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EFFECT OF WELDING CURRENT ON GAS METAL ARC WELDED BEAD OF 8MM THICK AISI 1020 STEEL

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ABSTRACT
An essential physical characteristic that influences the performance of welded joints and the distribution of stress under practical circumstances is bead geometry. This study investigated the effect of welding current on gas metal arc welded (GMAW) bead of 8 mm thick AISI 1020 mild steel plate using a Juba 250 A GMAW machine. A steel plate of 8 mm thickness in a single V-groove butt joint with currents 100, 140 and 180 A was employed. Results revealed the specimens' average widths of weld beads to be 9.44, 9.67 and 10.22 mm for welding currents of 100, 140 and 180 A, respectively. The heights of the beads were 4.56, 2.78 and 3.67 mm for currents of 100, 140, and 180 A, respectively. It was observed that bead width increased with increase in current. It was also observed that increase in weld current led to decrease in weld bead height with a slight discrepancy observed in 180 A which could be as a result of welding being controlled manually. Welding defects like spatters, excess protrusion or excess penetration, incomplete penetrations, irregular beads, overlaps were observed for higher welding current of 140 A and 180 A. However, more of the spatters were seen on the welded specimen where welding current of 180 A was employed. It can be concluded that welding currents of 100 and 140 A gave better results as the weld beads produced had less defects compared with those produced with current of 180 A
Keywords: Welding current, bead width, bead height, Welding defects

1. INTRODUCTION

The gas metal arc welding (GMAW) technique is also known as metal inert gas (MIG) or metal active gas depending on the type of shielding gas employed (Kah *et al*., 2013; Vairamani *et al*., 2020 and Madavi *et al*., 2022). This welding process has become accountable for improving the efficiency of the arc welding process, which is more productive and produces high-quality welded joints (Ibrahim *et al*., 2012). Its versatility allows it to be employed in the construction, aerospace, automotive, and maintenance equipment industries for the welding of different metals (Khrais *et al*., 2023). Welding joint quality, productivity, and cost are all determined by GMAW welding parameters (Kumar *et al.,* 2017). If all welding parameters comply, the ideal arc will be produced. The welding parameters include arc welding current, arc voltage, welding speed, torch angle, free wire length, nozzle distance, position and direction of the welding, and gas flow rate (Karadeniz *et al*., 2007). By carefully choosing the MIG welding parameters for each weldment, the angular distortion, transverse shrinkage, bead shape, and mechanical properties can all be

modified (Waheed *et al*., 2022; Khrais *et al*., 2023). In addition, the procedure necessitates the engineer and the welder technician to work together to identify the proper MIG parameter sets before beginning in order to ensure the quality of the final product and the desired outcomes. Therefore, the first step in guaranteeing the process' success is selecting the suitable parameters, guaranteeing the necessary product criteria to produce the optimum physical qualities of bead appearance and minimal distortion (Girón-Cruz *et al*., 2022). An essential physical characteristic that influences the performance of welding joints and the distribution of stress under practical circumstances is bead geometry. Numerous researches stressed how crucial it is to enhance bead geometry in order to do structural analysis. The width, height, and penetration depth are all parts of the bead geometry. Numerous welding parameters, including shielding gas, welding current, voltage, wire feed rate, and welding speed, have an impact on the bead shape (Adak *et al*, 2015; Chandrasekaran *et al*., 2019). Cardona *et al*. (2017) has stated that Low-carbon steel AISI 1020 is extensively employed in manufacturing machine components and as construction material. Dewangan (2021) maintained that the formability, weldability, and machinability of this steel grade are all good. Other mechanical properties including strength, toughness, and hardness combine well with AISI 1020 grade mild steel. Heat-treating AISI 1020 steel is a straightforward process. Since it has good properties and can be machined, welded, and formed, for this reason, it is widely used in fabrication and construction works. Hence, it is necessary to ensure the quality of the welded joints in various applications is free from welding defects that could lead to early failure of the component or structure. One way to ensure that this is achieved is to optimize the welding current in such a way that the weld beads produced are of good and acceptable geometry with minimal welding defects that can endanger lives or lead to catastrophic failure.
This study investigated the effect of welding current on gas metal arc welded bead of 8 mm thick AISI 1020 mild steel plate in a single V-groove butt joint using 100 A, 140 A and 180 A.

2. MATERIALS AND METHOD

2.1 Plate Preparation

Mild steel plate of thickness 8 mm was purchased from Ijako Iron market in Ado Odo Local Government Area of Ogun State and was analysed using atomic absorption spectroscopy (AAS) at the laboratory of Metallurgical and Materials Engineering Department, University of Lagos. The analysis was carried out to determine the elemental composition and grade of the mild steel. The plate was prepared into dimensions of 120 mm X 80 mm X 8 mm using cutting discs attached to a hand cutting/grounding machine. The edges were faced and squared with the aid of late machine and milling machine at the engineering workshop in Engineering Materials Research Department (EMRD) of Nigerian Building and Road Research Institute (NBRRI) Ota, in Ogun State. Then a 60^{o} V-groove angle was cut in the plates. Each plate had a groove angle of 30o cut along one of the length in such a way that when two grooved faces were brought together, a groove angle of 60o was created. The picture of the prepared plate is shown in Figure 1.

