Scientific Journal of Impact Factor (SJIF): 3.134
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 3, Issue 1, January -2016

Effect of welding voltage on microstructure and transition temperatures of MIG welded EN 8 steel weldments

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Abstract *-- This paper deals with the study of the absorbed impact energy in the temperature from range -100C to 80 C of EN8 steel weldments welded at different welding voltages using the MIG welding technique. The microstructure analysis were carried out in the weldments wherein regions such as the heat affected zone (HAZ), weld center, fusion line, base metal region etc. The influence of welding voltage on the microstructure and transition temperatures was studied. It is observed that the transition temperatures depend on the welding voltage.*

Key Words: EN 8 Steel,MIG Welding, Impact Toughness, Transition Temperature

I. INTRODUCTION

The optimization of alloying content in the iron – carbon alloy system, combined with different mechanical and heat treatments lead to immense opportunities for developing suitable materials for specific purpose**.** AISI 1040 – EN 8 steel is a very versatile material with a wide range of attractive properties and produced at a very competitive cost. This is an unalloyed medium carbon steel with good tensile strength. This steel is suitable for the manufacture of parts such as general purpose axles and shafts, gears, bolts and studs. This steel is increasingly used in a diverse range of applications such as bridges, pipelines, submarines, cranes etc. Constructions with lower structural thickness and weight, with the same load bearing capabilities are often possible with the use of such steels. In many of these applications it is essential to form strong joints. Welding technology needs constant upgrading and with the widespread applications of welding, [1]. Generally, welding is the preferred joining method since it alleviates corrosion problems often associated with fasteners. In many circumstances, it is a structural requirement that the weld metal has better strength in comparison to the steel in order to avoid design limitations. These requirements are possible to be achieved under well controlled conditions using for example metal inert gas (MIG) welding. The influence of heat input on the weld metal toughness was investigated earlier [2]. In an investigation on the effect of welding heat input on the microstructure and toughness in a V-N high strength steel [3, 4], it was found that hardness decreases with increase in heat input and a moderate heat input is recommended as optimal giving due consideration to the microstructure developed. The welding voltage, which is the electrical potential difference between the tip of the welding wire and the surface of the molten weld pool, determines the shape of the fusion zone and weld reinforcement. High welding voltage produces wider, flatter and less deeply penetrating welds than low welding voltages and depth of penetration is maximum at optimum arc voltage [5]. MIG welding was used for high reliability, all position capability, ease of use, low cost and high productivity of the process [6, 7]. This study presents the effect of MIG welding voltage and the resulting microstructure on the absorbed impact energy of AISI 1040 – EN 8 steel.

II. EXPERIMENTAL

EN8 steel sheets of dimensions 170 mm x 50 mm x 12 mm were procured having a chemical composition of (wt%) C-0.40, Mn-0.70, Si-0.20, P-0.03, S- 0.03, balance Fe. Flame cut sides were avoided since it may interfere with the metallurgical properties of the weldment. Edge was prepared on the longitudinal side and a double V joint with 60 degree angle was used for joining the pieces.

The root gap 2 mm is given between the plates. A welding wire with 2 mm diameter was employed in welding with electrode as positive polarity. After positioning the specimen correctly, the specimen is tack welded on both edges to create a temporary joint. The double V edge is welded one side at a time alternatively to avoid excess bending of the specimen plates due to heating. Carbon dioxide shielding gas was employed during MIG welding to protect the weldment from atmospheric effects. Welding was carried out at three different voltage levels namely 18 V, 20 V and 22 V. Welding was done manually at an approximate speed of 3m/min. Four passes were given on each side of the double V edge. Carbon steel 70S filler wire with 1.2 mm diameter was used in the welding process.

Microstructural examination of the base material, heat affected zone (HAZ) and the top, middle and the bottom portion of the weldment was carried out after metallographic polishing and etching the specimen. Nital etchant was used to reveal the microstructure.

Charpy impact specimens were prepared from the weld pad with the weldment at the middle and the v-notch on the weldment in the thickness direction. A 300 J capacity impact testing machine was used and impact tests were conducted at different temperature ranging from -100 C to 90 C. For attaining temperatures below and above room temperature, a liquid nitrogen bath and boiling water bath was respectively used. The specimens were immersed in the respective baths for at least 15 min or till equilibrium temperature is attained and then transferred to the testing machine using a special tong. The specimen was allowed to heat or cool as the case may be and the temperature was monitored by a contact thermocouple. After transferring the specimen to the impact machine, the hammer of the impact machine was released when the thermocouple showed the required temperature. At least three samples were tested at each temperature

III. RESULTS AND DISCUSSIONS

3.1 Microstructure of the base material:

Typical microstructure of EN 8 steel base material is shown in Figure. 1. The base metal is largely composed of equiaxed ferrite grains. The pearlite is seen as the dark region the lighter portion corresponds to the ferrite region in the microstructure.

