A Study on the Relationship Between CO_2 Welding Conditions and the Microhardness Characteristics of Structural Steel

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Abstract

In the current investigation, bead-on-plate welding trials were conducted on 304L austenitic stainless steel using a Synergic MIG welding setup. The process employed a 304L filler wire of 1.2 mm diameter, operated under a direct current electrode positive (DCEP) configuration. A shielding environment composed of Argon and CO_2 was provided to stabilize the arc and protect the molten weld pool from atmospheric contamination. The fusion zone produced during welding is generally described through several geometric attributes, including the width of the weld bead, the height of bead reinforcement, and the depth of penetration achieved. These characteristics are strongly governed by various process parameters such as the shielding-gas flow rate, applied voltage, welding travel speed, and the wire feed rate.
To obtain a more comprehensive understanding of the mechanical response of the welded joint, microhardness evaluations were carried out across both the weld bead and the adjoining base material. The Knoop microhardness method was employed to analyze hardness variations and assess the influence of the welding conditions on localized material behavior.

Keywords : Gas Metal Arc Welding (GMAW), Fusion zone, Regression analysis, Bead Geometry

1. INTRODUCTION

Because only inert gases were employed to protect the molten puddle, GMAW was originally known as MIG welding. Aluminum, deoxidized copper, and silicon bronze were the only materials that could be used in this method. Later, technique was successfully utilised to weld ferrite and austenitic steels, as well as mild steel, by using active vapours instead of inert gases, earning the name MAG welding [2]. Carbon steels, low alloy and high alloy steels, stainless steels, aluminium, and copper, as well as titanium, zirconium, and nickel alloys, can all be welded using the GMAW (MIG/CO2) technique. [3]. It is possible to weld connections in the thickness range of 1-13 mm in all welding positions by appropriately setting the process parameters. Several researchers have looked into the influence of different process variables on weld bead geometry and metal transport. Weld distortion, mechanical strength, and weld quality are all indicators of a good weld process.

Shape and characteristics of weld beads The weld bead geometry is the simplest of these characteristics to measure and control. All welding parameters could be controlled by a signal dial thanks to the synergic capability, which optimised the current peak pulse and background values, as well as the voltage and wire feed speed. Many researchers are interested in the impact of various welding process parameters on the fabrication of beads and bead shapes, pushing them to conduct further research. Kim I. S. et al. [4] looked into the effect of welding process parameters on weld bead penetration in the Gas Metal Arc Welding (GMAW) method. The welding process included variables such as wire diameter, gas flow rate, welding speed, arc current, and arc voltage. In the experiment, weld bead penetration increased as wire diameter, arc current, and voltage increased. Ganjigatti J.P.et al [5] used global versus cluster-wise regression analysis to predict bead geometry in the MIG welding process.

Welding current, arc voltage, and welding speed were chosen as variable parameters. The depths of penetration for each specimen were measured after the welding techniques, and the effects of these parameters on penetration were explored. According to the findings, increasing the welding current enhanced the penetration depth. Pires RM et al. [7] describe the effect of gases on the joining process' stability and melted metal movement over the electric arc. The effects of gas type, welding speed, and other process factors are explored. The convexity, colour, brightness, smoothness, and generation of surface pores of the bead are studied, with a focus on the impacts of gases on the bead's appearance and shape. Using a response surface technique, Murugan N et al. [8] discovered quadratic correlations between welding parameters and bead geometry for depositing stainless steel into structural steel.

2. EXPERIMENTATION

The goal of the design process is to come up with a product that fits all of the requirements for the least amount of money. Welding is a crucial design strategy since it is the greatest joining method. The most popular processes for bonding materials are fastening, welding, and casting. Welding, on the other hand, is less expensive and more flexible than casting. Welding takes much less overall material because it is 3 to 4 times stronger than other procedures. Castings are also more rigid, ductile, and less prone to cracking than other materials. Finally, when it comes to impact resistance, welding beats castings out.

The process parameters were varied one at a time during the trial runs. Previous research publications had established the operating range. +2 and 2 were used for the upper and lower bounds, respectively. The coded values for intermediate values can be calculated using the relationship.

$$X_i = \frac{2[2X - (X_{\max} + X_{\min})]}{(X_{\max} - X_{\min})}$$

Where Xi is the needed coded value of a variable X, and X is any value of the variable between Xmin and Xmax; Xmax and Xmin are the variable's maximum and minimum values. Table 1 lists the specified process parameters, as well as their upper and lower limits, as well as notations and units.

