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IMPROVING WELDABILITY AND ASSOCIATED PROPERTIES BY WELDING UNDER VARIABLE EXTERNAL MAGNETIC FIELD

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ABSTRACT

Welding is a widely used technique to join metal parts. In welding processes the current flows through the arc. The welding arc may be affected by magnetic field produced in a work piece adjacent to it. Magnetic disturbance surrounding the welding arc may cause arc instability which is responsible for lack of fusion, porosity and unevenly welded joints. At the same time, there is considerable spattering which, if avoided, obviously results in good quality and economy. If the arc can be confined into the smallest possible region, it is of considerable help in improving weldability and associated properties. An attachment for welding under variable external magnetic fields has been developed as an attempt for improving arc stability and better weld beads apart from savings in electrode consumption.

Keywords: Arc Instability, Magnetic Effects, MIG Welding, Spattering, Weldability, Weld Beads.

1. INTRODUCTION

Welding is the process of joining together two pieces of metal so that bonding accompanied by appreciable interatomic penetration takes place at their original boundary surfaces. The boundaries more or less disappear at the weld, and integrating crystals develop across them. Welding is carried out by the use of heat or pressure or both and with or without added metal. During welding, magnetic field is set up in the plane of the parts being joined and circumferentially around the electrode and the plate as shown in Fig 1. The field, F_1, is set up around the electrode; the field F_2, around the plate plates being joined and the field, F_3, in the plates adjacent to the arc and in a direction similar to that of field F_1. Since it is not possible to remove these fields from welding operation, it is necessary to use external control as a means to overcome these magnetic effects [1].

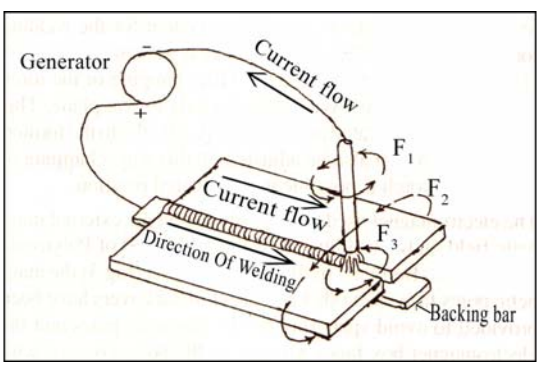

Fig 1. Planes of Magnetic Field Set-up

A magnetic field externally applied to the welding arc deflects the arc by electromagnetic force (Lorentz force) in the plane normal to the field lines. The magnetic field exerts force on the electrons and ions within the arc, which causes the arc to be deflected away from the normal arc path. The welding arc can be deflected forward, backward, or sideways with respect to electrode and welding direction, depending upon the direction of an external magnetic field. A transverse magnetic field deflects the arc in the welding direction, whereas a longitudinal magnetic field deflects the arc perpendicular to the bead. If unidirectional magnetic field is applied to an AC arc, or an alternating field is applied to a DC arc, then the arc can be oscillated in the position normal to the direction of welding. This has been used to improve welding with both gas tungsten arc welding (GTAW) and gas metal arc welding (GMAW) processes[2][3]. Deminskii, *et al.* [4], conducted experiments using a GMAW process on an aluminum-magnesium alloy while a longitudinal magnetic field was applied to the welding arc. The magnetic fields applied were alternating and of the order of 40 gauss. They reported the arc oscillated across the weld axis. They also applied an alternating, transverse magnetic field to the welding arc. It was reported this resulted in a change in the shape of the weld pool. Not only was the solidification affected but the mechanical properties were improved by the application of a magnetic field to the gas metal arc welding of aluminum and magnesium alloys.

Subjecting the welding arc to transverse magnetic fields has beneficial effects only when the arc is deflected forward with respect to the direction of electrode travel

[5] [6]. Applying an optimum magnetic field to a welding arc on both nonmagnetic and magnetic materials increases welding speed several times at which undercut-free and no porosity welds can be made [3]. It is known the extent of arc deflection is dependent upon the flux density of the applied magnetic field, the arc current, arc length, and so on [5] [7] [8]. To apply magnetic arc oscillation to welding automation such as weld quality control and joint tracking, therefore, quantitative information has to be obtained about the effect of welding conditions on arc deflection.

