Experimental Investigation on Magnetically Supported Welding

Dhiren R. Patel[a], A. D. Dhass[b]

[ab]Department of Mechanical Engineeriong, Indus University, Ahmedabad, 382115, India

Abstract

Arc welding is undoubtedly robust and commercially established joining technology for a variety of applications. Having said that, the quality of joints is a function of weld conditions. It determines through the reliability aspect of the joint while in service. Hence, final weld properties are a crucial consideration. The goal of this experiment is to regulate the effects of a welding arc in the subjected to a magnetic field upon its mechanical and metallurgical properties of mild steel. The bead area is depending upon the magnetic field at and around the arc. The ultimate effects of the aforementioned field are discussed in the article. The purpose is to improve the qualities of the arc constriction, such as tensile properties, hardness, and toughness properties. When magnets are placed transversely to the weld bead, there is a deflection in the welding arc, whereas deviation is limited when magnets are situated longitudinally. The qualities of the weld bead vary when the welding arc deflects. This study looks at how an external magnetic field affects numerous mechanical qualities like toughness, tensile strength, and hardness. A set of weld pieces is tested and compared to determine the effects of an external magnetic field on their properties.

Keywords: Arc; Magnetic Effects; Electric arc Welding; Metal Inert Gas welding; Joint

1. Introduction

Welding process wherein materials undergo local coalescence, i.e., produced with the help of both heat and pressure. The filler material may or may not be used which a subject of weld joint design, weld thickness, and weld conditions. The formation of primary chemical bonds results in what is called a “weld”. “Welding is a procedure wherein the continuity is obtained between parts for assembly, through various means,” according to the IS0 standard. As a result, two or more metallic components are fused utilizing the heat produced by an Electric Arc welding machine during the welding process. Retrospectively, the arc welding technique was discovered in the late 1800s. While welding using a naked metal rod on iron was being performed, a nearby stack of newspaper caught fire from the sparks of welding. Later, the welds were found to be of much better quality. This was because all the smoke produced from the fire removed the oxygen away from the welding milieu and reduced the perviousness. Hence, the better welds. In classic welding, the arc hits between the metal and an electrode to heat the metal to its melting temperature. The electrode is then removed, which breaks the arc between the electrode and the metal, causing the molten metal to solidify and freeze. When an electrical current flows through a high-resistant air gap between the electrode and the work metal during welding, the arc appears as a flame of heat. As a result, the magnetic field is built along the plane of the work undergoing welding. Figure 1 indicates the development of such incidental magnetic field around the electrode and the plate during welding. While the magnetic fields namely F1, and F2 denote the fields set up around electrode, and plates respectively, In the plates close to the arc, field F3 appears. Application of external control becomes imperative to bring these magnetic forces under control because it is impossible to remove them completely [2]. An electromagnetic force (Lorentz force) operating in the plane normal to the field lines is produced by an externally applied magnetic field. This causes the arc to divert from its normal direction due to the force exerted on electrons and ions in the arc. Zi Qi Guan et al [3], studied the effect of a longitudinal and alternating magnetic field of the order 40 gauss on welding arc in a GMAW process on an aluminum-magnesium alloy. The results revealed that the arc oscillated across the weld axis. It is observed that under a transverse magnetic field, the welding arc that deflects forward about the direction of electrode travel has beneficial effects [4]. Welds without porosity and undercut can be produced by using welding arc under optimum magnetic field on both magnetic and nonmagnetic materials as these conditions augment welding speed several times to yield quality welds [5]. The flux density of the applied magnetic field, the arc current, the arc length, and other factors all influence the degree of arc deflection. [6].

Figure 1. Symmetric diagram of the magnetic arc welding process [6].

The angle formed by the flow of the electron streaming and magnetic lines of force when the magnetic force acts on the arc is not zero. The arc is shaped like a cone. The current-carrying electrons also migrate around the arc's surface. As a result, their motion can be divided into two components, one parallel to the arc's axis and the other perpendicular to the arc's axis, as illustrated in Figure 2. The magnetic movement is not the result of the component along the arc. Rather, the force on the arc is exerted by the element perpendicular to the arc's axis. The magnetic field path and the polarity utilized determine whether the arc rotates clockwise or anticlockwise.