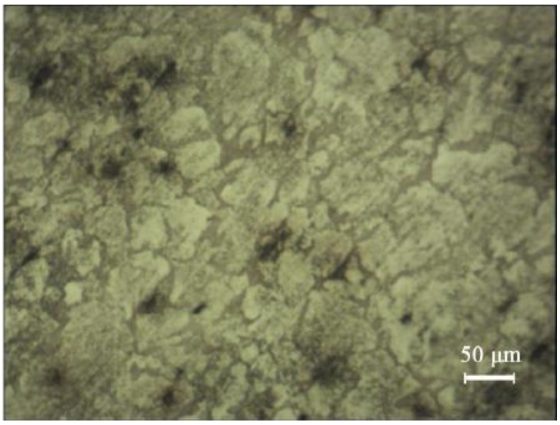

Figure 1. Microstructure of EN 8 steel base material

3.2 Microstructure of the HAZ:

The effect of manual metal arc welding parameters on the HAZ was investigated earlier by Ajay N. Boob and Gattani, 2013 for MS 1005 steel. They have shown that the heat input affect the width of the HAZ. Fig. 3 shows the microstructure near the fusion zone for three different welding voltages. From the microstructures obtained, the following observations can be made.

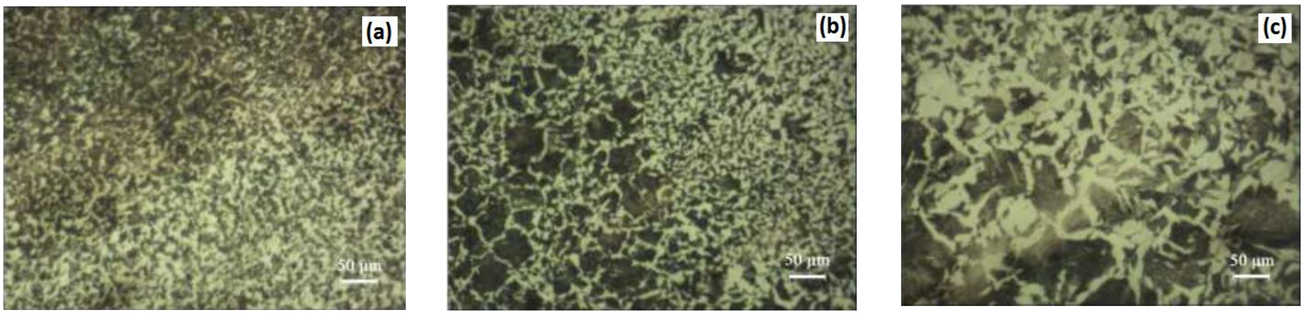

Figure.2. Microstructure of the HAZ under different welding voltages. (a) 18 V, (b) 20 V, (c) 22 V

The fusion line is clearly distinguished from the base metal by the Heat Affected Zone. The HAZ is seen as the darker region consisting of ferrite and big colonies of pearlite. The coarse grained region is adjacent to the weld fusion zone and contains grains larger than those in the base metal. The weldment is of mild steel and hence the pearlitic microstructure of a mild steel is seen at the weldment. A grain growth in the HAZ is seen as the welding voltage increases. This can be attributed to the fact that as the welding voltage increases, the heat input also increases. Higher heat input will cause a larger temperature at the weld area and grain growth can take place [2].

3.3 Microstructure of the weldment:

Figure 3. Shows the details of the typical microstructure of the upper and middle regions of the weldment for different welding voltages. The microstructure that evolved in the weld is heterogeneous due to the temperature gradient and chemical gradients that evolve during the cooling process. It is clearly seen that the microstructures in these three regions

are characterized by pseudo-grains and a microstructural inhomogeneity. All the zones zone contain mainly ferrite and some colonies of pearlite.

