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Influence of Welding Current and Joint Design on the Tensile Properties of SMAW Welded Mild Steel Joints

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ABSTRACT
Present study includes welding characteristics of weldment with respect to different types of weld design and welding current. Mild steel plates of 6mm were welded using different joint designs. Single V, Double V and Flat surfaces were joined by Shielded Metal Arc Welding process. Welding current was varied in all the cases. Mechanical properties such as ultimate tensile strength, yield strength and percentage elongation were evaluated. Results indicated that the single V joint design depict maximum UTS in comparison to other welding joints and also weld properties of joints (weldment) increases to some extent up-to a particular current level, after which the strength decreases. Welding current also affect the welding speed.
KEYWORDS: Shielded Metal Arc Welding (SMAW), Tensile Strength, Welding Current, Mild Steel.

I. INTRODUCTION

In the heavy as well as small industries, welding is widely used by metal workers in the fabrication, maintenance and repair of parts and structures. While there are many methods for joining metals, welding is one of the most convenient and rapid method available.

A welded joint is obtained when two clean surfaces are brought into contact with each other and either pressure or heat or both are applied to obtain a bond. The tendency of atoms to bond is the fundamental basis of welding. The inter-diffusion between the materials that are joined is the underlying principle in all welding processes. In welding the metallic materials are joined by the formation of metallic bonds and a perfect connection is formed. As pointed out earlier, any welding process needs some form of energy, often heat to connect the two materials. The relative amount of heat and pressure required to join two materials may vary considerably between two extreme cases in which either heat or pressure alone applied. When heat alone is applied to make the joint, pressure is used merely to keep the joining members together. Examples of such a process are Shielded Metal Arc Welding (SMAW), Gas Tungsten Arc Welding (GTAW) and Submerged Arc Welding (SAW) etc. On the other side pressure alone is used to make the bonding by plastic deformation, examples being cold working, roll welding, ultra sonic welding etc. There are other welding methods where both pressure and heat are employed, such as resistance welding, friction welding etc. Electric arc is by far the most popular source of heat used in commercial welding practice [1]. Among the several arcs welding methods the SMAW arc welding is the oldest of the arc welding processes. It is characterized by versatility, simplicity and flexibility. The SMAW process commonly is used for tack welding, fabrication of miscellaneous components and repair welding. There is a practical limit to the amount of current that may be used. SMAW also is used in the field for erection, maintenance and repairs. SMAW has earned a reputation for depositing high quality welds dependably. It is however slower and is more dependent on operator skill for high quality welds.

The goal during welding is to obtain the best possible combination of strength and toughness for the welded joints. Strength and toughness are both strongly influenced by the microstructure [2]. However with optimal selection of welding current and speed, it is possible to obtain a weld metal microstructure that provides strength comparable to the base steel.

These are several different types of weld joints that can be used in this process. Each joint is joined in a different way and has different strengths and uses, and thus it is important to use the right one for the right job. When two pieces of metal joined end to end a butt weld joint is used. Butt joints are frequently used when a smooth face is desired. Some applications that use butt joint are pressure vessels, piping and takes. There are several variations on the butt joint including the square joint, the single ‘V’ and double ‘V’ joint.

Present study has been framed keeping in view obtaining appropriate joint design that meet the strength and safety requirements for the service exposed conditions to be encountered in actual application. In the present work the effect of welding current on tensile properties, to obtained optimal welding current value for mild steel weldment by SMAW process have been investigated. Mild steel which is most frequently used in fabrication and erection of steel structure are used for this purpose. The different process parameters which affect the weld quality in Arc welding are:

Welding Current:

Welding current is the most influencing parameter in welding process which controls the depth of fusion; the electrode feed rate and depth of penetration. The amount of heat developed during welding depends upon the current used for a given size of electrode and filler wires. It is therefore essential that a correct current is used to produce good quality of weld and reduce the distortion problems on the job.

Welding Voltage:

This is the electrical potential difference between the tip of the welding wire and the surface of the molten weld pool. It 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. Depth of penetration is maximum at optimum are voltage.

