Effect of Welding Process Parameters on Toughness and Microstructure Characterization of IS 2062 Grade A Structural Steel Weldment

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ABSTRACT

In this research article, the effect of welding process parameters such as arc welding current, arc voltage, wire feed speed, and shielding gas flow rate on mechanical and metallurgical properties of IS 2062 Grade A steel bonded by MIG welding was investigated. In this experimental work, parent metal was welded by an ER70S-6 filler wire in the presence of a mixture of 75%Ar+25% CO_2 gases for shielding purpose. The Toughness of weldment was determined as mechanical properties. In metallurgical investigation of the weldment, Optical Microscopy (OM), Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS) were used. Fracture surfaces of notched toughness specimens were examined after toughness test. From experimental results, it was observed that on increasing the arc voltage, toughness value of weldment decreased and the grain size of microstructure of weldment varied throughout the weldment surface. Microstructure of weldment was also found influenced by the composition of shielding gases.

Keywords: MIG; IS 2062; Microstructure; Toughness; mode of fracture; SEM; shielding gas.

1.0 INTRODUCTION

Nowadays, Metal Inert Gas (MIG) welding is commonly used in industries to joining the materials, as it is having more advantages over other welding process. MIG welding is a process which involves the heating and melting of base metal and a continuous copper coated filler wire. Shielding purpose an inert gas is used [1]. MIG welding process was introduced in later 1950 [2]. Primarily it was introduced to bond the aluminum with an atmosphere of inert gas. Hence, it is also known as Gas metal arc welding (GMAW). It may be used as an automatic or semi-automatic process for mass production purpose. Moreover, aluminum Metal Inert Gas (MIG) welding is also suitable to weld all most ferrous metal such as low carbon steel, stainless steel, high strength low alloys steel, alloys of aluminium, magnesium and titanium [3].

IS 2062 E 250A, structural steels are widely used in various industries such as structural industries, petrochemicals and shipbuilding, construction industries due to its good mechanical properties and excellent weldability [4]. Chennaiah et al. [5] studied IS 2062 to determine the effect of heat input on mechanical properties and they concluded that there was an improvement in properties of weldment by using optimal PWHT process. Akselsen and Grong [6] predicted the weld joint V-Charpy test and informed that toughness of the weldment was usually controlled by the volume fraction of acicular ferrite. They also concluded that control of the weldment microstructure became most important at high strength level to avoid trouble with the fracture toughness. Svensson and Gretoft [7] studied the toughness and microstructure of C-Mn weld metal and found significant improvements in toughness at low temperatures that were achieved with increasing amounts of acicular ferrite. Magudeeswaran et al. [8] determined the effect of different welding process parameters on tensile strength and toughness of AISI 4340 steel weldment which is also known as high strength quenched and tempered steel and they reported that welded joints prepared by the shielded metal arc welding (SMAW) process showed excellent quality of ultimate tensile strength, toughness, and low degree of course grain (CG) heat affected zone (HAZ) softening compared to flux core arc welding (FCAW).

Abson [9] investigated the mechanical properties of BS4360:1 986 Grade 50EE steel welded by pulsed welding and concluded that Charpy toughness exceeded the plate toughness requirement (>27 Joule at -50°C) for the deposits formed with both the solid welding wire and the basic flux cored wire, but not for the metal cored and the self-shielded deposits. Park et al. [10] evaluated fracture toughness of microsphere Al_2O_3–Al fine particle in powder form (metal matrix composites) and concluded that fracture toughness reduced gradually with particle volume fraction, but at a reducing rate. Rizvi et al. [12] optimized the process parameters affecting weldability of IS2062 and mentioned that welding current and welding voltage had significant effect whereas gas flow rate had insignificant effect on tensile strength of the welded joint.

2.0 EXPERIMENTAL METHOD

2.1 Material

IS 2062 E250A structural steel is used in this investigation. Chemical compositions of IS 2062 E250A steels and filler wire used in this experimental are listed in **Table 1**.

2.2 Welding parameters

IS 2062 material is welded with the help of a Metal Inert Gas welding process. Welding parameters are fixed as per pre-experimental studied. A list of process parameters is shown in **Table 2**. From each group, at least three samples are tested.

Heat input in a welding process can be determined by the following formula:

$$H = 60\ \frac{AV}{S}$$

Where A is welding current in ampere, V is arc voltage in volt, and S is welding arc traveling speed in mm/min. Heat input is always expressed in kJ/mm, kJ/cm, etc.