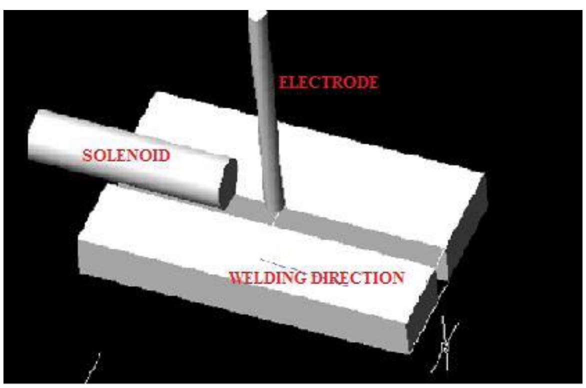

Figure 2. Longitudinal magnetic field set-up

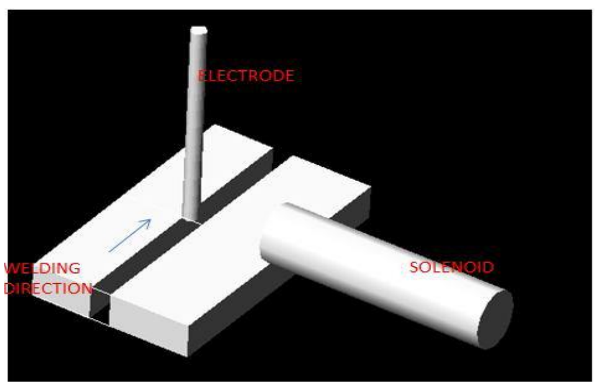

Figure 3. Transverse magnetic field set-up

When a transverse magnetic field is applied, the arc will be reflected in the forward or backward direction by magnetic field path and the polarity of the welding system, according to the Flemings left-hand rule. Figure 3 shows how an earlier inquiry can be examined in light of this. A study by Alexander D Razmyshlyaev et al exhibited that depth of penetration can be automatically modulated by the transverse magnetic field [7]. When the arc is deflected forward, Ji Chen et al discovered that a constant transverse magnetic field is advantageous in terms of electrode travel speed [8]. The welding speed was increased by four times. The welds obtained were devoid of undercuts. Furthermore, weld width was found to be inversely proportional to magnetic field. The application of a transverse magnetic field improved the productivity of a submerged arc welding technique for making butt connections between prepared edges, according to a study by A. D Razmyshlyaev et al. [9].

2. Experimental Procedure

A carbon steel plate was the choice of material for this study considering its major use in welding and fabrication work. The dimension of the plate was 300 × 150 × 6 mm. The chemical composition with mechanical properties is shown in Table 1 and Table 2 respectively.

Table 1. Chemical composition of the carbon steel plate

Elements	C	Mn	Si	S	P	Al
% Atoms	0.16	0.25	0.21	0.020	0.030	0.0155

Table 2. Mechanical Properties of The Carbon Steel Plate

Ultimate Tensile Strength in Mpa	Yield Strength in Mpa	% Elongation	Hardness Value in HV
540	415	10	170

The first stage marks the preparation of the plate for the said dimension by gas cutting followed by the grading process. Grading was needed to prepare the plate with the appropriate edge before the welding.

Moreover, with the help of the shield metal arc welding process (SMAW) or (MMAW), the welding was performed with the condition of a 12-gauge electrode and 195-watt power supply, and the absence of a magnetic field as shown in Figure 4(a). On the other hand, the second plate was welded in presence of a magnetic field, as shown in Figure 4(b). Here, a magnetic field was applied with the magnet fixed as per Figure 4(b). when the experiment was done with the help of transverse magnetic field conditions while keeping other parameters constant during the welding.

