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Effect of the Shielding Gas Flow Rate on Mechanical Properties and Microstructure of Structural Steel (IS2062) Welds

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Structural steel is frequently used for industrial purpose as it is more economical as compared to other steels .In the present research article an attempt has been made to find, how the mechanical properties and microstructure properties of the IS2062 structural steel are affected by the different welding parameters such as shielding gas flow rate, voltage, wire feed speed and welding current. In this research work 75%Ar+25%CO_2, is used as shielding gas because it is a best shielding gas mixture for getting a good quality mechanical properties and micro structural properties of welded joint. For study of fracture mode of tensile fracture, SEM test carried out which help to understand the factor influence the microstructure and it is found that the Fractures of tensile samples are brittle in nature which shows the low ductility and brittle fracture. Micro hardness values change throughout weld metal varying by shielding gas flow rate.

Keywords: acicular ferrite, SEM, inclusion, shielding gas, fracture mode, mechanical properties.

1. Introduction

Gas Metal Arc Welding (GMAW) is a joining process, in which arc is established between a continuous, copper coated consumable wire and the metal being welded. Fig 1 shows working principle of GMAW process while Fig 2 shows actual set up of process. In a GMAW a welding torch, electric power source, shielding gas & a wire pool drive control unit is used. The welding process is very simple. GMAW process can be employed on a thick metal plate with high current. The primary function of the shielding gas, in this process is, to protect the molten metal pool from the atmospheric contamination. The gas also promotes a stable arc and uniform metal transfer. In GMAW process shielding gas not only affects the Mechanical/Metallurgical properties of the weld but also determines the shape and penetration pattern [2, 3]. The quality, efficiency, and overall operating acceptance of the welding operation are basically dependent upon the shielding gas, since it affects the mode of the metal transfer in GMAW process [4]. Moreover, shielding gas composition, during welding, affects microstructure of joined materials and hence their mechanical properties. In addition, quality of welded joint, metal transfer rate, and efficiency of welding process vary based on shielding gas composition [5–6]. In general, the presence of inclusions is detrimental to weld properties. However, under a given set of conditions, certain oxide inclusions help in the formation of an acicular ferrite phase which improves toughness [7].

Ramy Gadallah et al [8] reported that toughness of the weld decreases with increase of the CO_2 gas %age in the shielding gas composition. Furthermore the hardness of Weld metal decreases with the increase of the CO2 gas % age in the shielding gas composition. The effect of welding speed and heat input rate affect the stress concentration factor of butt welded joint [9] of IS 2062 E 250 A steel plates. A series of experiments were conducted at fixed wire feed rate, distance between gas nozzle and plate, arc voltage, welding current, gas pressure and the vertical angle of welding and. It was observed that with increase in the welding speed, angle and width of weld bead, reinforcement height decreases, stress concentration factor decreases on increasing the notch radius. H.R. Ghazvinloo et al [10] studied the effect of welding voltage and other parameters to determine the impact energy and other related properties of AA6061 welded joint by the GMA welding and finally they reported that when heat input increases, fatigue life of weld metal decreases whereas impact energy of weld metal increases in first and then drops significantly.

P. Sathiya et al [11] studied the effect of shielding gases on metallurgical and mechanical properties of DSS welds. Argon (Ar) and helium (He) were employed as shielding gases. In their research article they told that the hardness of the weld metal is much higher than that of the BM and HAZ for both studied shielding gases. X. LI et al [12] studied the effect of O_2 contamination in the argon shielding gases on weld joint microstructures and mechanical properties during laser welding and they analyzed the mechanical properties such as strength, ductility, hardness and microstructure properties and conduct the experiment on SEM and they concluded that on increasing the content, the weld strength increased first and then decreased because the microstructure changed from mainly serrated alpha in welds made with pure Ar shielding gas to mainly acicular and platelet alpha. Mohamad Ebrahimnia et al [13] investigated the effect of shielding gas composition on the mechanical weld in gas metal arc welding and they found that energy absorbed in the Charpy impact test first increases then remains constant with increase of the amount of carbon dioxide in the shielding gas composition.