2. APPROACH

Gas-shielded metal arc welding (GMAW) has been chosen for the purpose of welding. The main advantage of the process is because of its continuous nature, it generally facilitates automation [9]. Due to availability of MIG welding machine, MIG Welding process is chosen. A variant of GMAW process is MIG (Metal Inert Gas) welding with an inactive gas as the shielding gas. The process finds its main application in welding of aluminum and stainless steel [10]. In MIG welding, the wire electrode serves both as filler material and as arc electrode. The molten material is protected from oxygen by an inactive gas like CO_2, argon or helium. However, a major problem is the erratic metal transfer and splashing because of the manner in which the metal droplets detach from the electrode resulting in non-axial transfer [11].

The basic MIG welding equipment consists of a power source, wire feeder, welding torch and shielded gas supply system [12]. MIG welding in this semi-automatic version requires holding of the welding torch by moving over the workpiece and welding is carried out on the stationary workpiece. During manual welding operation, welding speed and arc length varies which is not desirable. An attempt will be made to provide automation in the welding equipment.

A special shape electromagnet will be used to impose a magnetic field on the welding arc. DC power supply with variation of current will be provided so that different magnetizing currents could be used. By applying variable external magnetic field an attempt will be taken to improve the arc stability and weld beads [13]. Arc is said to be stable if it is uniform and steady. A stable arc will produce good weld bead and a defect free weld nugget. Defects commonly introduced by unstable arc are slag entrapment, porosity, blow holes and lack of proper fusion. Defects of welding will be reduced and better welding beads will be developed for applying variable external magnetic field during MIG welding process.

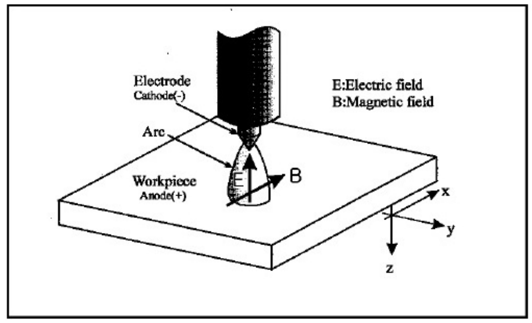

Fig 2. Welding operation with the developed system

Fig 2 illustrates the experimental set up condition for improving weldability by providing external variable magnetic field.

An electromagnet attachment will be fabricated as an approach to improve weldability and associated properties under variable external magnetic field by using MIG welding operation.

3. DEVELOPMENT AND FABRICATION OF THE MAGNET AND EXPERIMENTAL SETUP

An attachment which will create external magnetic field is the one of the most important factor for this experiment. To fulfill the requirement, an attachment has been designed which is capable of moving throughout the weld run with the welding torch and produce variable external magnetic field. The external magnetic field is designed for 220 voltage Alternating Current (AC). The current flowing through the coil can be varied by using a regulator. The attachment is made of 19.05 mm (¾ inch) square Mild Steel square bar, 23 gauge copper wire, a ferromagnetic core which will increase the magnitude of the magnetic flux density in the solenoid and a variable resistance. An arrangement has been made for moving the attachment by using four bearing wheels.

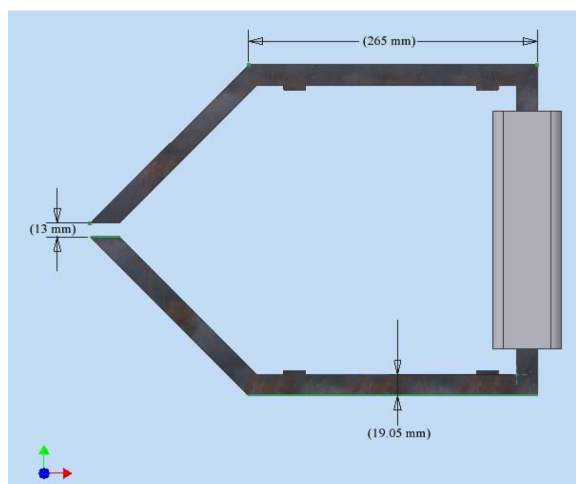

Fig 3. Design of the electromagnet (Units are in millimeters)

A 19.05 mm (¾ inch) square Mild Steel square bar is selected for the attachment which will create variable external magnetic field. The Mild Steel square bar is designed in such a shape (shown in Fig. 3) that it can produce sufficient magnetic field during welding process.

The air gap is taken as small as possible to maximize the effect of the magnetic field. The attachment is constructed in a flexible desired shape so that the arc and temperature of the welding will not hamper the attachment. The back side of the attachment is integrated with a ferromagnetic core which will increase the magnitude of the magnetic flux density in the solenoid. The ferromagnetic core and mild steel bar combination should be so rigid that there will be no air gap between the ferromagnetic core and mild steel bar. Then the core is insulated by the heat resistant paper which will create insulation between the core and Solenoid. Insulated copper wire of 23 gauge is selected for the solenoid. After looping the 23 gauge copper wire around the core, the attachment is ready for creating external variable magnetic field. A variable resistance is placed in the system in order to get different strength of the magnetic field by varying the supply of current.