Figure 4(a). Welded carbon plate with SMAW and non-magnetic field

Figure 4(b). Welded carbon plate with SMAW and magnetic field

Next, a second experiment was conducted for welding of two carbon plates of 6 mm thickness by MIG under two separate welding conditions- One with a non-magnetic field and an optimized gap. Other parameters were current 8 A, voltage 0.06 V, and wire diameter 1.2 mm. The second welding operation was under the influence of a magnetic field created using magnets on both the sides of the welding edge and keeping all other parameters constant. The resulting welded plates appeared as shown in Figure 5(a) and Figure 5(b).

Figure 5(a). Welded plate with the help of MIG welding and non-magnetic field

Figure 5(b). Welded plate with the help of MIG welding and magnetic field

3. Results and Discussion

After welding, the welded plates were then subjected to a destructive test to assess the quality of the weld joint.

3.1. Tensile test

The tensile strength of a welded junction is measured in this test. Tensile strength is measured in kilograms per square meter. Mathematically, the tensile strength of a weld joint is a ratio of breaking load to the cross-sectional area of the specimen. Universal Testing Machine (UTM) was employed to conduct the test the results for which are shown in Table 3. Figure 6 shows that the arrangement was done in such a manner that the weld joint was midway between the jaws of the machine. The gripping and rupture points are indicated in Figure 6.

Table 3. Tensile strength results of the all-welded plate

Experiment condition	SMAW	SMAW (M)	MIG	MIG (M)
Tensile (N/mm2)	520.987	394.987	91.94	482.57

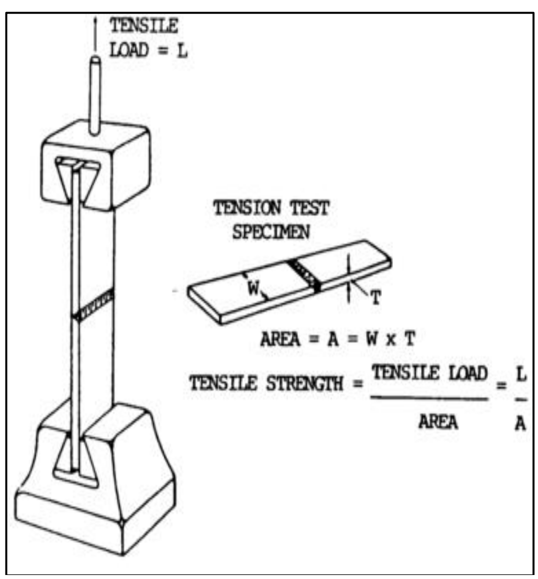

Figure 6. Tensile test as per the ASME Section IX

Before testing, the test specimen's weld thickness was measured, and the area in square inches was computed.

The specimen was then subjected to the tensile test by mounting it in a stationary machine that applies pull on the specimen such as to break it. Under tensile load, the specimen was broken, and the maximum load in pounds was found out. The maximum load was then divided by the length of the cracked fillet weld to determine the weld's tensile strength in pounds per linear inch. As shown in Figure 7, the shearing strength in pounds per square inch is calculated by multiplying the shearing strength in pounds per linear inch by the weld's average throat dimension in inches.

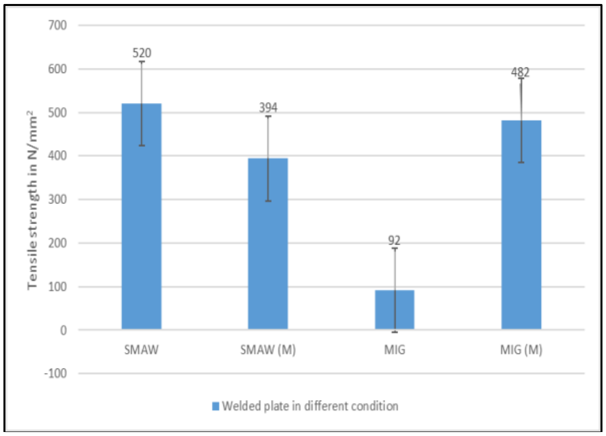

Figure 7. Tensile strength results

3.2. Impact test

The Impact test examines the welds' capacity to resist impact force and thus talks about specimen toughness. Thus, the higher the test reading, the higher is the weld toughness. As shown in Table 4 and Figure 8, an Impact test was carried out using two types of specimens namely Charpy and Izod. While testing, the specimens were broken in an Impact testing machine. Here, two specimens were anchored on the machine differently such that both received the impact differently. While the Charpy piece rested between two anvils in a horizontal position, the Izod section was reinforced as a vertical cantilever beam. The way the specimens are arranged in an impact testing machine determines the method of impact. In the case of the Charpy piece, the pendulum stroked contrary the notch. The Izod section, on the other hand, was struck on the free end that protruded over the retaining vice.