Saadat Ali Rizvi and SP Tewari [15] optimized the process parameters for IS2062 steel weld with joining of GMA Welding process and they correlated the mechanical properties with metallurgical characterization and they also informed that SEM image of toughness test piece on low heat input shows ductile, whereas on high heat input images shows brittle fracture.

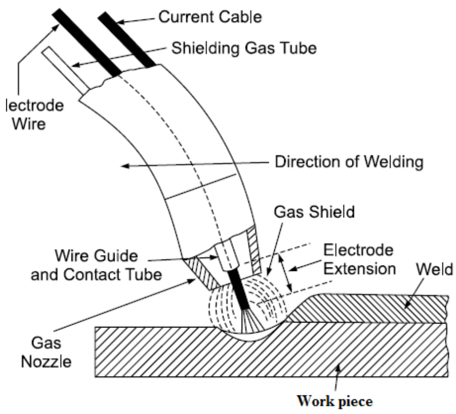


Figure 1 The working of metal inert gas welding (MIG) [1]

Fig. 1 showing the working of metal inert gas welding (MIG) [1].

Figure 2 The actual set up of metal inert gas welding (MIG)

Fig. 2 showing the Actual set up of metal inert gas welding (MIG).

2. Experimental procedure

Trials were performed on IS 2062 structural plates in this experimental studies. Tab. 1 illustrates chemical compositions of joined materials and filler metal Tab. 2 used. Plates (300×120×10 mm^3) for producing the joints and a 60° single V groove edge preparation was followed with a root face/gap of 6 mm as shown in Fig. 3. Multipass welding processes were performed via the GMAW method by using ER 70S6 filler metal. The nominal compositions of the base and filler materials are given in Table 1 and Tab. 2. The shielding gas used; throughout the experimentation was 75%Ar+25%CO_2.

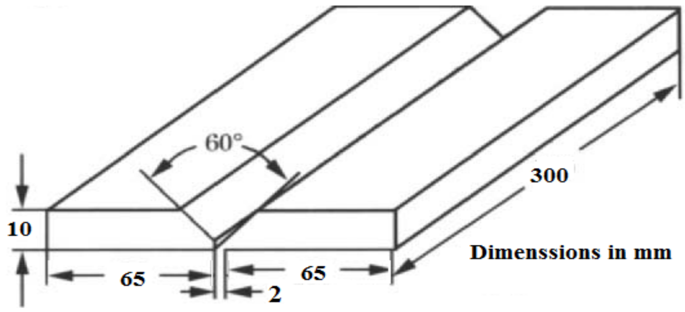


Figure 3 Scheme of joint preparation, V-shaped groove design

Table 1 Chemical Composition of IS 2062 steel Grade A

IS 2062 steel for structural steel purpose				
% C Max	% Mn Max	% S Max	% P Max	% Si Max
0.22	1.5	0.049	0.050	0.37

Table 2 Chemical Composition of consumable electrode

Electrode Chemical Composition of Filler Wire					
ER70S6					
C	Si	Mn	Cu	P	S
0.19	0.98	1.61	0.025	0.025	0.025

2.1. *Preparation of microstructure samples*

To reveal the actual weld configuration, microstracture samples were ground with 80-2000(microns) grit emery papers, polished to a mirror-like finish using 6 mm and 1 mm diamond compounds and etched with a solution of 90% ethanol with 10% HNO_3.actual microstructure samples are shown in Fig 4.In one blow at a time 4 to 5 welded samples prepared as per ASTM.

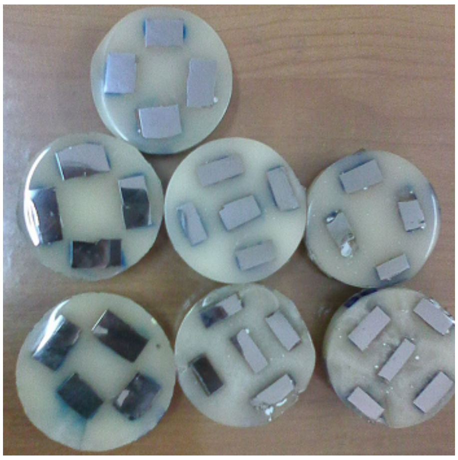


Figure 4 Test piece for Microstructure examination

Parameter that affect the microstructure and mechanical properties of welded joint are given in Tab. 3.