Table 1 : Chemical Composition of Parent (Base) Metal and Filler wire

Material	% C	%Mn	%S	%P	%Si	%Cu	Fe
Grade A IS2062	0.21	0.87	0.051	0.055	0.10	--	rest
ER70S6 (filler wire)	0.18	0.92	0.025	0.024	0.20	0.24	rest

Table 2 : Process parameters used in welding

Group. No	Voltage (V)	Current (A)	Welding speed (IPM)	Heat input (Kj/mm)
1	25	210	90	3.5
2	26	220	88	3.9
3	27	230	85	4.4
4	28	240	79	5.1
5	29	250	82	5.3
6	30	260	76	6.1

2.3 Impact toughness

Mechanical property, i.e., Charpy 'V'-notch toughness of weldment is investigated at room temperature on Charpy testing machine.

Charpy V-notch samples are fabricated as per SATM standard [11]. Charpy "V" test samples are cut from a 55 x 10 x 10 mm^3 weldment of IS2062 grade A, and are investigated at room temperature as per ASMT. Notch is located at the centre (to concentrate the stress) of the weldment. Orientation and location of Charpy V notch test actual sample are shown in **Fig. 1.**

Fig. 1 : Charpy Test Sample after preparation [11]

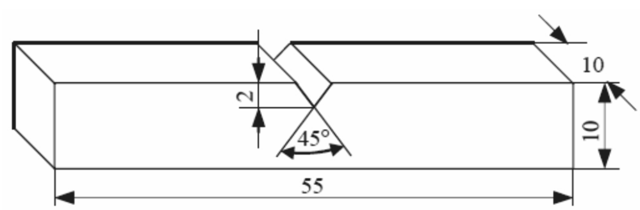
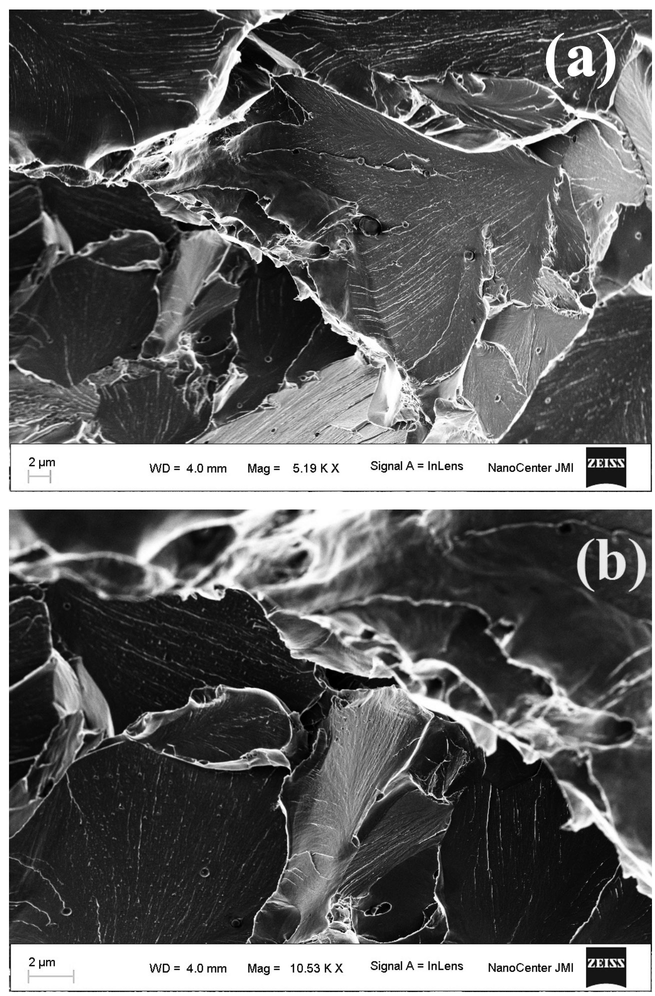


Fig. 2 : Impact test sample as per ASTM

2.4 Factrography study

Fractography of toughness test piece is conducted by Scanning Electron Microscopy (SEM). Toughness test samples are sectioned at mid-section perpendicular to the V notch to investigate the cracks under optical microscope and it is observed that mode of fracture in weldment is brittle with distinct cleavage structure in all area, including those near to notch tip. **Fig. 3** shows fracture mode of sample a, b & c.

