Journal of Manufacturing Engineering, December 2018, Vol. 13, Issue. 4, pp 194-198

EFFECT OF WELDING ON THE IMPACT TOUGHNESS OF LOW CARBON STEEL

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ABSTRACT

The present study examines the effect of welding parameters on impact toughness of welded low carbon steel samples. The welding parameters selected were welding current and welding electrode diameter. The welding operation was conducted on low carbon mild steel specimens. The welding currents used for welding the specimen were 95, 110 and 125 Amps and the electrode diameters used were 2.5 mm, 3.2 mm and 4 mm respectively. The specimens were welded at the junction of the 450V-notch primarily to facilitate Charpy impact test rig for determining impact toughness. The results showed that, an increase in the welding current results in increase in the impact toughness of the weld. Moreover, impact toughness of the welded specimen also increased as the electrode diameter increased from 2.5 mm to 3.2 mm, however decreased for further increase of 4mm. This is mainly due to residual stresses in welded joint that primarily develops due to differential weld thermal cycle (heating, peak temperature and cooling at the any moment during welding) experienced by the weld metal and region close to fusion boundary i.e. heat affected zone.

Keywords: *Welding, current, electrode diameter, Charpy impact test.*

1. Introduction

Traditionally mechanical components have been joined through fasteners, rivet joints etc. In order to reduce time for manufacturing, weight reduction and improvement in mechanical properties, welding processes are usually adopted [1]. Today, a variety of welding processes are available, such that welding is extensively used as a fabrication process for joining materials in a wide range of compositions, part shapes and sizes. Welding is a widely accepted joining process because of its high joint efficiency, simple set up, flexibility and low fabrication costs [2]. Fusion welding processes are widely used for fabrications in many engineering applications such as aerospace, automobile and ship building industries. Oxy-Acetylene Welding (OAW) is the most commonly used gas welding process because of its high flame temperature. The main advantage of the OAW process is that the equipment is simple, portable and inexpensive. The total heat input per unit length of the weld in OAW process is rather high, resulting in large Heat Affected Zone (HAZ) which causes severe distortion [2]. Shielded Metal Arc Welding (SMAW) is one more welding process that melts and joins metals by heating them with an arc established between a stick-like covered electrode and the metals. The welding equipment is also simple, portable and inexpensive [3]. In view of the fact that arc welding processes like SMAW offer a wide spectrum of thermal energy for joining different thicknesses of steel [4, 5], it was considered important that undertaking the present study would be very beneficial in gaining a better understanding of the mechanical properties of mild steel that influence the service performance of the welded joints under different heat input combinations.

Mild steel is an important engineering material. It has found applications in many areas such as vehicle parts, truck bed floors, automobile doors, domestic appliances etc. It is capable of presenting economically, a very wide range of mechanical and other properties. The chemical composition of steel has impact on the weldability and the mechanical properties of the material [5]. According to Monika et al. [6], several elements are purposefully added in the production of structural steel, but other undesirable elements may equally be present arising from the scrap materials charged during the steelmaking process. Carbon, manganese, tungsten and other elements increase strength and may increase the risk of cold cracking and therefore higher preheat and inter pass

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temperatures. Ueji [7] had concluded that the chemical composition of low carbon steel largely affected the microstructure at the fusion zone of the weld. Welding current and time were the important welding parameters that govern the heat input used for melting the metal. Increasing current decreases the fusion zone size while increasing time increases the fusion zone size [8, 9]. Metallic materials can be used for structural applications by means of ultrafine grains which are 1 µm when compared to the conventional 10 µm grain size. Careful control of welding parameters can reduce the amount of heat input into the weld thereby avoiding the excessive grain growth and allotropic transformation in metals, thus improving the mechanical properties of the welded steel metal. This work is therefore aimed at investigating the effects of welding current and welding electrode diameter on the impact toughness of V- notch welded mild steel specimen, using shielded metal arc welding (SMAW) processes.

2. Materials and Methods

The composition of the mild steel sample is shown in Table 1. Hot-rolled plate of low-carbon steel of 10 mm thickness were cut and prepared for welding. Two edge preparations were done to perform welding on single V groove joints. Work piece surfaces and edges were suitably prepared using wire brush prior to the welding processes. The plates were welded together by the SMAW process employing basic coated electrodes. A 7018 low hydrogen electrode rod was used for the welding operation. High voltage DC generators with rectifiers, capable of supplying current of up to 600 Amps were used for the welding operation. Pair of metal plates prepared for welding were abutted by leaving a gap of about 3 mm in between, while the gap is filled completely, taking into consideration the root, hot pass, fill, cap and bead. The welding was done under controlled and varying welding variables. The welded samples were allowed to cool and tapped with hammer to remove the slag in order to ensure the gap was perfectly filled. The completely filled welded joints were thereafter ground by grinding machine to standard dimensions.