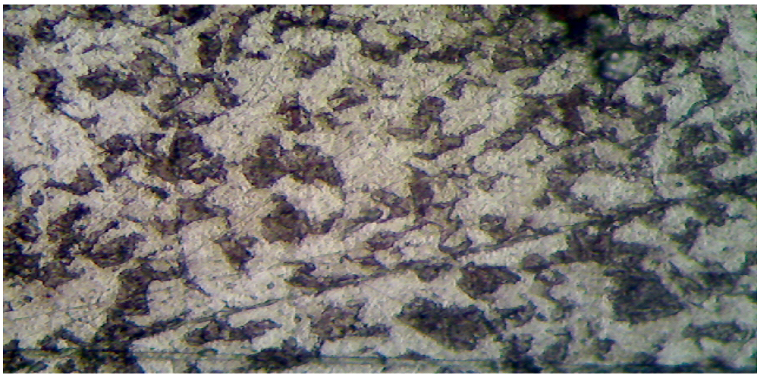
Table 3 MIG welding parameters

Experimental code	Welding current	Voltage	Gas flow rate (l/min)
A1	200	25	10
A2	206	25	15
A3	212	25	20
B1	212	26	10
B2	198	26	15
B3	220	26	20
C1	220	27	10
C2	208	27	15
C3	230	27	20

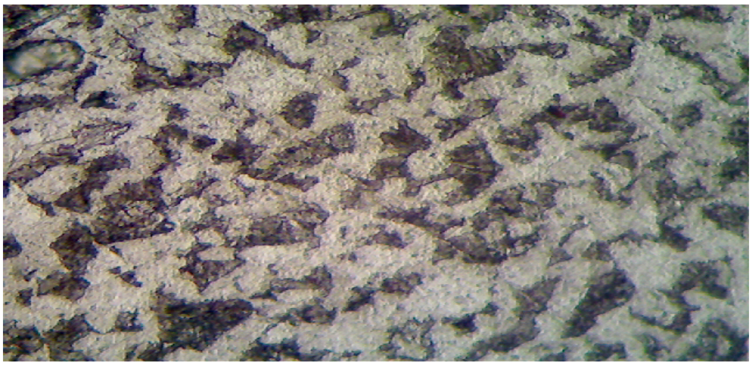
3. Results and discussion

3.1. *Micro structural studies*

Microstructure of base metal are shown in Fig. 5 a–c whereas microstructure of the welds at different parameters are presented in Fig. 6 a–c. Various microstructural defects such as martensite formation, grain-coarsening, and carbide precipitation often occur in the HAZ of low alloy steel welds, which reduces the fracture toughness of joint with increasing tendency to brittle fracture.



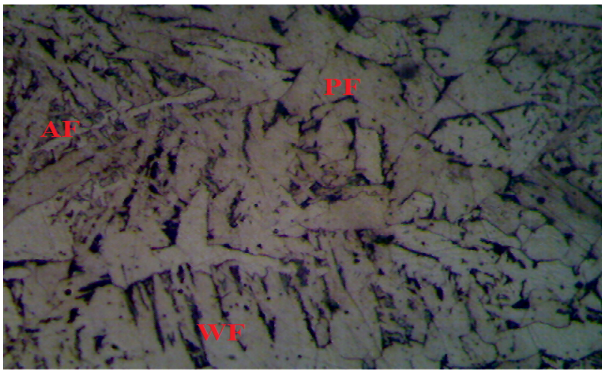
(a)



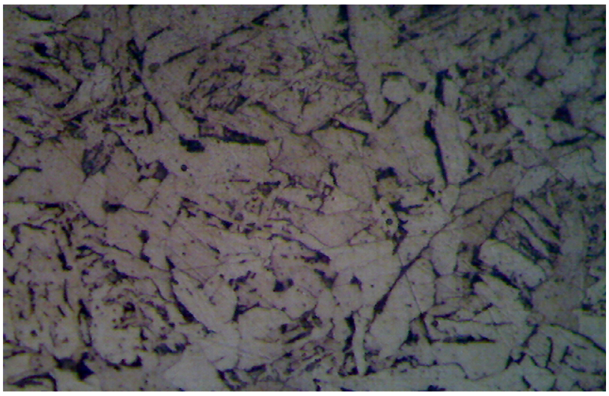
(b)