Fig. 3 : Impact test sample after fracture



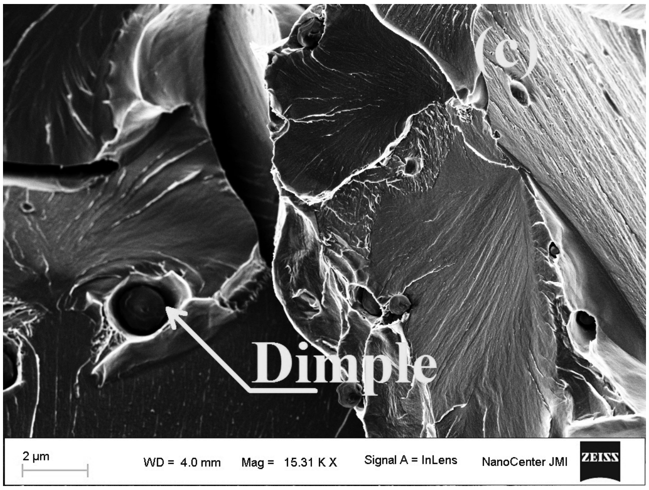


Fig. 4 : Fracture features of impact samples of weld at different gas flow rates & 25V, 26V & 27V at room temperature

When SEM image of fracture toughness V notch sample is taken for investigation purpose, fracture surface as reticulated dimples are found in the joint; such fracture shows the brittle fracture mode of the weldment. Impact fracture of sample d, e & f is shown in **Fig. 4**. It is observed that to produce finer dimple in structure, higher energy per unit area is required.

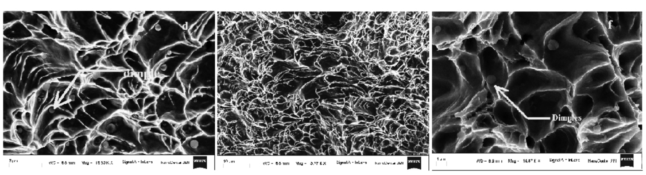


Fig. 5 : Fracture features of impact samples of Weld at different gas flow rate and at 28V, 29V & 30V

2.5 EDS (Energy Dispersive Spectroscopy)

To determine micro inclusion, EDS analysis is conducted. These micro inclusions are produced in the weldment. **Fig. 5** shows the result obtained during EDS test and from **Fig. 5**, it is observed that inclusion produced in weld metal contains a higher amount of C, Mn, Si and rest Fe. This condition shows that inclusion has oxide form, such as oxides of MnO_2, SiO_2 form. Usually the amount of inclusion depends upon the amount of CO_2 present in shielding gas mixture.

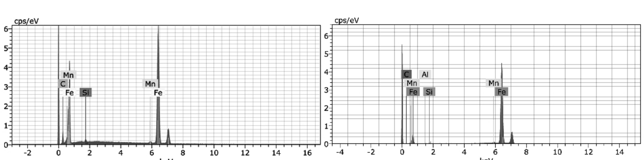


Fig. 6 : Energy Dispersive spectroscopy line scan showing variation of element across the weldment of IS 2062 steel interface

2.6 Microstructure

To investigate the microstructure of weldment, samples are cut from the weld bead portion. A set of samples is ground on a polishing machine with various grades of emery papers for 10 min; after polishing, samples are etched in a solution of ethanol and HNO_3 and finally, samples are examined on a metallurgical microscope for microstructural observation. The microstructure of IS 2062 E250A is given in **Fig. 6**. This microstructure consists of pearlite and ferrite. This microstructure is for sample A1 to A3, B1 to B3 and C1 to C3. From **Fig. 6**, it is clear that the grain size formats in all samples are not uniform. This microstructure of weldment consists of the coarse grain of α ferrite, widmanstatten ferrite, and pearlite (Fig. 6). These results validate with the reported observation in a literature [8].