Welding Speed:

Speed of welding is defined as the rate of travel of the electrode along the seam or the rate of the travel of the work under the electrode along the seam. Some general statements can be made regarding speed of travel. Increasing the speed of travel and maintaining constant arc voltage and current will reduce the width of the bead and also increase penetration until an optimum speed is reached, at which penetration will be increasing the maximum speed beyond this optimum will result in decreasing penetration.

Heat Input Rate:

Heat input is a relative measure of the energy transferred per unit length of weld. It is an important characteristic because it influences the cooling rate, which any affect the mechanical properties and metallurgical structure of the weld and the HAZ. Heat input or energy is calculated from mathematical formulae.

$$\text{Heat I/p} = \frac{60VI}{S} \quad \text{in joule/mm}$$

Where,

H I/p = heat input (joule/mm)
V = arc voltage (volts)
I = current (amps)
S = welding speed (mm/min)

Wire Feed Rate:

Wire feed rate is a measure of the rate at which the electrode is passed through the welding torch and delivered to the arc. The deposition rates are directly proportional to wire feed speed and directly related to the current. When all other welding conditions are maintained constant, an increase in the wire feed rate will directly lead to an increase in current. For slower wire feed rates, the ratio of the wire feed rate to current is relatively constant and linear.

II. EXPERIMENTAL PROCEDURE

The welding of all the specimens was done at Bent Joints Industry Govindpura Industrial Area, Bhopal M.P with the following set up "Warp Engineering' Model-WS-400 Time Inverter, MMA/TIG Welding Machine with a 400A capacity. In this investigation Mild steel alloy plate of dimension 150mm × 50mm × 6mm (figure 1) were taken for SMAW welding technique. These plates are cleaned of dirt, grease and other foreign materials and were cut into the required dimensions by power hacksaw. Edge preparation is carried out where single V edge is prepared for a bevel angle of 37.50, double V edge is prepared for a bevel angle of 45^0 and square butt joint plates were prepared by smoothing their faces. In all the cases the root gap of 1.5 mm and root of 1mm was maintained. The mild steel plates are placed on welding table and in order avoid the undesired distortion to the minimal the right size of stiffeners was provided at critical locations where the welding process is carried out.
There are 12 numbers of specimens were prepared from SMAW process viz., single V, double V and square butt joint. The first 4 specimens of single V joint design at four different values of welding current (specimen code 1V at 90 amps.,2V at 100 amps., 3V at 110 amps., 4V at 120 amps) similarly another 4 of double V joint design(specimen code 1D,2D,3D,4D) and remaining 4 of square butt joint design (specimen code 1S,2S,3S,4S) were prepared

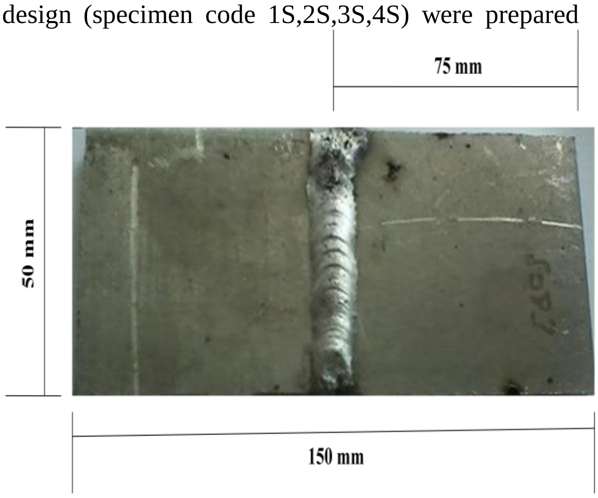

Figure 1: Pictorial View of Single V Butt Joint Welded Specimen

In this process all the various welding parameters such as the arc voltage, number of passes, welding speed, wire feed rate, arc time and welding current were recorded during the welding of each specimen only welding current was varied during the welding of specimens, to study the effect of welding current on the tensile strength, yield strength and elongation of the weldment. Having finished the welding of the joints in order to measure the tensile strength, welded plates were cut using power hacksaw and then machined to the required dimensions to make the tensile test pieces with the help of the shaper and lathe machine. The dimensions of a tensile test specimen shown in Figure No.2