Two independent process variables, i.e. welding current and welding electrode diameter were selected for the study. For experimentation, the welding currents used for welding the specimen were 95, 110 and 125 Amperes. and the electrode diameters used were 2.5 mm, 3.2 mm and 4 mm respectively. A ‘V’ notch in the Charpy impact test specimen was prepared according to ASTM E23 standard. The Charpy impact test specimen is shown in Fig 1.The prepared specimen was placed on the Anvil with V-notch gauge. The pendulum was set to predetermined level (298.642 J) and released to strike and fracture the positioned specimen. The value of energy impacted was recorded. Impact tests were conducted using the Charpy impact testing machine. Charpy impact testing preferred over other impact tests owing to its configuration which places the specimen horizontally into the machine thereby encouraging the specimen to fracture. Each experiment was repeated three times and the average values were recorded.

3. Results and Discussions

The effect of various combinations welding current and welding electrode diameters on Impact toughness (J/mm^2) of the low carbon/ mild steel welded joints have been shown in Fig. 2 and 3 respectively.

3.1 Effect of welding current on Impact toughness of the welded joint

The test piece is supported at each end while notched at the mid-point between the two supports. The notch is on the face directly opposite to where the pendulum strikes the test piece. The welded V-notch was 2 mm deep and of angle 45°. The energy absorbed in breaking the test piece is measured in joules. The ability of the material to withstand the applied load is referred to as toughness. The Fig. 2 (a, b & c) show that the impact toughness of the welded joint increased with increase in current.

Table 1. Chemical composition of Mild steel.

Element	C	Al	Si	Mn	P	Cu	Fe
wt. (%)	0.16	0.07	0.168	0.18	0.025	0.09	Balance

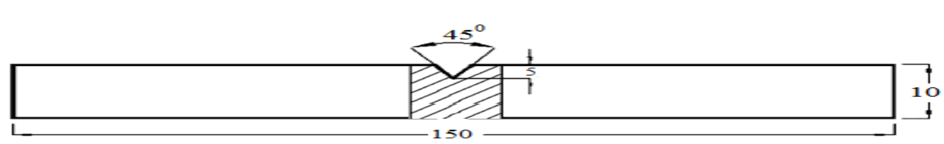
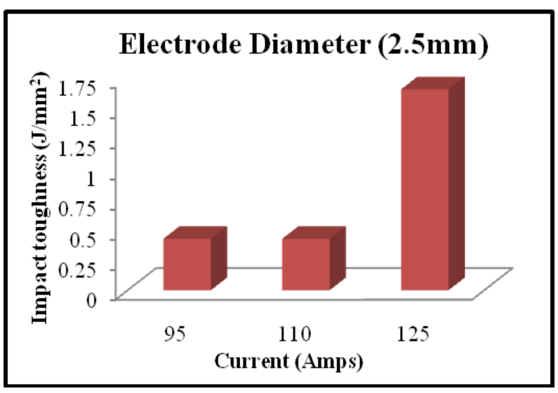
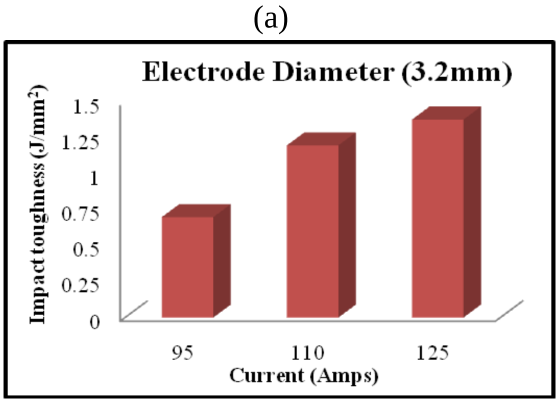


Fig 1. V-notch test specimen for impact testing.

For an electrode of diameter 2.5mm, a maximum increase in impact toughness from (0.425 to 1.66) i.e. by almost 290% was observed for increase in current from 95 Amps to 125 Amps. Similarly for an electrode diameter 3.2mm, the toughness was found to increase by 96% was observed for increase in current from 95 Amps to 125 Amps. A similar trend has been observed for the electrode diameter of 4.2mm as well where an increase in impact toughness of almost 170% was observed. This phenomenon for increase in toughness can be related to structural changes of weld metal during solidification and chances of formation of varying grain sizes in the various welding conditions [10]. The weldment increased toughness values are mainly due to increased grain size. The increase in temperature due to increasing currents yields increased grain size [11, 12, 13]. This increase in toughness values indicates that the welded joint is prone to brittleness than the base metal; hence post welding heat treatment will be required to optimize the mechanical property.