TABLE 1: THE LIMITATION OF DESIGN PARAMETERS

PARAMETERS considered	LEVELS				
	1 (-2)	2 (-1)	3 (0)	4 (1)	5 (2)
Plate thickness(mm)	4	6	8	10	12
Gas flow rate (lit/min.)	5	9	12	15	20
Current(A)	140	180	220	280	320
Travel speed (cm/min.)	22	29	31	38	43

The weld beads were placed on stainless steel plate (304L) utilising a semi-automated welding station and the bead on plate procedure. The experiment used five different variables: plate thickness, gas flow rate, travel speed, and current. In response, 30 plates measuring 6 inches in length and five various thicknesses were cut:

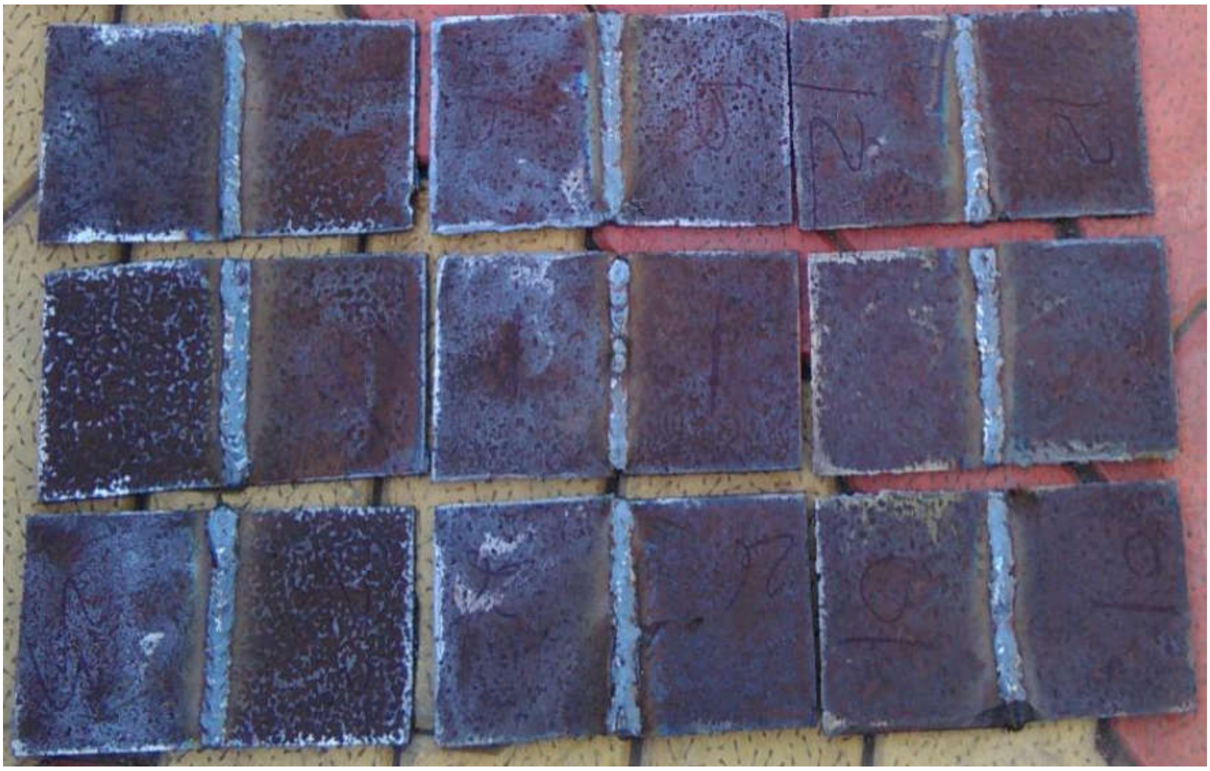

Fig.1 welded plates

TABLE 2: PLATE THICKNESS DISTRIBUTION

Thickness (mm)	No. of plates
4	01
6	08
8	13
10	07
12	01

Following the cutting of all plates, each plate was individually welded according to the conditions provided. A 304L filler wire with a diameter of 1.2 mm was used for the welding experiment. All experiments were conducted at five different flow rates with a contact tip to work distance of 20 mm and a shielded gas mixture of Argon and CO2. The bead on plate was created using a direct current power supply and a synergic MIG method. The welded components are depicted in the diagram. 1 Synergic MIG is a cutting-edge welding technique that incorporates both spray and pulse transfers. Optimal conditions can be set and simply duplicated by the welder for a range of applications. All welding parameters could be controlled from a single signal dial, which optimised the current peak pulse and background values, as well as the voltage and wire feed.

This specimen preparation approach includes the way of preparing the samples cut out of the plates for examination under a metallurgical microscope. The ultimate goal is to get a mirror-like, smooth, scratch-free surface.

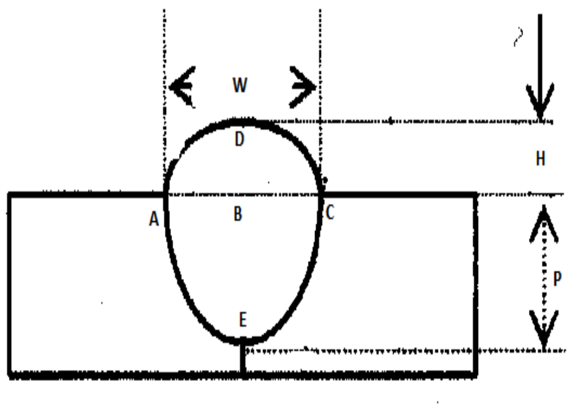

Fig. 2: samples after etching

3. MICRO HARDNESS

Micro hardness varied between sites and the micro hardness was measured using the Omnitech MVH Auto Micro Hardness tester with a 100 gm load and a dwell time of 20 seconds.

