region

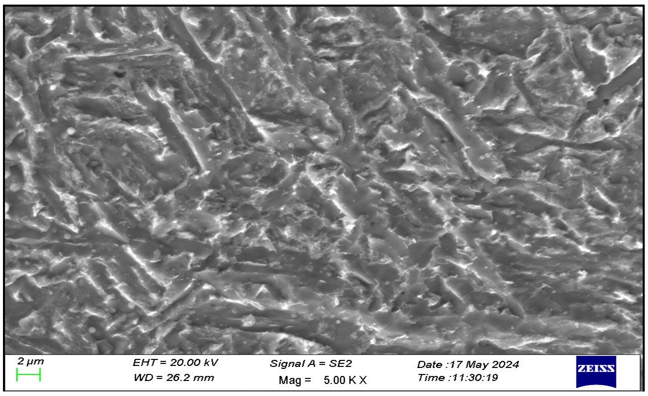

Fig 12: Microstructure of the Base Metal

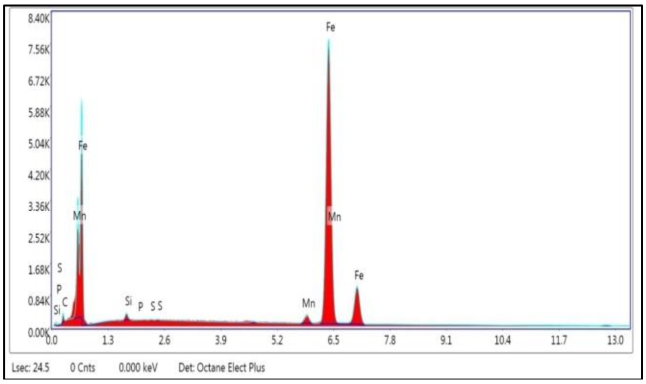

Fig 13: Typical EDAX Spectrum of the Inclusions

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