Figure 1: Prepared plate for welding

2.2 Welding Operation

The gas metal arc welding (GMAW) of the plates was carried out at Gateway Industrial and Petro-gas Institute (GIPI) Oni, in Waterside Local Government area of Ogun State. The GMAW machine used for the welding is a JUBA GIANT MIG-250A (GMAW Machine (left) and the settings (right) shown in Figure 2.

Figure 2: JUBA GIANT MIG-250A (GMAW Machine (left) and the settings (right)

Different welding current settings of 100 A, 140 A and 180 A were selected for the welding of the plates after several trials using literature as a guide and considering the capacity of the welding machine utilised for the welding operation. The GMAW welding parameters used for the investigation in addition to the shielding gas with a composition of 80% argon (Ar) and 20% Carbon dioxide (CO_2) are shown in Table 1.

Table1: Welding parameters and their level considered for the experiment

Parameters	Unit	Level 1	Level 2	Level 3
Welding Current	Ampere A	100	140	180
Voltage	Volts	20	24	25.5
Wire Feed Rate	Mm/sec	20	30	40

2.3 Design of Experiment

The design for this experiment was done using Taguchi L9 orthogonal array in Minitab 18 Application shown in Figure 3. This design of experiment was expanded using Microsoft excel and each specimen was properly identified as shown in Table 2. Following the design of experiment, the GMAW process was carried out manually as shown in Figure 4 in triplicate for each set of parameters. The welding speed was determined by using stopwatch to record the time in seconds required to start and complete each run of the beads. The ratio of total length of the weld beads denoting distance to the time required to complete the weld was also computed for each welded samples and they were tabulated.

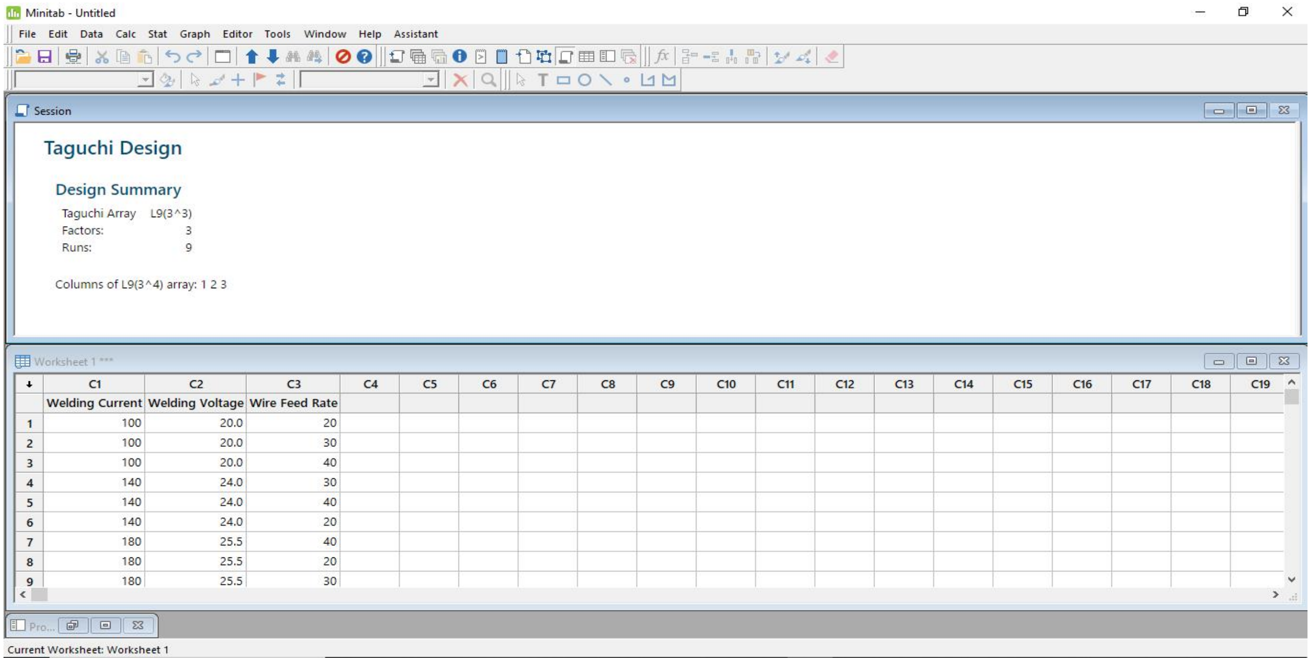

Figure 3: Taguchi L9 orthogonal array design of experiment

2.3 Examination of Beads

With the aid of vernier callipers, the width and height of each bead was measured and the average computed. Various welding defects that were observed through visual inspection were also recorded.