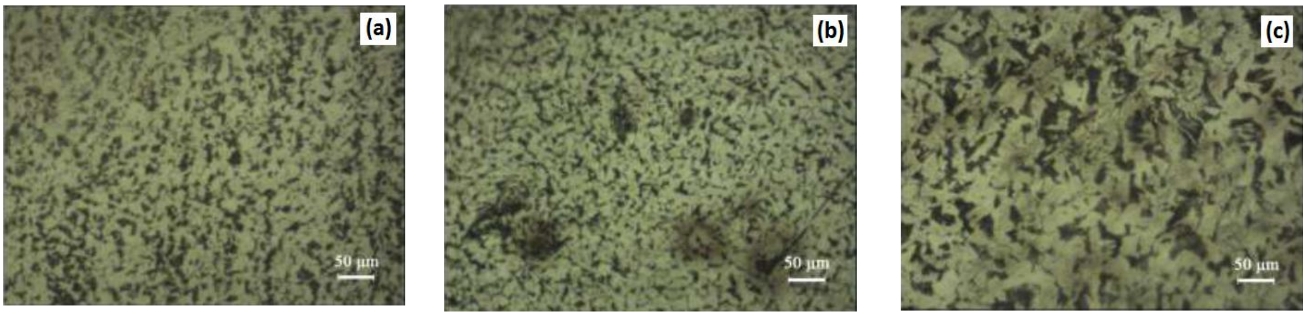

Fig 3a. Microstructure of the upper region of the weldment (a) 18 V, (b) 20 V, (c) 22 V

3.4 Impact test results:

The impact test hammer was lifted and kept at its resting place and the dial needle is set at 0 J. After the release of the hammer, the dial reading is recorded as the energy absorbed by the specimen. Three samples were tested at each condition. Table 1 shows the average value of the results obtained

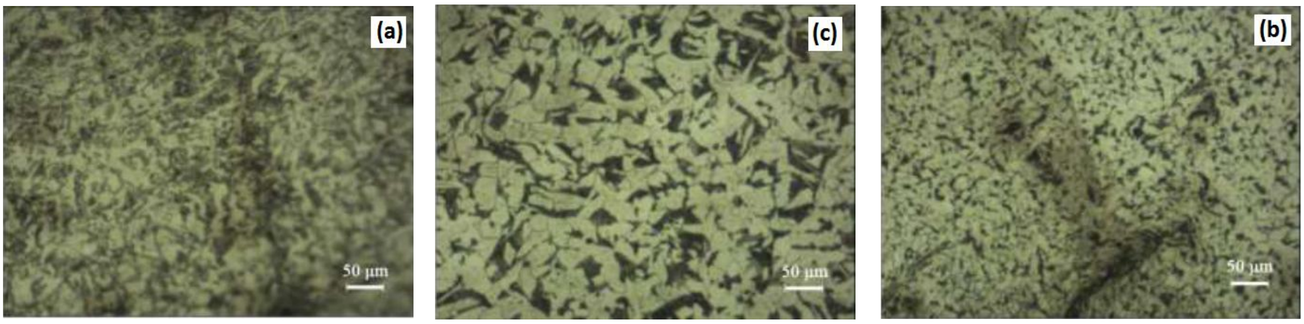

Figure. 3b. Microstructure of the middle region of the weldment (a) 18 V, (b) 20 V, (c) 22 V

Table 1 Average values of impact energy at different test conditions

Testing Temperature	Charpy Impact energy values		
	18 V	20 V	22 V
-100 C	4	4	4
-60 C	30	22	12
-30 C	52	40	29
0 C	84	62	47
35 C	88	77	61
80 C	90	81	74

3.5 Transition temperatures

Results of the impact tests gives the energy needed to fracture a material and can be used to measure the toughness which is a measure of the ductility of the material. The dependence of impact energy with temperature enables us to determine different transition temperatures like temperature for fully plastic behavior, Temperature below which material is brittle and the temperature at which the material is 50% brittle and 50% ductile. If the material breaks on a flat plane, the fracture was brittle, and if the material breaks with shear lips, then the fracture was ductile. If the absorbed impact energy is high, then the material is tough and ductile while low impact energy is representative of a brittle material. Various transition temperatures were illustrated in Fig. 4.

FTP is the temperature at which the fracture changes to totally ductile in nature. This is represented by the temperature at which 0% cleavage fracture is observed or the temperature corresponding to the upper shelf energy. Brittle to ductile transition temperature on the basis of an arbitrary low value of energy absorbed (20J), below which the material is considered to be brittle. This temperature is designated as NDT. The temperature corresponding to the average of the upper and lower shelf values is designated as fracture appearance transition temperature (FATT) and represents the temperature at which the material has 50 % fibrous (ductile) and 50% cleavage (brittle).