(c)

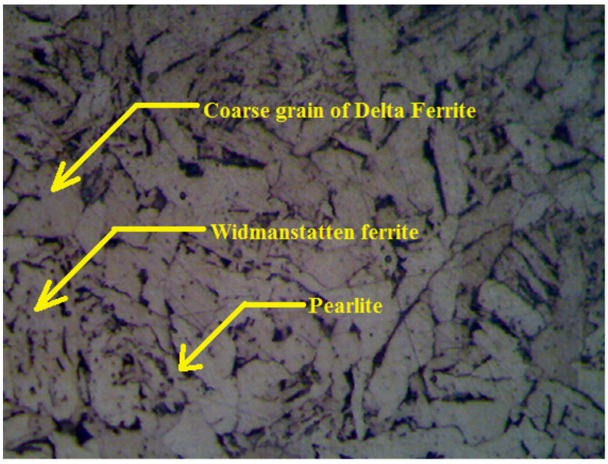
Figure 5 Microstracture of parent metal at 40X



(a)



(b)



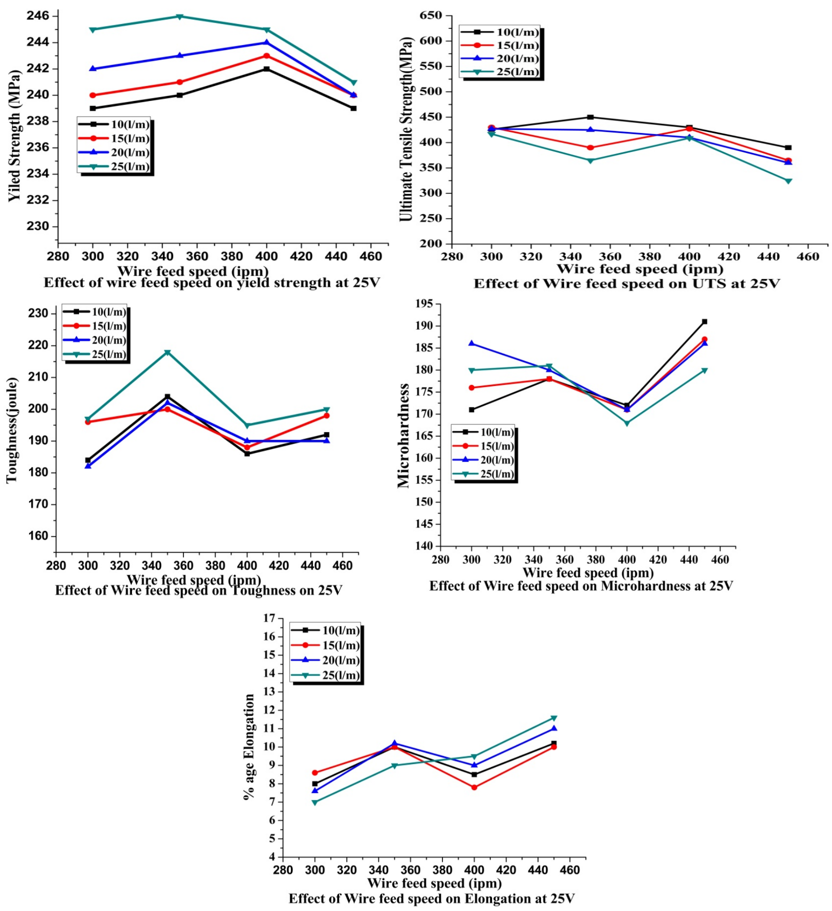
(c)

Figure 6 Metallographic micrographs of weld pool. (a) A12 (75% Ar + 25% CO_2) weld pool etched in 2% Nital, AF: acicular ferrite, WF: Widmanstatten ferrite, PF: polygonal ferrite