The electromagnet attachment works on the principle of Electromagnetism. In this attachment, the magnetic poles of the electromagnet face each other. When there is a flow of current in the solenoid, a magnetizing effect is produced in the air gap (i.e. e. between the two poles of the electromagnet). To move the attachment with the feeder, four bearing wheels have been welded to the four corner of the mild steel bar attachment.

To avoid manual flexibility in operation and to provide automation in the equipment, a constant feed system is setup with the attachment as shown in Fig 4. For this purpose, four bearing wheels are attached with the electromagnet which will move with the constant feeding device. The electromagnet can be attached with the constant feeding device which can move at a constant speed. It also can be detached from the feeding device when not in use. The feeding device can move forward and backward and speed can be varied so that different welding speeds can be obtained which are constant during the entire weld run. To keep the arc length same during the weld run and electrode to work angle constant, a clamping system for the welding torch is provided by attaching with the feeding device which is shown in Fig 4. A holder is used for clamping of the torch handle which holds the welding torch tightly. After clamping the welding torch tightly, the torch can move forward and backward with the feeding device at a constant speed. Clamping of the welding torch is possible in any desired position by adjusting the holder.

Fig 4. Setting up electromagnet and welding torch with the auto feeding device.

The magnet used for superimposing the external magnetic field on the welding arc is a special shape mild steel square bar electromagnet. A covers have been provided to avoid spattering on the solenoid. An AC power source with variable resistance is used to provide different magnetizing currents to the electromagnet. The welding process with magnetic field which is produced by the special shape electromagnet is shown in Fig 5.

Fig 5. Automatic welding under external magnetic field.

4. PERFORMANCE TEST

Samples in the form of MS flats are taken. An edge joint is formed with V-groove on both sides and welding is carried out on one side without magnetic field and other side with magnetic field with other parameters same in both the cases.

Details of welding on eight sets of samples are:

i. Electrode wire size 1.00 mm.
ii. Gas used CO_2 (Carbon dioxide)
iii. Gas flow rate 16 liter/min
iv. Gas pressure in Cylinder 75 bar
v. Samples in the form of Ms flats of size 140 mm x 45 mm(approximately)
vi. Thickness of the samples, t = 5 mm
vii. OCV(Open Circuit Voltage) 35 V

viii. Electrode to Work angle 80°
ix. Nozzle to work distance (NWD) = 20 mm
x. Air gap between two poles = 15 cm

Table 1: Details of Welding on samples under variable external magnetic field

Sample No	t, mm	Current, Amp	Magnetizing current, Amp	Wire feed speed, m/min
1.	5	195	0.02	8
2.	5	195	0.02	10
3.	5	195	0.03	8
4.	5	195	0.03	10
5.	5	230	0.02	8
6.	5	230	0.02	10
7.	5	230	0.03	8
8.	5	230	0.03	10

In this experiment, Metal Inert Gas (MIG) welding is done without magnetic field and with magnetic field with two different speeds which is given in Table 2.

Table 2: Different speed of the welding torch

Speed Chart		
Distance mm	Welding time second	Welding speed meter/minute
140	25	0.34
140	40	0.21

From the microstructure test, better weld beads with fine grain structure are achieved under external magnetic field than without magnetic field. Less porosity is found in the microstructure of weld beads while superimposed magnetic field is used.
The observed microstructures of weld bead with and without magnetic field are shown in Fig 6 and Fig 7.

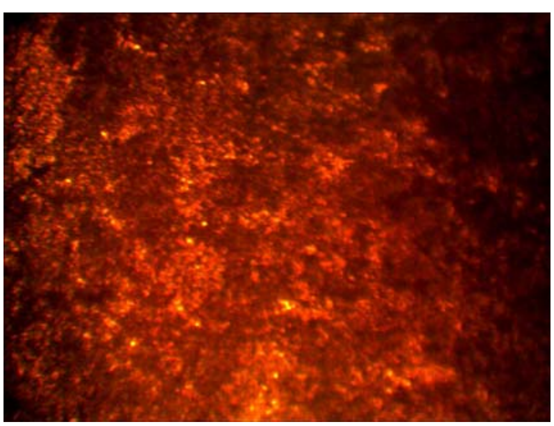

Fig 6**.** Microstructures of weld bead with magnetic field (Magnification Factor 100x)

