Effect of Welding Speed on Depth of Penetration During Arc Welding of Mild Steel Plates

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Abstract
Generally the high speed welding is considered as an important approach to productivity improvement and cost reduction in mechanical manufacturing industry. So, it becomes important to understand interrelationship between welding speed and depth of penetration. To achieve the objective single-pass welds of Mild Steel plates having 6mm thickness were fabricated by using Electric arc welding process which is one of the most widely used welding methods because of its relatively high productivity and low cost. The welding current and arc voltage were kept constant. By varying welding speed thus heat input, different specimens in butt position were prepared. The depth of penetration was measured for each specimen after the welding process and the results were analyzed to study the effect of speed on depth of penetration. It was found that at constant arc voltage and welding current the depth of penetration will increase with increasing welding speed and is found to be maximum at optimum value after which depth of penetration starts decreasing with increase in welding speed.

Keywords
Metal Arc Welding, Welding Current, Arc voltage, Mild Steel, Depth of Penetration

I. Introduction

Welding is a process for joining different metals or materials. American Welding Society (AWS) has defined the welding process as a "materials joining process which produces coalescence of materials by heating them to suitable temperatures with or without the application of pressure or by the application of pressure alone and with or without the use of filler material."

In welding there are different process parameters which influence the weld quality and weld deposition rate like Welding Current, Arc voltage, Welding speed, Electrode feed speed, Electrode diameter, Electrode extension and Joint Geometry etc. Welding mainly depends on arc energy that is transferred as heat to the work piece. The total Heat Input (H) transferred to the weldments per unit time, per unit length of the weld is given by:

$$H = \eta \frac{AB}{C}$$

Where A = Arc Current (in Amperes) B = Arc Voltage (in volts)

C = Welding Speed (in mm/min)

η = Heat transfer efficiency

It is clear from the above equation that the heat transfer which is contemporary to the metal transfer, depends mainly on Welding Current, Arc voltage & Welding speed. So they are the primary parameters in welding. In present work welding current and voltage are kept constant. Only welding speed is varying which further changes the penetration due to different heat input rate

II. Primary Welding Parameters

A. Welding current

Amperage is used to increase or decrease the overall size of weld bead as well as the penetration depth of weld bead. It controls the depth of fusion, geometry and the electrode burn off rate. Change in welding current changes the transition current and mode of metal transfer get changed accordingly. So, Welding current is also one of the major factors dominating the metal transfer [4].

B. Arc Voltage

Arc voltage is the electrical potential difference between the tip of the electrode and the surface of the molten weld pool on the surface of job. It determines the shape of the fusion zone and weld reinforcement. Arc voltage is the voltage between electrode and the job during welding. Open Circuit Voltage (OCV) is the voltage generated by power source when no welding is done. Voltage is usually used to either increase or decrease the width of weld bead. Change in arc voltage not only affects the bead width, but also influence the microstructure. Higher arc voltage results in flatter beads due to increased arc cone. Excessive high voltage causes porosity, spatter and undercut. Arc length is about proportional to the voltage. It should not be more than the electrode diameter. Decrease in arc voltage cause narrow weld bead with deeper penetration.

C. Welding Speed

The speed of movement of the welding torch determines the welding speed. Broadly it may be 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. Welding Speed influences both penetration and weld pool width. High welding speeds increase penetration, thus resulted in higher dilution.

III. Principle of Arc Welding

Electric arc welding is the process of joining metals in which an electric arc is formed by using a welding machine that serves as a step down transformer. Low amperage, high voltage current is converted to high amperage, low voltage current.