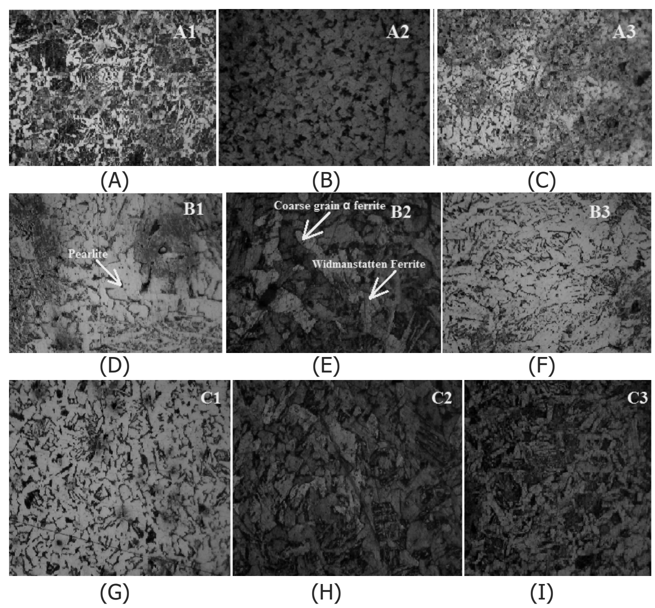


Fig. 7 : Microstructure of weldment of IS 2062 steel at different voltage

3.0 RESULTS AND DISCUSSION

To investigate the Impact strength of the welded joint, at least three samples of each group are considered and their average value of impact strength is considered. **Fig. 7** shows the variation in impact strength at different voltage and it is observed from **Fig. 7** that at 26V impact strength of weldment is higher while at 29V it is lower.

3.1 Effect of heat input on impact strength of weldments

Charpy V-notch test is done to investigate the toughness of the weldment. **Table 3** shows the toughness value of welded joint, whereas **Fig. 8** shows the graph between toughness and heat input. From point 1 to point 4, there is not much changes in toughness of weldment but from point 4, toughness of weldment decreases up to point 5 and then again starts increasing.

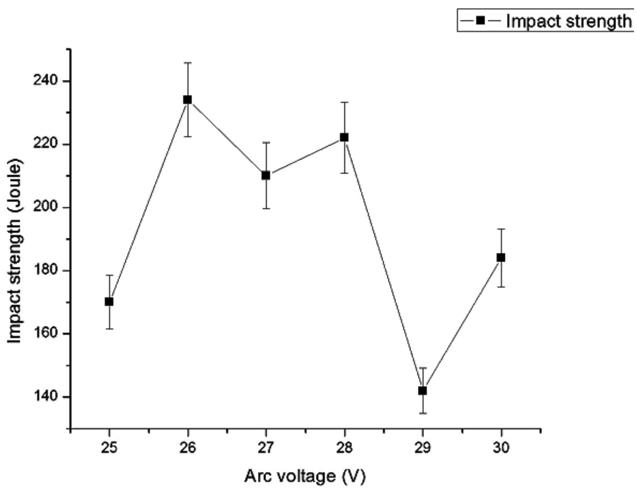


Fig. 8 : Variation in impact strength at various voltages

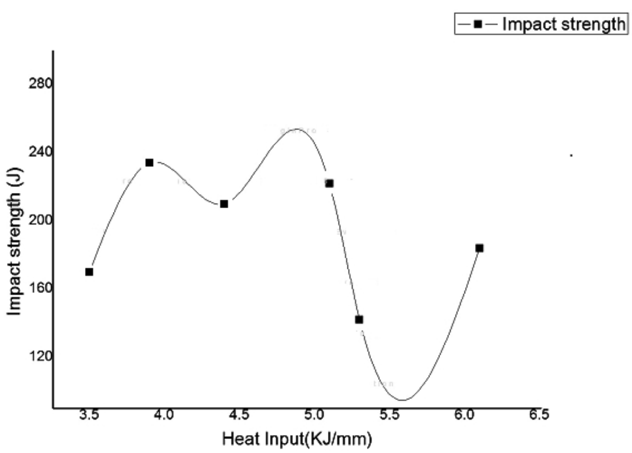


Fig. 9 : Toughness at the different heat input

4.0 CONCLUSIONS

In the present study, the effect of welding parameters on the toughness and on microstructure of IS 2062 grade A steel welded by MIG welding is investigated. Main conclusions are listed as follows:

1. The mixture of 75% Ar + 25% CO_2 produce defect free weld joint.
2. Microstructure of weldment has a nearly equal volume of austenite and ferrite phase.
3. Impact fracture surface appears as a transition from ductile fracture through plastic deformation to brittle fracture by cleavage.
4. Toughness of weldment decreases with respect to heat input.
5. SEM image of a Charpy fractured surface of the welded joint shows that the mode of fracture is brittle. It shows dimples with bright cleavage
6. Full penetration and good weld bead are produced by the mixture of Ar and CO_2 shielding gas.
7. There is a decrease in toughness of weldment with an increase in heat input. It is likely due to the presence of coarse grain α ferrite.

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Table 3 : Mechanical properties of weld metal using solid wire

Equipment No.	Voltage (V)	Gas flor rate (l/min)	Wire feed speed (IPM)	Impact Strength (Joule)
1	25	10	300	170
2	26	15	350	234
3	27	20	400	210
4	28	10	350	222
5	29	15	400	142
6	30	20	450	184

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