Table 4. Results of the impact test

Experiment condition	SMAW	SMAW (M)	MIG	MIG (M)
Impact (Joule)	14.33	14.67	7.33	27.50

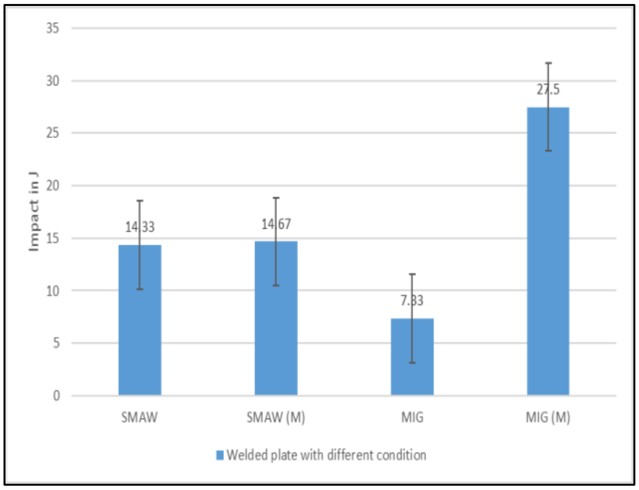

Figure 8. Impact test results

3.3. Hardness test

Hardness is another parameter based on which weld quality is assessed. It is defined as a material's ability to withstand indentation caused by localized displacement. The hardness of weld metal is assessed by the Hardness test.

To be specific, the Rockwell hardness test was used to conduct the test. In this, the specimen was mounted on the anvil in such a way that it remained in contact with a hardened steel ball. Then the load was applied against the ball and allowed to remain for half a minute before releasing. And the depth of the depression made by the steel ball on the specimen was measured. the depth of the depression made by the ball on the specimen is measured and noted from the machine dial. The hardness number is called the "Rockwell number." Results and comparisons are given in Table 5 and Figure 9.

Table 5. Results of the hardness test

Hardness test results	SMAW	SMAW (M)	MIG	MIG (M)
WELD	192.67	187.67	211.33	193.00
HAZ	187.33	185.00	195.67	180.00
BASE	182.67	175.67	187.33	175.33

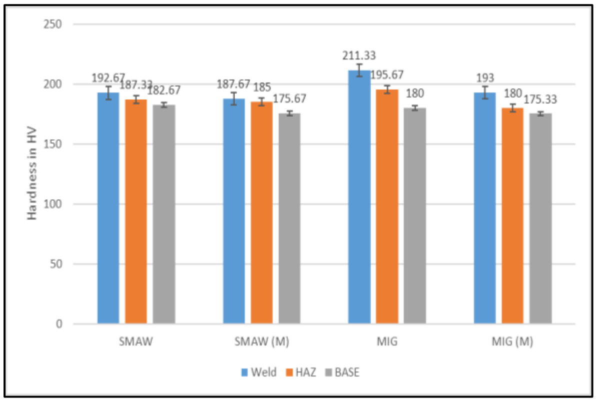

Figure 9. Hardness test results

4. Conclusion

The following conclusions about the impact of magnetic fields on the welding process are drawn from the research:

- A magnetic field affects the bead width of the weld joint when applied transversely to the welding direction, increasing it in the presence of a magnetic field.
- In presence of a magnetic field, welding effects like undercuts and spatter are reduced.
- The tensile strength of the weld joint is improved by refining grains in the applied magnetic field.
- When compared to weld-pieces welded without a magnetic field, the toughness of the weld reduces.
- Impact Strength of the weld metal increases in presence of a magnetic field.

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