Figure 5 shows the variation of absorbed impact energy at different test temperatures for the three different welding conditions. It has been reported [2] that weldmetal toughness is extremely sensitive to the welding heat input and the impact toughness decreases with an increase in heat input. As the welding voltage increases, it is observed that the absorbed impact energy decreases at all testing temperatures. Various transition temperatures as per the Figure.4 is determined from the impact energy versus temperature plot and tabulated in Table. 2. The transition temperatures increased with increase in welding voltage.

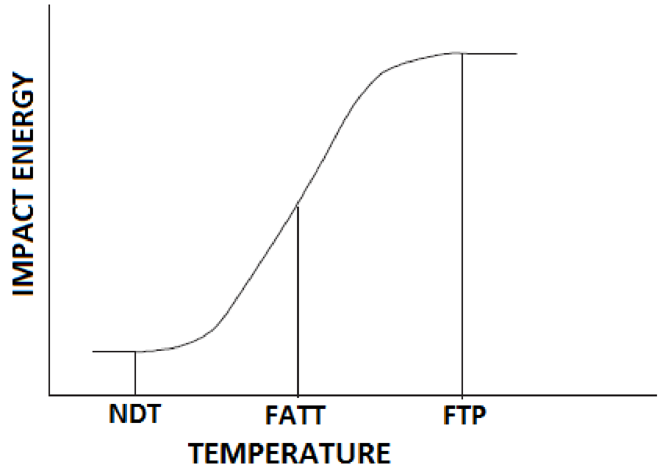

Figure 4. Definitions of various transition temperatures

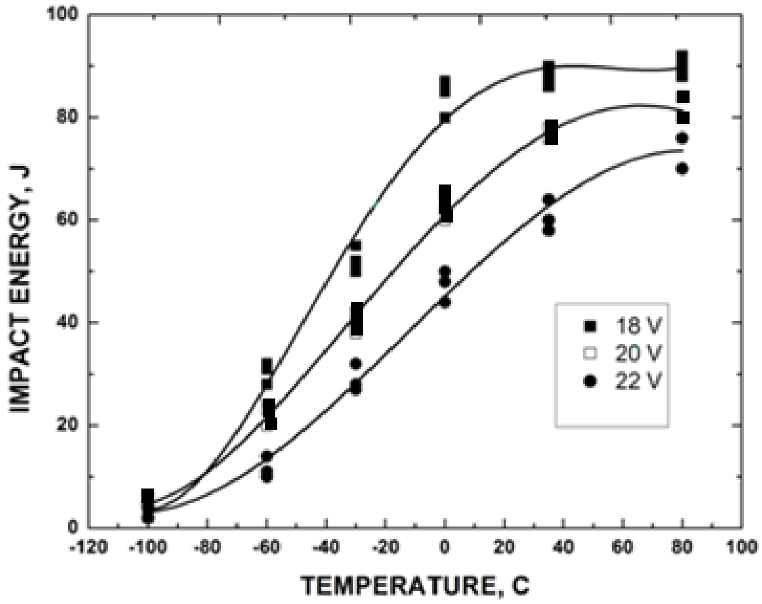

Fig 5. Variation of impact energy with temperature at different welding voltages

Table 2. Transition temperatures at various welding voltages.

Welding Voltage	FTP, C	NDT, C	FATT, C
18	30	- 69	- 40
20	65	- 62	- 28
22	80	- 46	- 16

IV. CONCLUSIONS

From the experiments conducted the following inferences can be made.

1. The welding voltage influences the impact energy of the weldment. Impact energy decreases with increase in welding voltage.

2. Transition temperatures characterizing ductile and brittle nature of fracture increases with increase in welding voltage.
3. At subzero temperatures the welds become very brittle
4. The optimum welding voltage for EN 8 steel plates using MIG welding is found to be 20V.
5. Also from the microstructure it can be seen that the HAZ is influenced by the welding voltage and coarse grains are formed at higher welding voltages.

Acknowledgements

The authors wish to express their gratitude to Shri. K, Sreekumar, Head, Mechanical Engineering Department for the encouragement during the course of the investigation. Thanks are also due to Shri. K. Harikumar and Shri. P.P. Jeleshmon for assistance in welding and metallographic investigation. The encouragement and permission to publish this work by Rev. Fr (D). Jose Kannampuzha, Principal, Amal Jyothi College of Engineering is also gratefully acknowledged.

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