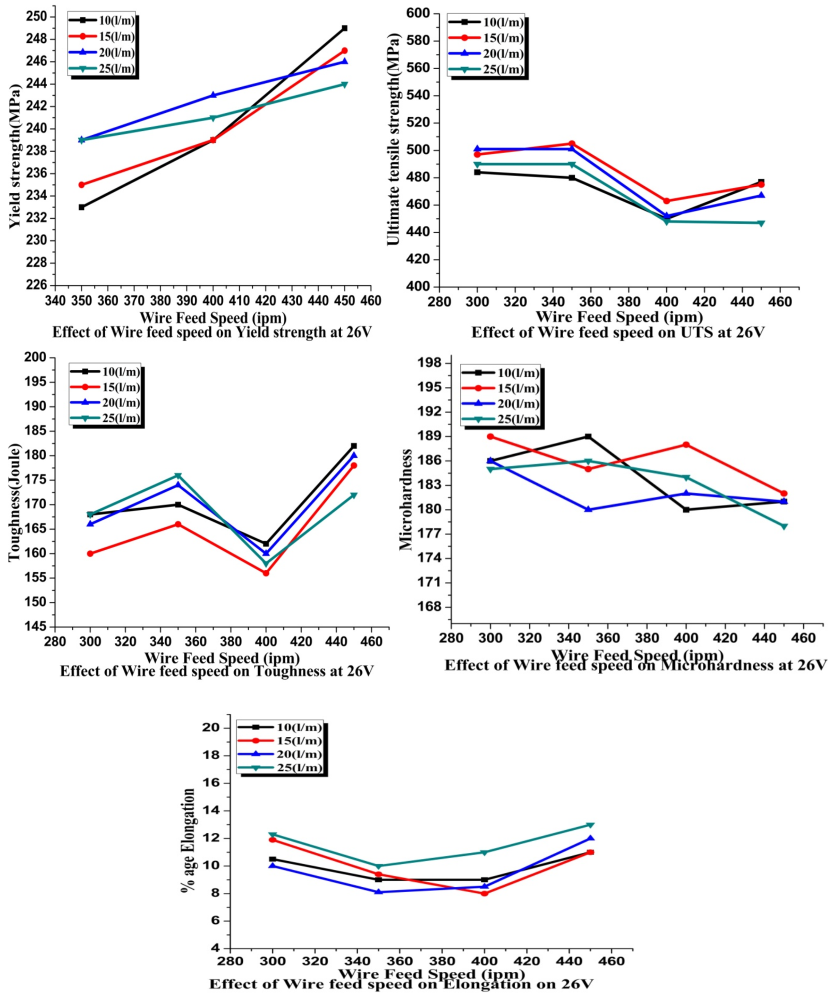
3.2. *Mechanical properties of welded joint*

