INFLUENCE OF PROCESS PARAMETERS ON DEPTH OF PENETRATION OF WELDED JOINT IN MIG WELDING PROCESS

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Abstract

The effect of various welding process parameters on the weldability of Mild Steel specimens of grade EN-3A having dimensions 150mm× 100mm× 6 mm, welded by metal inert gas welding were investigated. The welding current, arc voltage, welding speed, are chosen as welding parameters. The depth of penetrations were measured for each specimen after the welding operation is done on closed butt joint and the effects of welding speed, current, voltage parameters on depth of penetration were investigated.

Index Terms: *Mild Steel (EN-3A), metal inert gas welding, welding current, arc voltage and welding speed.*

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1. INTRODUCTION

Metal inert gas/ metal active gas (MIG/MAG) welding is an arc welding process, the melting takes place by Joule effect and a continuous electric arc, where the additional metal is supplied by a roll of wire [1]. The weld is made by falling successive drops on the weld puddle. Argon gas (MIG welding) or active gas, CO_2 (MAG welding) are used as plasma for providing protective atmosphere for the weld metal, so that contamination between oxygen and nitrogen is avoided. Electric energy is supplied from the welding generator for melting between wire and workpiece to weld. According to two different control modes (1) the arc mode, where voltage supplied from the generator is controlled to reach a point chosen by the welder. (2) the short-circuit mode, where current flows at pre-defined law, in gas metal arc welding the molten metal drop detachment form an electrode have complex interactions between different physical phenomena. Some of the researchers have studied the electromagnetic effects [2-5], and some studied the thermal effects [6] and the fluid dynamics [7]. It is an arc welding process where heat is generated for arc between the workpiece and a consumable electrode. A bare solid wire called electrode is continuously fed to the weld zone, it becomes filler metal as it is consumed. Gas metal-arc welding overcomes the restrictions of using electrode of limited length and overcomes the inability to weld in various positions, which is a limitation of submerged-arc welding [8]. In gas metal arc welding, the variations of power supplies, shielding gases and electrodes have significant effects, resulting in different process variations [9]. All important metals used in different commercial applications such as aluminium, copper, stainless steel and carbon steel can be joined by this MIG welding process by choosing appropriate electrode, shielding gas and different welding conditions [10]. It has been very important to know the performance of a welding process over a wide range of input process parameters. MIG welding is such a welding process which is extensively used in the industries for its high precision and accuracy capability. But performance of the welding depends largely upon the parameters like voltage, current and also on type of work-piece materials, electrode material combinations. A large amount of research works have been noticed to find out the most suitable combination of input process parameters for a desired output. Ghosal et al. established an ANN model to predict and optimize penetration depth of CO2 laser MIG hybrid welding for 5005 Al-Mg alloy. The input parameters are power, focal distance, torch angle, distance between laser and welding torch [11]. Ganjigatti et al. also investigated the input-output relationships of MIG welding by regression analysis. Input parameters are welding speed, voltage, gas flow rate, nozzle to plate distance, torch angle and the responses are bead height, bead width, and bead penetration [12]. Junsheng et al. investigated the effect of welding heat input on the weld pool behavior in MIG welding for low carbon steel [13]. Now a days most of the welding is done by different arc welding processes; therefore it is essential to investigate the effects of welding parameters on the weldability of the materials during the arc welding. Mild steel is the most common form of steel provides material properties that are acceptable for many applications. In our present study workpiece of mild steel material of grade EN-3A has been used.

2. EXPERIMENTAL DETAILS

2.1 Selection of Welding Parameters

Depth of penetration of a butt welded joint depends on a number of influencing factors like welding parameters, properties of workpieces, electrode used, welding phenomenon etc. Studies reveal that, the Welding speed, Voltage, Current are the three welding parameters which influence in determining the depth of penetration of a butt welded joint and thus these three parameters are considered as design factor in the present study.

2.2 Selection of Response Variables

A literature review has been carried out which shows whether experimental or analytical, most of the studies concentrates on finding the depth of penetration of welded joint of different material for different input parameters.

2.3 Work Piece Material Used

The present study is carried out with low carbon steel of grade EN-3A. The chemical composition of base metal EN-3A and wire En-3A are shown in Table 1 and Table 2 respectively.

2.4 Specimen Preparation

In the present work, two mild steel specimens, with dimensions of 150 mm x 100 mm x 6 mm of each was used as the workpiece. These specimens were prepared with a V-shaped groove, where the groove angle, the root face, and the root gap were 30°, 3 mm and 0.75 mm respectively. Thereafter 24 pairs of such specimen with constant groove angle, and root face were prepared, and faces were cleaned by a surface grinder. To make a butt joint, two plates were tacked at the two ends along the width, with a constant root gap of 0.75 mm. Once the welding is over all the plates were cut by using a power hacksaw, to a required shape for measuring depth of penetration. The welding torch was mounted on a fixed arm of a portable gas cutting machine, which can move at different known speed. Copper coated mild steel wire of 1.2 mm diameter was used in the experiment as the electrode. The wire was fed through the welding gun by a roller drive system. The shielding gas used was CO_2, supplied in a regulated manner at a constant flow rate and at a constant pressure.