(a)



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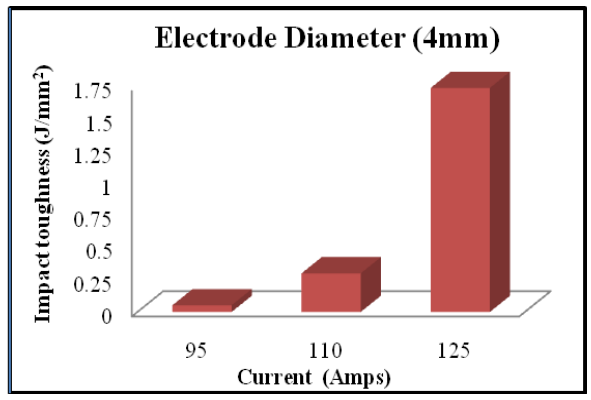
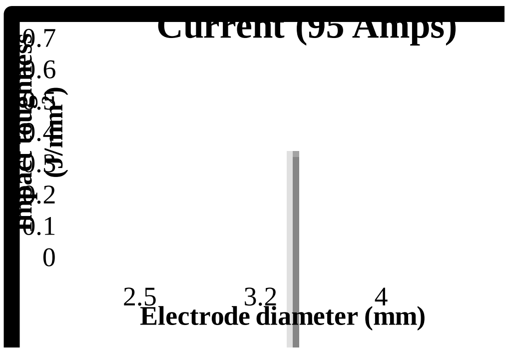


(c)

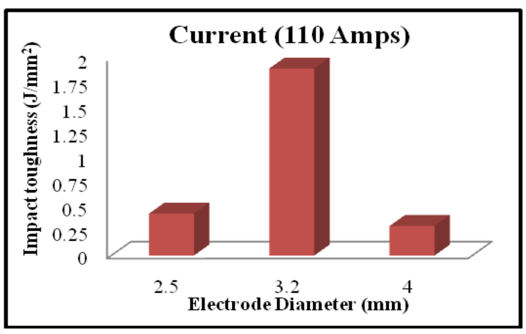
Fig 2. Effect of current on the Impact of the welded joint for electrode diameter of (a) 2.5mm, (b) 3.2mm, and (c) 4mm.

3.2 Effect of electrode diameter on Impact toughness of the welded joint

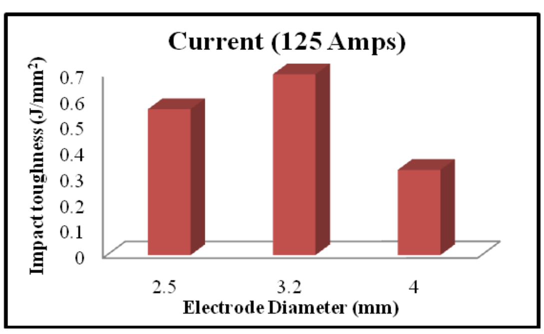
The effect of welding electrode on Impact toughness (J/mm^2) of the welded joints for various different welding currents has been shown in Fig 3.It is observed from Fig. 3 (a, b& c) that as the electrode diameter increases from 2.5mmto 3.2 mm, the impact toughness of the specimen also increased. However, for an electrode diameter for 4mm the impact decreased. This behavior was found to be similar for all the currents implemented in the current study. The generic tungsten electrodes consist of a tip angle of 180^0. As a result of this tip angle for the 2.5mm and 3.2mmdiameter electrode, the area of heat projected on the welded surface increases as a result of which the toughness increases. Also, the increased toughness is due to electrode coating which provides alloy addition to the weld deposit [14, 15]. However for the electrode diameter of 4mm, the size of the electrode fails to consume the space between the welded junctions at the V-notch, thereby leading to the creation of voids due to which the impact toughness of the weld drastically decreases.



(a)



(b)



(c)

Fig3. Effect of electrode diameter on the Impact of the welded joint for various currents of, (a) 95 Amps; (b) 110 Amps and (c) 125 Amps.

4. Conclusions

The effect of welding parameters was examined and discussed in other to be able to predict the Impact toughness of welded mild steel samples. The results have shown that the selected welding parameters (welding current and welding electrode diameter)have significant effect on the impact toughness of the welded samples. Increase in the welding current resulted in increased impact toughness. This phenomenon for increase in toughness was mainly due to increased grain size. The increase in temperature due to increasing currents yields increased grain size. Impact toughness of the welded specimen also increased as the electrode diameter increased from 2.5mm to 3.2mm, however decreased for electrode diameter of 4mm. The reason for the decrease was attributed to the size of the electrode as it failed to consume the space between the welded junctions at the V-notch, thereby leading to the creation of voids.

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