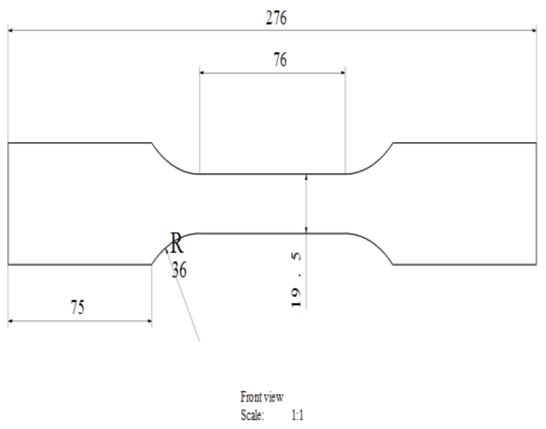

Figure 2: Tensile Test Specimen

Figure 3: Shielded Metal Arc Welding Machine (Warp Engineering Model WS-400)

The rectangular smooth tensile specimens were prepared to evaluate tensile properties of the joints such as yield strength and ultimate tensile strength. After machining operation the specimen was tested in a tensile testing machine at CIAE, Bhopal to record the reading of different tensile test specimens which was made at varying welding current input. The tested broken samples were shown in figure 4.

Figure 4: Broken Test Samples after Tensile Tests

The chemical composition of mild steel plate which is used as base metal were given in Table No.1

Table 1: The Chemical Composition of the Base Metal

Material	C	Mn	Si	S	P
Mild Steel	0.14	0.76	0.28	0.013	0.010

E6013L electrodes were used to weld the specimen using Shielded Metal Arc Welding process. The chemical composition E6013L electrode were given in Table No.2

Table 2: Chemical Composition of Electrode

Material	C	Mn	Si	S	P
E6013L	0.08	0.40	0.25	0.02	0.02

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

The tensile strength of the joints was evaluated. The specimens were tested and the results were presented in Table No.3

Table 3.1: Effect of Welding current on Welding Parameters

Specimen code	Joint design	Voltage (volts)	Current (ampere)	Arc Time (sec)	Welding speed (mm/min)	Wire feed rate (mm/sec)
1V	Single V	20-24	90	21	142.85	3.78
2V	Single V	20-24	100	19	157.84	3.47
3V	Single V	20-24	110	19	157.89	4.10
4V	Single V	20-24	120	15	199.99	4.46
1D	Double V	20-24	90	35	171.42	3.45
2D	Double V	20-24	100	34	176.47	3.47
3D	Double V	20-24	110	32	193.54	3.83
4D	Double V	20-24	120	27	222.22	4.40
1S	Square butt	20-24	90	19.70	152.28	3.5
2S	Square butt	20-24	100	18.47	162.42	3.62
3S	Square butt	20-24	110	15.76	190.35	4.46
4S	Square butt	20-24	120	14.60	205.47	4.11

Table 3.2: Effect of Welding current on Ultimate Tensile Strength

Specimen code	Heat Input Rate (J/mm)	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)	Percentage Elongation
1V	831.65	290.36	386.21	25.41
2V	836.03	302.11	418.64	18.59
3V	919.63	340.23	435.59	20.39
4V	792.04	327.11	427.11	19.90
1D	693.04	286.21	377.40	22.40
2D	748.00	297.81	387.74	23.35
3D	750.24	296.62	386.27	25.42
4D	712.81	237.44	375.66	22.80
1Ss	780.15	237.31	375.64	22.21
2S	812.71	284.93	394.16	24.11
3S	762.81	271.32	386.25	25.22
4S	770.85	225.64	377.49	23.14

Effect of Welding Current and joint design on Ultimate Tensile Strength:

From the values of UTS (ultimate tensile strength) obtained for joint design single V at 90amp, 100amp, 110amp,120amp,it is observed that 110amp weldment depicted maximum ultimate tensile strength when compare to weldment of 90amp, 100amp and 120amp.Compartively the single V joint design depict maximum value of ultimate tensile strength 435.59Mpa.at 110 amp than those of double V joint design(ultimate tensile strength 387.74 MPa at 90amp) and square butt joint design (ultimate tensile strength 394.16MPa at 100 amp). From the above analysis it was observed that the single V joint has maximum tensile strength in comparison to other joint design. It was also observed that the tensile strength increases with increase in current up to 110 amp which was optimum value to obtain maximum ultimate tensile strength in case of single V joint, it means that the rate at which the welding electrode is melted, the amount of base metal melted, dilution, depth of fusion, the deposition rates, the depth of penetration was good at this value and optimum weldability can be achieved at joint design of single V current 110 amp, arc time 144.52sec, welding speed 145.30 mm/min, wire feed rate 4.72 mm/sec. Increasing welding current beyond this optimum value increases the amount of wire feed rate and penetration.

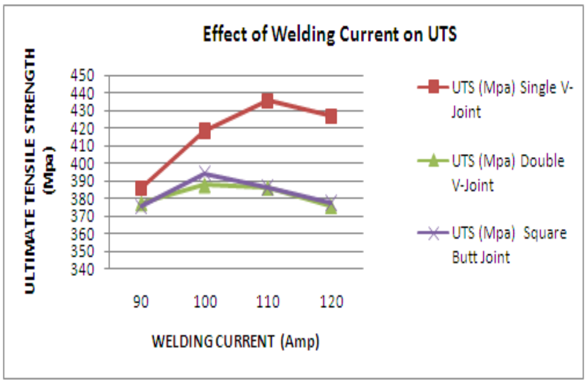

Figure 5: Effect of Welding Current on Ultimate Tensile Strength

Effect of Welding Current on Yield Strength:

From the values of yield strength obtained for joint design Single V at 90Amp, 100 Amp, 110 Amp, 120 Amp. It is observed that 110 Amp current has maximum value of yield strength in comparison to weldment of same joint design. Also the values obtained by other joint design taken for this investigation (Double V and Square Butt Joints) have lower value of yield strength.

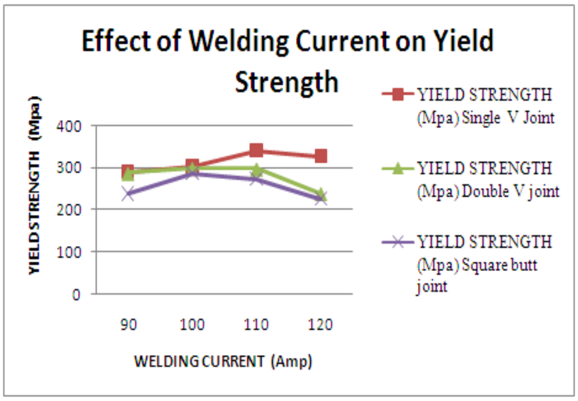

Figure 6: Effect of Welding Current on Yield Strength

Effect of Welding Current on Arc Time:

It can be clearly seen from the table no.3 that the arc time is maximum in case of double V joint in comparison to single V and square butt joint. This is due to the fact that in case of double V joint welding is done on both sides of the weldment. Although in case of single V joint and square butt joint welding was also done on both sides, but in single V joint most of the welding was done on one side of the weldment, only back gouging is done after grinding at the back of the joint to completely fuse the edges. Similarly, in the case of square butt joint welding was done on both sides to fuse the metal as there is no edge preparation, so the arc time was less.

In all the joint designs, the effect of welding current on each time, which help to analyze the arc time with respect to varying welding current was that by increasing welding current the arc time decreases in all the cases of different joint design. It is clear from the figure that describes the arc time decreases with increasing welding current.