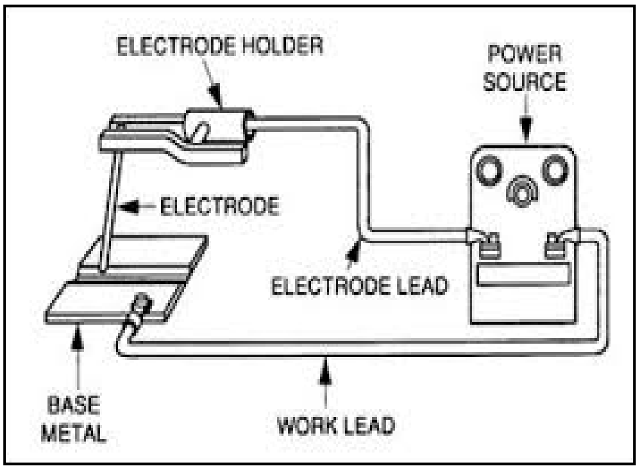


Fig. 1: Electric Arc Welding Set up

The machine has two cables, the ground cable which is attached to the metal being welded and the electrode cable which is cable is attached to an electrode holder that holds the electrode. When tip of the electrode is touched to the base metal spark is produced that forms arc. Voltage is the force that pushes the electrons to flow across the arc. The length of the gap between the electrode and the metal provides resistance to the flow of electrons. When the proper gap is maintained the arc generates enough heat to melt the electrode and the base metal. This molten puddle is moved along the joint to join the two metals. The correct usage of heat and electricity is the main challenge to get the excellent welds even stronger than parent metal itself.

IV. Literature Review

At constant arc voltage and welding current, width of bead will reduce and penetration will increase with increasing speed. There will be maximum penetration at optimum speed. If the speed is increased beyond this optimum value there will be decrease in penetration [3].

In the arc welding increase in welding speed results in decreasing the heat input per unit length of the weld, electrode burn off rate and the weld reinforcement. Also undercut, arc blow, porosity and uneven bead shape may result. If it decreases beyond a certain value then the arc impinges on the molten weld pool, rather than on the base metal, there by reducing the effective penetration. This is because of the pressure of the large amount of weld pool below the electrode, which further cushions the arc penetrating force [8]. Welding speed depends on the thickness of the work piece and desired cross-sectional area of the weld [6].

V. Design of Experiment

Objective of this present investigation is to study the effect of welding speed and heat input on the depth of penetration in the weld zone of specimens. In this analysis, electricl arc welding is used. Firstly, twenty pieces of dimensions 60mm× 40mm are cut from a commercially available 6mm thick plate of Mild Steel (E6011).

A. Pre weld Surface Cleaning

The surfaces of edges of the work pieces are suitably prepared by removing surface contaminations like dirt, metal particles, oil grease, paint and moisture with wire brush and alkaline cleaner.

B. Edge Preparation

Groove preparation before the welding at the mating edges improves joint strength. So grooves in present work are cut with groove angle of 600 by keeping 2mm root face and 1.5 mm root gap.

C. Welding Procedure

Welding is done by using Arc welding machine TORNADO 401 because of its certain features like good anti stick property, stable arc, adjustable arc force, digital current meter etc.

It is very important to maintain the constant welding speed during welding manually. Speed of welding is defined as the rate of travel of the electrode along the seam or the rate of travel of the work under the electrode along the seam. The plates to be welded are placed in butt position inside the fixture in order to avoid distortion. Torch is moved at different speeds for each specimen in such a way that a 70 to 150 forehead angle of the electrode relative to the work is maintained during the welding.

Fig. 1: TORNADO 401

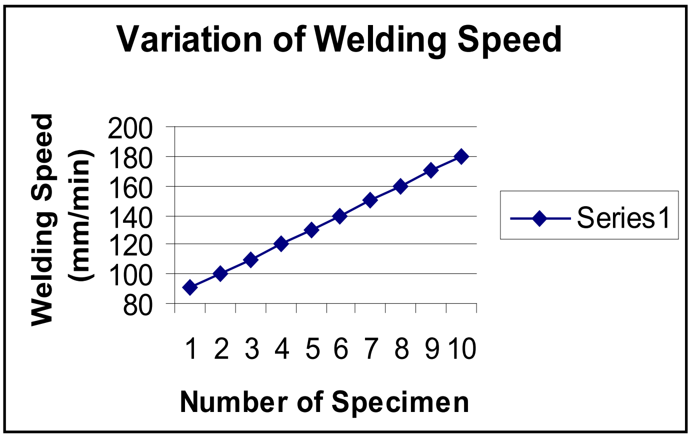
By using the electrode of the same material of 2.5 mm diameter, total ten single pass butt joints are prepared at constant voltage of 25 Volts and current of 110 Amperes. Only welding speed is varied manually for each welded specimen to study its effect on the depth of penetration in different specimens. After the welding, specimens are cut perpendicular to the direction of welding. Then depth of penetration in different specimens is measured and recorded.