Figure.3: the micro hardness of a bead vary the points on the bead.

The micro hardness values were calculated at several locations. These points are in various -2 zones from point A to point E. The points are depicted in Figure 3. Koop's Micro hardness is represented by the figures given. After a pyramidal diamond tip is driven into the polished surface of the test material with a known force for a defined dwell period, the resulting indentation is measured using a microscope.

Table.3 shows the micro hardness values calculated.

TABLE.3: MICRO HARDNESS NUMBER

Trial	A	B	C	D	E
2	1432	1410	1433	1339	1478
5	1289	1255	1318	1214	1323
19	1739	1658	1723	1434	1777
24	1619	1538	1689	1623	1818
30	1378	1325	1416	1299	1445

Micro hardness levels are calculated at different places. Base metal has a micro hardness of 1125 KHN. The graphs depict the link between different points and micro hardness. Hardness tests were conducted at a depth of 2 mm below the base metal surface. In the table above, the KHN values for the weld zone and the base metal are comparable, whereas peak hardness is shown at points A, C, and E. These locations are in a high-risk area (HAZ). As a result, HAZ has the greatest micro hardness value. The presence of pearlite and the microstructure's size range can explain this discovery. The base metal and the weld zone had almost equal pearlite concentrations and size distribution ranges. The HAZ exhibits a higher pearlite concentration and a higher number of grains in the lower range than the weld zone and base metal, indicating a finer microstructure. Because of the increased pearlite content and finer microstructure, the HAZ has a higher micro hardness. Micro hardness is likewise highest in the grain refined zone, which contains the most Pearlite and has the most refined grains.

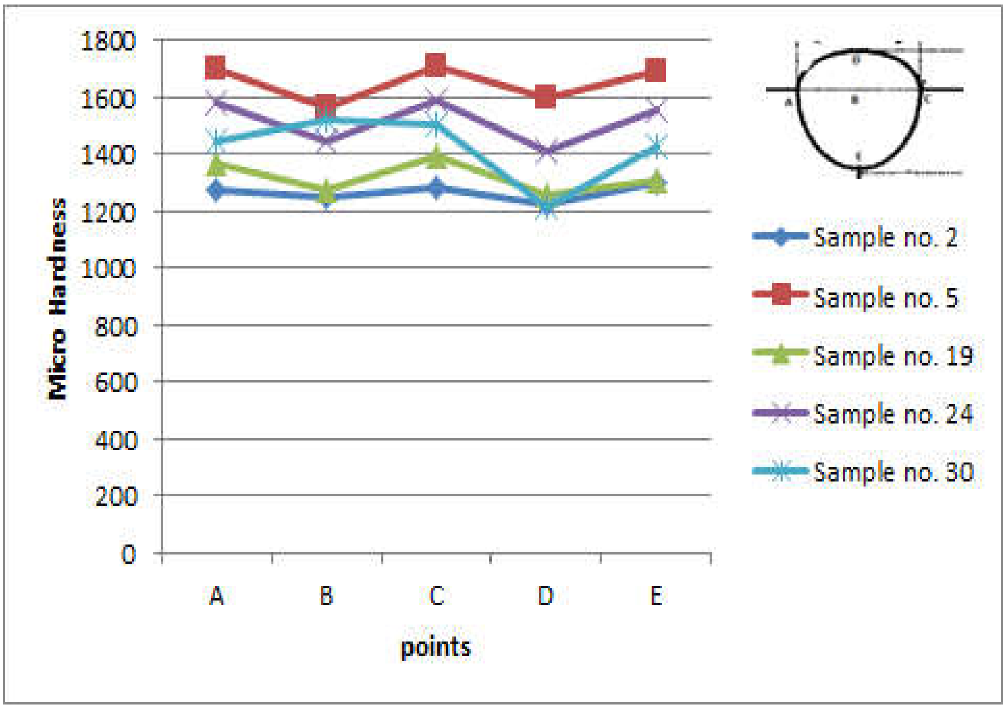

Figure.4: Micro hardness varies in different parts of the body.

3. CONCLUSION

The mixed mode was created by high welding current and high welding voltage, however it was mostly axial spray with some short circuiting. The weld bead ripples were quite consistent, and the bead's overall appearance was excellent. HAZ has the highest micro hardness value. As a result, the HAZ has the smallest grain sizes. Starting at the bottom, the micro hardness value rises. The impacts of wire feed rate (W), arc voltage (V), and welding speed (S) on dilution are all increasing, whilst GAS FLOW RATE and welding speed (S) are decreasing. While the gas Flow rate has little effect on dilution on its own, when combined with other parameters to boost weld dilution, it has a significant impact.

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