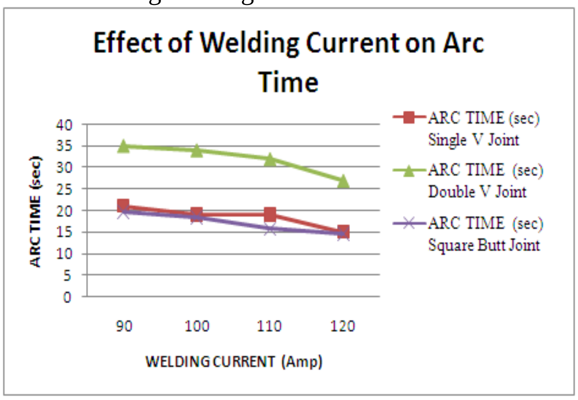

Figure 7: Effect of Welding Current on Arc Time

Effect of Welding Current on Welding Speed:

The welding speed is maximum in case of double V joint because welding speed depends upon the current and the thickness of the material. From the above graph it can be observed that there is an increase in welding speed with an increase in welding current. The welding speed in all the cases increases with an increase in current.

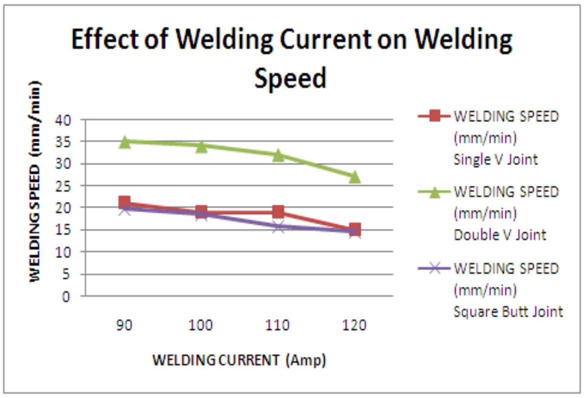

Figure 8: Effect of Welding Current on Welding Speed

Effect of Welding Current on Wire Feed Rate:

From the above graph it can be evaluated that the wire feed rate increases with an increase in welding current. It seems that due to increase in welding current the electrode melt at higher rates.

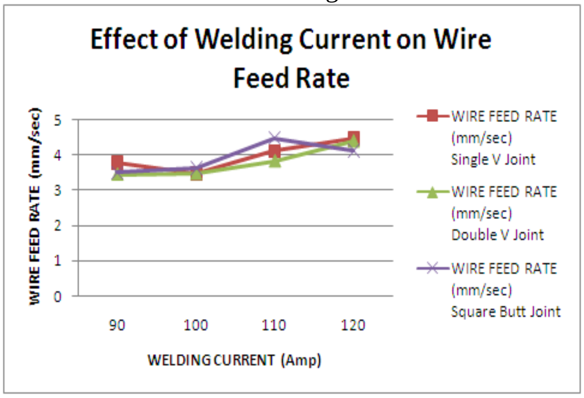

Figure 9: Effect of Welding Current on Wire Feed Rate

IV. CONCLUSION

From this experimental investigation, the following conclusion has been derived. At the welding current of 110amp the tensile strength was maximum for single V joint design in comparison with weld carried out of 90amp, 100amp and 120amp. And also in comparison to other types of joint design, i.e. double V (UTS 387.74MPa, YS 297.81MPa) and square butt joint (UTS 394.16MPa, YS 284.93MPa) the ultimate tensile strength of single V joint design was maximum. With the increase in welding current which was taken as a variable parameter the ultimate tensile strength 435.59MPa, yield strength 340.23MPa and percentage elongation of 20.39 was recorded. Maximum/optimum value of tensile strength of single V joint design was obtained when welding speed was 157.80mm/min. The maximum UTS was obtained when the heat input rate was 919.63 J/mm. Hence it can be concluded that the ultimate tensile strength in case of the single V joint was maximum as a result of correct fusion between weld metal and base metal, right joint design and edge preparation for this type of material thickness. Also, it may be concluded that with the increase in welding current the UTS will increase until an optimum value. Increasing the current beyond this optimum value will result in decreasing UTS.

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