VI. Results and Analysis

A. Results of Experiment

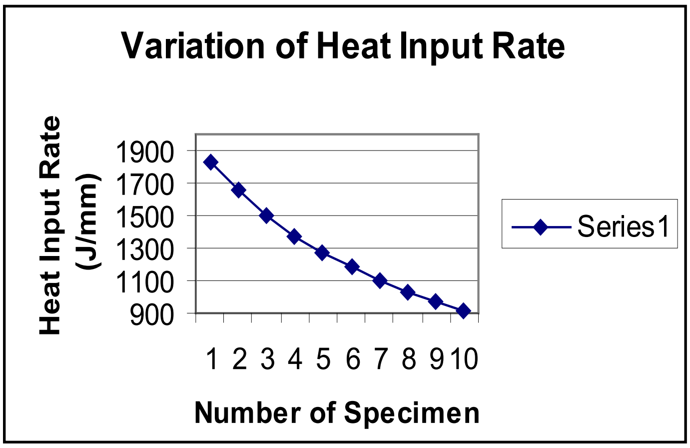
Table 1: Observation Table

Sr. No.	Welding Speed (mm/min)	Heat input (V×I×60/C J/mm)	Mean Penetration (mm)
1	90.4	1825.2	4.6
2	99.8	1653.3	4.9
3	110.2	1497.2	5.2
4	120.5	1369.2	5.6
5	130.3	1266.3	5.0
6	139.7	1181.1	4.7
7	150.4	1097.0	4.4
8	160.2	1029.9	3.8
9	170.3	968.8	3.4
10	180.1	916.1	3.1

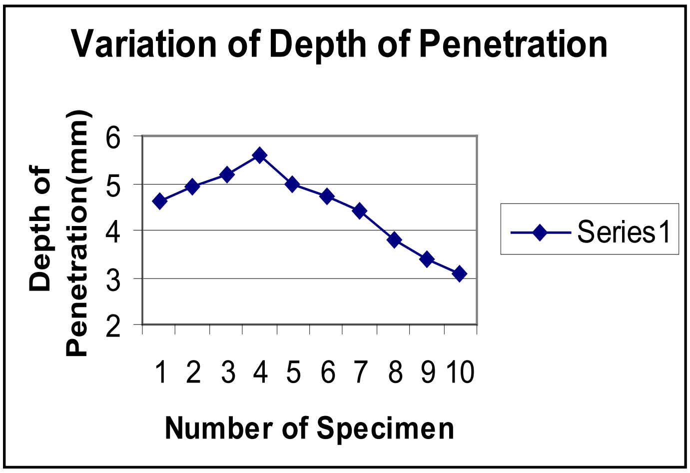


Graph-1: Variation of Welding Speed

ISSN : 2249-5762 (Online) | ISSN : 2249-5770 (Print)



Graph-2: Variation of Heat Input



Graph-3: Variation of Penetration

B. Analysis

Each welding specimen is cut in to three pieces, perpendicular to the direction of welding and depth of penetration is measured for every piece through measuring instrument. Then the mean of three values which are almost same for specific specimen is recorded in the table. The graph between welding speed and penetration is plotted. It is found that depth of penetration increases with increasing welding speed up to 120.5 mm/min after this penetration starts decreasing with increasing welding speed. This indicates that this is optimum value of speed at which penetration is maximum.

Actually when the welding speed is increased beyond optimum value this results in decreasing the heat input per unit length of the weld and electrode burn off rate. As a result there is decrease in the depth of penetration. On the other hand when welding speed is less than the optimum value the depth of penetration is again decreased. This occurs because of the pressure of the large amount of weld pool beneath the electrode, which will cushion the arc penetrating force.

It is evident from the table that with increase in welding speed the heat input is going to decrease. This is because of the inverse relation between heat input and the welding speed. The maximum depth of penetration occurs at heat input rate of 1369.2 J/mm. So, the optimum weld quality can be obtained with this heat input rate.

Although the results for effect of welding speed are studied for mild steel only, it is proposed that these results can be extended to the plates of varying thickness and any other welding variable.

VII. Conclusions

Following conclusions are drawn from the present work:

1. Welding of Mild Steel specimens of dimension 60mm× 40mm× 6 mm using current of 110Ampere, arc voltage 25 Volts, electrode of Mild Steel with diameter 2.5 mm, can be optimized when welding is done at 120.5 mm/min because the deepest penetration of 5.6 mm is obtained at this optimum speed with heat input of 1369.2 J/mm.
2. With the increase in welding speed the heat input rate is going to decrease.
3. Hence it can be concluded that at constant arc voltage and welding current the depth of penetration will increase with increasing welding speed and is found to be maximum at optimum value after which depth of penetration starts decreasing with increase in welding speed.

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