2.5 Design of Experiment

In the present study welding speed (m/min), voltage (v) and current (A) are selected as design factors while other parameters have been assumed to be constant over the experimental domain Taguchi's L25 orthogonal design have been implemented here with five levels to carry out the experiments as it allows only 25 numbers of experiments which reflects the whole process quite satisfactorily while being economic and as well as time saving. The levels are chosen on the basis of the recommendations made by the machine manufacture i.e. Technocrates Plasma Systems Pvt. Ltd. The recommended welding conditions while MIG welding are given in the Table 3.

Table -1: Chemical composition of the base metal, EN-3A

Element	Weight %	Element	Weight %
C	0.15	S	0.021
Mn	0.78	P	0.029
	0.23	Si	

Table -2: Chemical composition of the wire, EN-3A

Element	Weight %	Element	Weight %
C	0.16	S	0.020
Mn	0.76	P	0.026
	0.22	Si	

Table -3: Recommended welding conditions

Parameter	Unit	Minimum Value	Maximum Value
Current	Ampere	0	400
Voltage	Volt	0	54
Welding speed	m/min	0.11	1.10

The five levels chosen within the recommended welding parameters by trial and error method are given in the Table 4.

Table -4: Selected levels for welding parameters

Parameter	Unit	Level 1	Level 2	Level 3	Level 4	Level 5
Current	Ampere	140	150	160	170	180
Voltage	Volt	24	25	26	27	28
Welding speed	m/min	0.165	0.179	0.193	0.206	0.220

Taguchi's L25 orthogonal design for the above mentioned three welding parameters along with 5 levels are given in the Table 5.

Table -5: Design of experiment using Taguchi's L25 orthogonal design

Experiment No.	Current (A)	Voltage(V)	Welding speed (m/min)
1	140	24	0.165
2	140	25	0.179
3	140	26	0.193
4	140	27	0.206
5	140	28	0.220
6	150	24	0.179
7	150	25	0.193
8	150	26	0.206
9	150	27	0.220
10	150	28	0.165
11	160	24	0.193
12	160	25	0.206
13	160	26	0.220
14	160	27	0.165
15	160	28	0.179
16	170	24	0.206
17	170	25	0.220
18	170	26	0.165
19	170	27	0.179
20	170	28	0.193
21	180	24	0.220
22	180	25	0.165
23	180	26	0.179
24	180	27	0.193
25	180	28	0.206

2.6 Experimental Setup

A CPT400, CO2 MIG/MAG WELDING MACHINE THYRISTORISED OR STEP CONTROL, manufactured by Technocrats Plasma Systems Pvt. Ltd. is used for MIG welding test. This machine is shown in Fig -1.

Fig -1: CO2 MIG/MAG Welding Machine Thyristorised or Step Control

The important specifications of the MIG welding machine have been shown below:

Maximum welding current : 400 A
Open circuit voltage (V) DC : 54V
Approx weight (kgs.) : 200
Cooling : Forced air
Wire dia (mm) mild steel : 1.2

For mounting the welding torch, for maintaining known welding speed, a portable gas cutting machine has been used during the experiment, shown in Fig -2

Fig -2: View of gas cutting machine used during experiment for controlling different welding speed

The important specification of the portable gas cutting machine has been shown below:

Make : ESAB India Ltd.
Volts : 220V-250V
AC/DC AMPS : 0.35

3. RESULTS & DISCUSSIONS

Initially, specimens were prepared and the experiments were conducted as per the design of experiment and the welding was carried out.

Table -6: Experimental Results

S No.	Experiment No.	Current (A)	Voltage (v)	Welding Speed (m/min)	Penetration (mm)
1	1	140	24	0.165	5.3
2	2	140	25	0.179	5.1
3	3	140	26	0.193	4.9

4	4	140	27	0.206	4.7
5	5	140	28	0.220	4.6
6	6	150	24	0.179	5.2
7	7	150	25	0.193	5.0
8	8	150	26	0.206	4.9
9	9	150	27	0.220	4.8
10	10	150	28	0.165	6.7
11	11	160	24	0.193	5.2
12	12	160	25	0.206	5.0
13	13	160	26	0.220	4.9
14	14	160	27	0.165	6.9
15	15	160	28	0.179	6.5
16	16	170	24	0.206	5.1
17	17	170	25	0.220	5.0
18	18	170	26	0.165	6.9
19	19	170	27	0.179	6.7
20	20	170	28	0.193	6.5
21	21	180	24	0.220	5.1
22	22	180	25	0.165	6.9
23	23	180	26	0.179	6.8
24	24	180	27	0.193	6.5
25	25	180	28	0.206	6.4

To visualize the influence of the designed process parameters over Depth of Penetration and also to find their nature of variation with respect to the designed parameters, three dimensional surface plots have been developed using MINITAB 14 software and shown in Fig 3, 4, 5. The surface plots physically represent the variation of the depth of penetration with the welding process parameters. In each of the plots, two welding parameters are varied simultaneously along X and Y axis while the depth of penetration is recorded along Z axis. It is seen from these plots that there is significant amount of curvature indicating non-linearity in the variation.