3.2.1. *Tensile test*

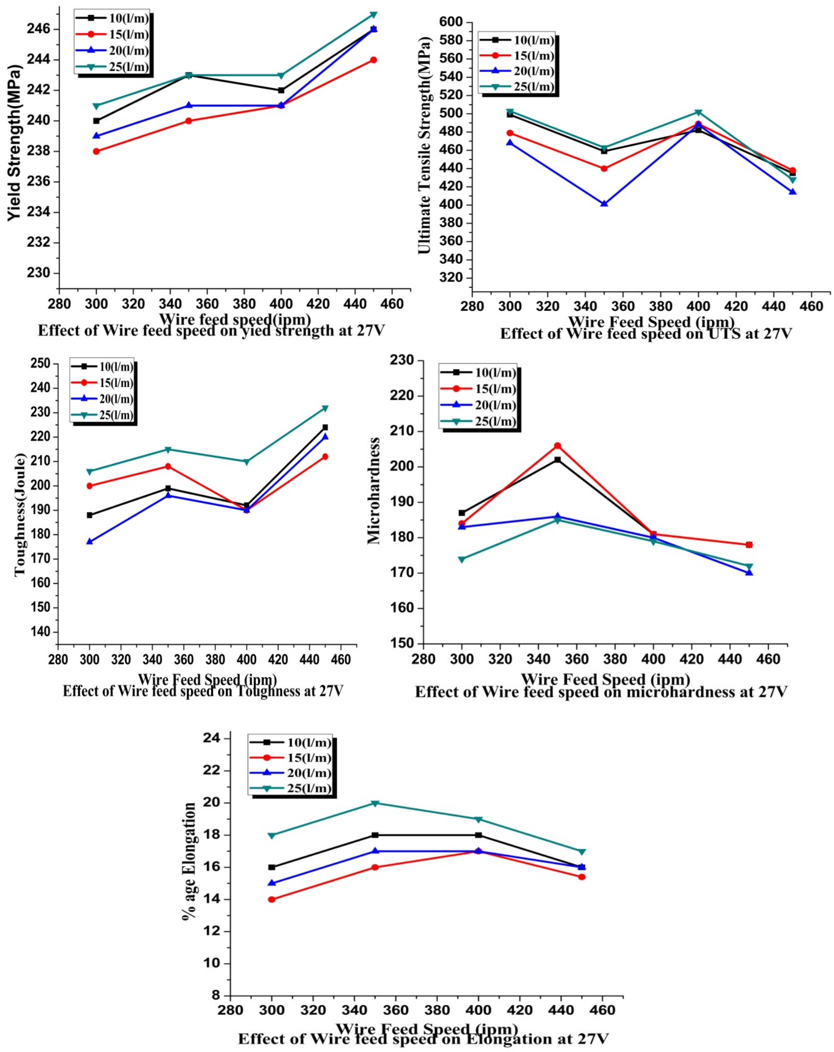
Tensile test was carried out on UTM machine as per IIW standard. Quantitative metallography of the transverse sections of welds was carried out according to the scheme proposed by the International Institute of Welding. Fig. 7 a to c shows the effect of wire feed speed & gas flow rate at different voltage on mechanical properties. From graph it is clear that UTS first increases and then decreases, very less effect on elongation and It is also clear that the weld metal tensile strength is much higher than the base metal tensile strength.SEM observations of fracture surfaces of the welds after the tensile test are shown in Fig. 8. Fracture mode of these specimens was brittle. It appears that critical micro-crack nuclei form on nonmetallic inclusions which satisfy the Griffith theory of crack propagation, and may promote unstable cleavage fracture.



(a) At 25V


10(l/m)
15(l/m)
20(l/m)
25(l/m)
Yield strength(MPa)
Wire Feed Speed (ipm)
Effect of Wire feed speed on Yield strength at 26V
Ultimate tensile strength(MPa)
Wire Feed Speed (ipm)
Effect of Wire feed speed on UTS at 26V
Toughness(Joule)
Wire Feed Speed (ipm)
Effect of Wire feed speed on Toughness at 26V
Microhardness
Wire Feed Speed (ipm)
Effect of Wire feed speed on Microhardness at 26V
% age Elongation
Wire Feed Speed (ipm)
Effect of Wire feed speed on Elongation on 26V

(b)At 26V



(c)At 27V

Figure 7 Effect of Parameters on Mechanical properties

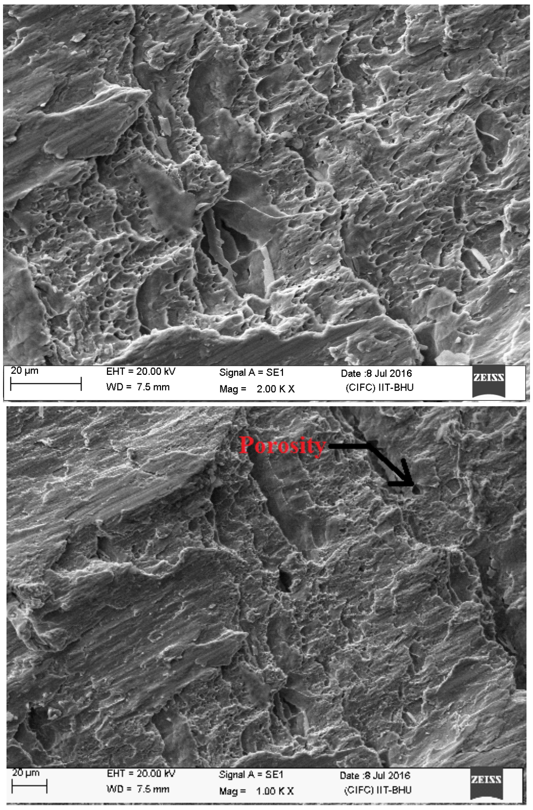


Figure 8 SEM image (Fracture morphology) of tensile specimen fractured at room temperature