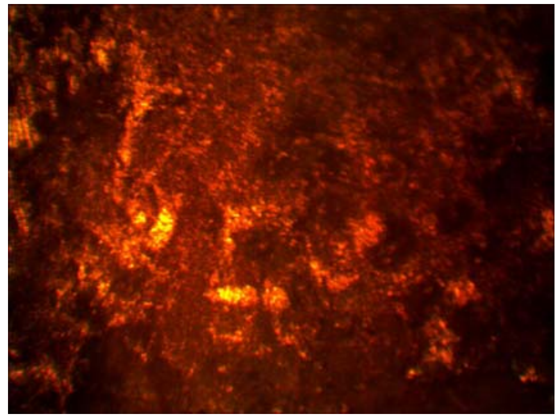

Fig 7. Microstructures of weld bead without magnetic field (Magnification Factor 100x)

Weld beads of MS Flat samples with and without magnetic field are shown id Fig 8.

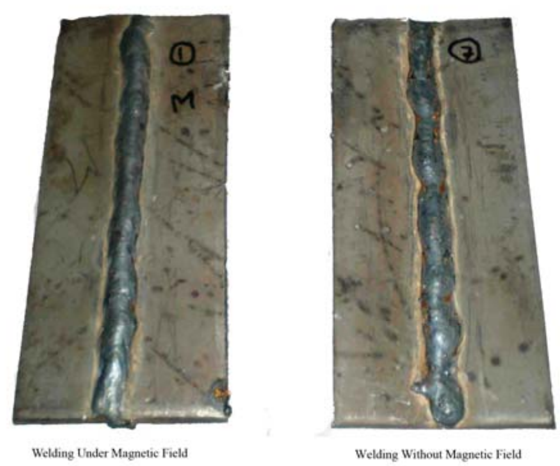

Fig 8. Weld bead with and without Magnetic field

From Brinell Hardness Test, Brinell Hardness Number of the weld bead with magnetic field is = 234 and without magnetic field is = 187. So, it is seen from the experiment that when welding is done under magnetic field Brinell Hardness Number is increased.

More penetration and fusion is found while external magnetic field is used. The bonding of welding bead is more strong and unique under external magnetic field than without external magnetic field.

5. DISCUSSION AND OBSERVASION

In case of welding under external magnetic field, improved stability of arc gives regular fusion and minimizes spatter. Therefore, the weld bead is smoother, regular and shows no sign of porosity. Excessive spattering of weld metal is prevented and saves electrode consumption. Welded joint obtained on the specimen with and without magnetic field are analyzed. It is observed that the effects of arc instability such as poor weld bead appearance, irregular and erratic weld deposition, lack of fusion, etc have been overcome in case of welding with a superimposed magnetic field.

Lack of fusion may be due to forward and backward arc blow, it happens particularly at the ends of weld bead without magnetic field. This happens since magnetic flux lines get crowded near the starting and finishing ends of the workpiece because they find an easy path through the workpiece than air. The arc seeks the path of least resistance and deflects towards the weak flux side. Due to arc instability spatter, i.e., scattering of molten globules of wire electrode occurs. This is enormous at higher currents. If spatter is prevented, it results in considerable financial saving apart from improved weld bead quality. From economy consideration, it is observed that more weld metal have been poured into the joint in case of welding under external magnetic field in comparison with welding without magnetic field. This is due to the fact that spattering of weld metal is prevented by superimposing external magnetic field. Further, for higher currents savings are more. This is due to the fact that at higher currents, arc instability is more and more amount of spatter takes place. The desired position of the arc is maintained throughout the weld run in case of welding with magnetic field and with minimum spatter; the amount of metal deposited per unit time is more.

6. CONCLUSIONS

The proposed attachment for welding under variable external magnetic field in MIG welding has the following main advantages:

1. Desired position of arc and better fusion is achieved.
2. Amount of metal deposit per unit time is more; hence increase in production rate;
3. Weld bead quality is improved with better fusion, penetration, weld bead appearance, fine grain structure etc;
4. Due to improved arc stability, spattering is less. So, electrode consumption is less.

So, welding under external magnetic field is a welding technique that can be used for smooth and regular welding and better weldability which can be used in different industrial works, construction and machine repair works, automotive industry, aircraft machine frames & structural works, joining heavy and hard metals, shipbuilding and repair industry, pipe line fabrication in thermal power plant and refineries, fabrication of metal structures, etc.

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