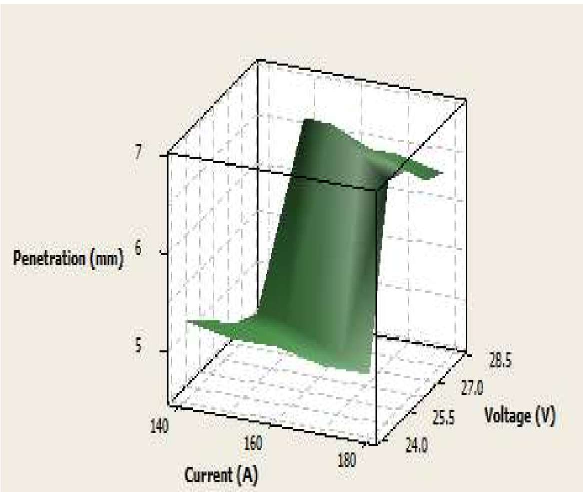

Fig -3: Surface plot of depth of penetration with respect to Voltage and Current

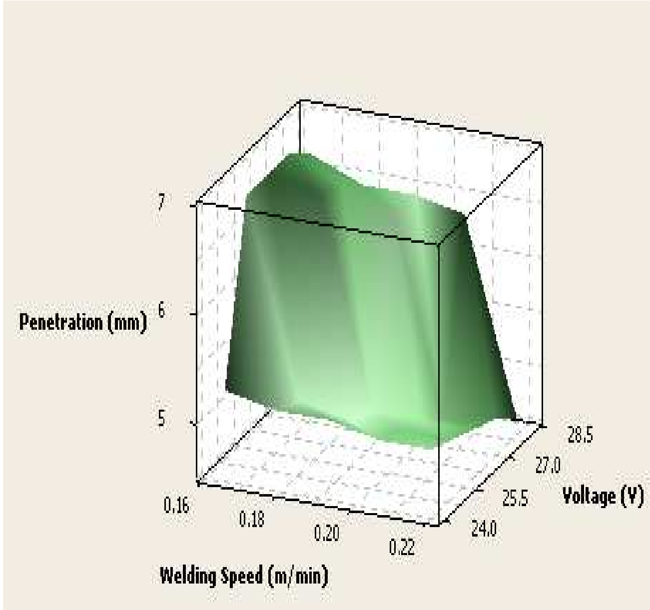

Fig -4: Surface plot of depth of penetration with respect to Voltage and Welding Speed

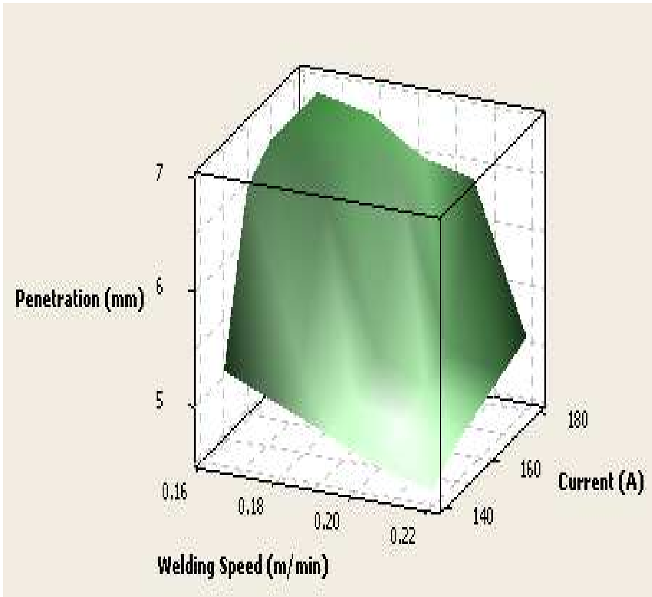

Fig -5: Surface plot of depth of penetration with respect to Current and Welding Speed

It is evident from the Fig. 3 and Fig. 4 that higher voltage (> 26.5 V) causes abrupt rise in penetration depth value whereas Fig. 3 and Fig. 5 depicts that very high current (> 150 A) also causes the same. And also it could be found from Fig. 4 and Fig. 5 that very high welding speed (> 0.16 m/min) causes decrease in penetration depth. These may be due to the reason that, at the higher welding speed, it gets less time to penetrate the weld puddle. And as the current and voltage increases it creates more heat, so more metal is melted and thus it creates more depth of penetration.

CONCLUSIONS

An experimental study has been done for finding the depth of penetration of welded joint in MIG welding process for welding a mild steel specimen of grade EN-3A. The conclusion may be drawn, from Fig 3, 4, 5 that higher voltage (> 26.5 V) causes abrupt rise in penetration depth value, whereas Fig. 3 and Fig. 5 depicts that very high current (> 150 A) also causes the same. And also it could be found from Fig. 4 and Fig. 5 that very high welding speed (> 0.16 m/min) cause's decrease in penetration depth.

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