The inclusion is indicated by arrow. The EDAX spectrum of the inclusions of weld joint is shown in Fig. 9

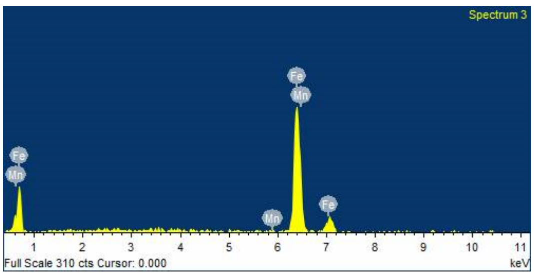


Figure 9 Typical EDAX spectrum of the inclusions

3.2.2. *Charpy test*

Scanning electron micrographs of fracture surfaces of Charpy impact toughness test specimens V-notched in welded metal and test is carried out at room temperature is shown in Fig. 10. Accordingly, cleavage cracks propagate more easily in the GF than in AF. This examination confirms that Accicular Farrite (AF) has a beneficial effect on toughness of joint [14].

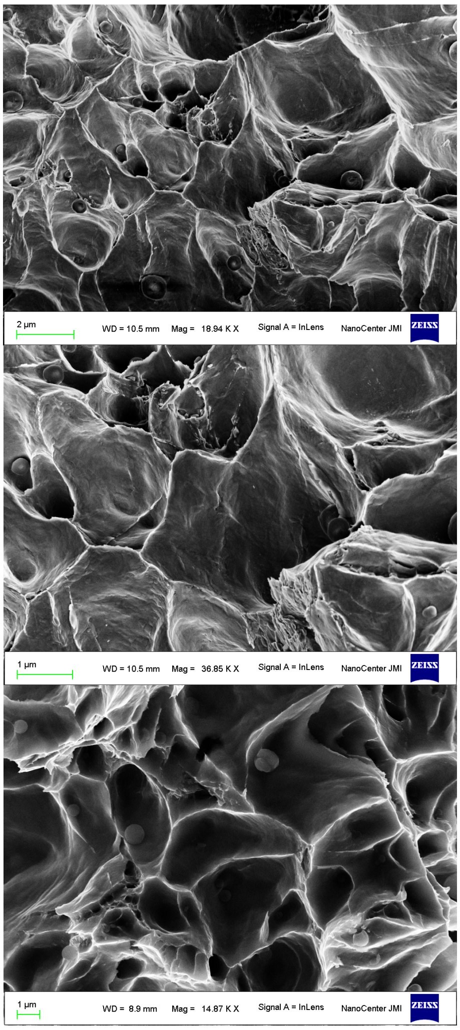


Figure 10 Fracture morphology (SEM image) of Charpy test specimen fractured at room temperature

4. Conclusions

The various factors significantly affect the mechanical properties and microstructure of IS2062 steel welds .MIG welding was employed on 10-mm thick steel with 75% Ar + 25% CO_2 as inert gas. The micro-structural characteristics of the weld joint were investigated via optical, scanning microscopy and energy dispersive spectroscopy. On the basis of experiment the conclusions are drawn:

1. The micro structural constituents like AF, WF and PF in IS 2062 structural steel weld metals are affected by the carbon dioxide and oxygen content which are present in the shielding gas.

2. The SEM image of a tensile fractured surface of welded joint reveals that the fracture mode is brittle. It shows dimples with bright cleavage.

3. Micro hardness values change throughout weld metal varying by shielding gas flow rate.

4. Shielding gas mixture of 75% Ar+25% CO_2 produced acceptable of weld metal properties due to balance of cooling rate and the formation of a high amount of AF which leads to the enhancement of strength and impact toughness.

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