3. RESULTS AND DISCUSSION

The face of the welds as well as the root are shown in Figures 5 and 6 for the samples and the results of the weld beads width and height measurement noted are shown in Tables 3 and 4 respectively. The welding defects observed were also noted for each specimen welded with their respective welding parameter settings. Observing the widths of the weld beads produced, it was noted from the measurement carried out and computed that the average widths for all the specimens welded were 9.44, 9.67 and 10.22 mm for welding currents of 100, 140 and 180 A respectively. This shows that as the welding current increased, the overall average width of the weld beads increased. This observation noted was in agreement with Thakur *et al*. (2020). From the results obtained, the least average for the bead width is 8.33 mm while the highest value of the bead width average obtained was 10.67 mm; these values fall within the range of weld bead width values measured by Thakur *et al*. (2020). The least weld bead width measured was 8.74

Table 2: Design of experiment showing sample Identification (ID)

Expt. runs	Welding current	Voltage	Wire feed rate	Sample ID
	Ampere (A)	Voltage (V)	mm/s	
1	100	20	20	A
2	100	20	30	B
3	100	20	40	C
4	140	24	30	D

5	140	24	40	E
6	140	24	20	F
7	180	25.5	40	G
8	180	25.5	20	H
9	180	25.5	30	I

Figure 4: GMAW operation.

mm while the highest value was 15.30 mm. Though they employed submerged arc welding process on a 10 mm thick plate. The difference in welding processes utilised and the variation in thickness of the plate welded could be the reason for some discrepancies noted. The results for the average weld bead heights were 4.56, 2.78 and 3.67 mm for welding currents of 100, 140 and 180 A respectively. Thakur *et al.* (2020) also noted that the least bead height was 3.34 mm and the highest weld bead height was 6.14 mm. The results showed that increase in welding current led to decrease in the weld bead height, which is in tandem with the findings of Yadav and Paswan (2019) as well as Khrais *et al*. (2023). However, the trend is not well pronounced as discrepancies could be observed between welding currents of 140 and 180 A, this could be as a result of the welding being manually controlled. The welding speed could not be maintained at a constant rate for every specimen welded. The heat input is directly proportional to the welding current, hence when the welding current is high, more heat will be supplied and more fusion will occur. As more fusion takes place, the welder needs to control the welding speed in such a way as to minimise weld bead height without going too fast to prevent under-fill, and spending uniform deposition time throughout the welding process.

However, the welding speed should not be too fast in order to ensure that adequate amount of weld bead is deposited at the weld joint, otherwise welding defect known as under-fill will occur (Gupta *et al.,* 2019). If the welding speed is too slow on the other hand, another type of welding defects known as excess weld bead height will take place (Gupta *et al*., 2019). These welding defects have adverse effects on the performance and the life-span of a welded component as these could lead to stress concentration or serve as crack initiation points in weldment (Panji *et al*., 2019). Ahiale and Oh (2014) in the study of microstructures and fatigue performance of butt-welded joints in advanced high-strength steels were of the view that the fatigue life of welded structures is significantly influenced by weld bead geometry parameters. When the stress concentration caused by the bead geometry outweighs the microstructural effect, primary cause of failure could be the geometrical notch in the weldments. Hence the need to avoid excessive weld bead height. Some welding defects were also observed to be unique to current trend. Welding defects like spatters, excess protrusion or excess penetration, incomplete penetrations, irregular beads, overlaps were observed for higher welding current of 180 A and 140 A. However, more of the spatters were seen on the welded specimen on which welding current of 180 A was employed. Welding defects like excess protrusions or excess penetrations, incomplete penetrations, under-fills, were more of the welding technician skills and experience.

For the welding current of 100A, no spatter was noticed. However, welding defects like irregular beads, excessive bead height, incomplete penetrations, starts/stops, lack of side wall fusion and pinhole were observed, these could be due to the welding technician skills and capability.

Table 3: Bead width measurement for the samples

Expt. runs	Welding current	Voltage	Wire feed rate	Samples ID	Bead width for triplicates (mm)			Average
	Ampere (A)	Voltage (V)	mm/s		1	2	3	±
1	100	20	20	A	10	9	9	9.33
2	100	20	30	B	8	9	8	8.33
3	100	20	40	C	12	10	10	10.67
4	140	24	30	D	10	10	10	10
5	140	24	40	E	10	8	10	9.33
6	140	24	20	F	10	9	10	9.67
7	180	25.5	40	G	10	9	11	10
8	180	25.5	20	H	10	11	10	10.33
9	180	25.5	30	I	10	11	10	10.33

Table 4: Bead height measurement for the samples

Expt. runs	Welding current	Voltage	Wire feed rate	Samples ID	Bead Height for triplicates (mm)			Average
	Ampere (A)	Voltage (V)	mm/s		1	2	3	±
1	100	20	20	A	4	4	4	4
2	100	20	30	B	4	4	4	4
3	100	20	40	C	6	6	5	5.67
4	140	24	30	D	2	2	2	2
5	140	24	40	E	2	3	3	2.67
6	140	24	20	F	5	3	3	3.67
7	180	25.5	40	G	3	3	3	3
8	180	25.5	20	H	3	5	3	3.67
9	180	25.5	30	I	5	4	4	4.33

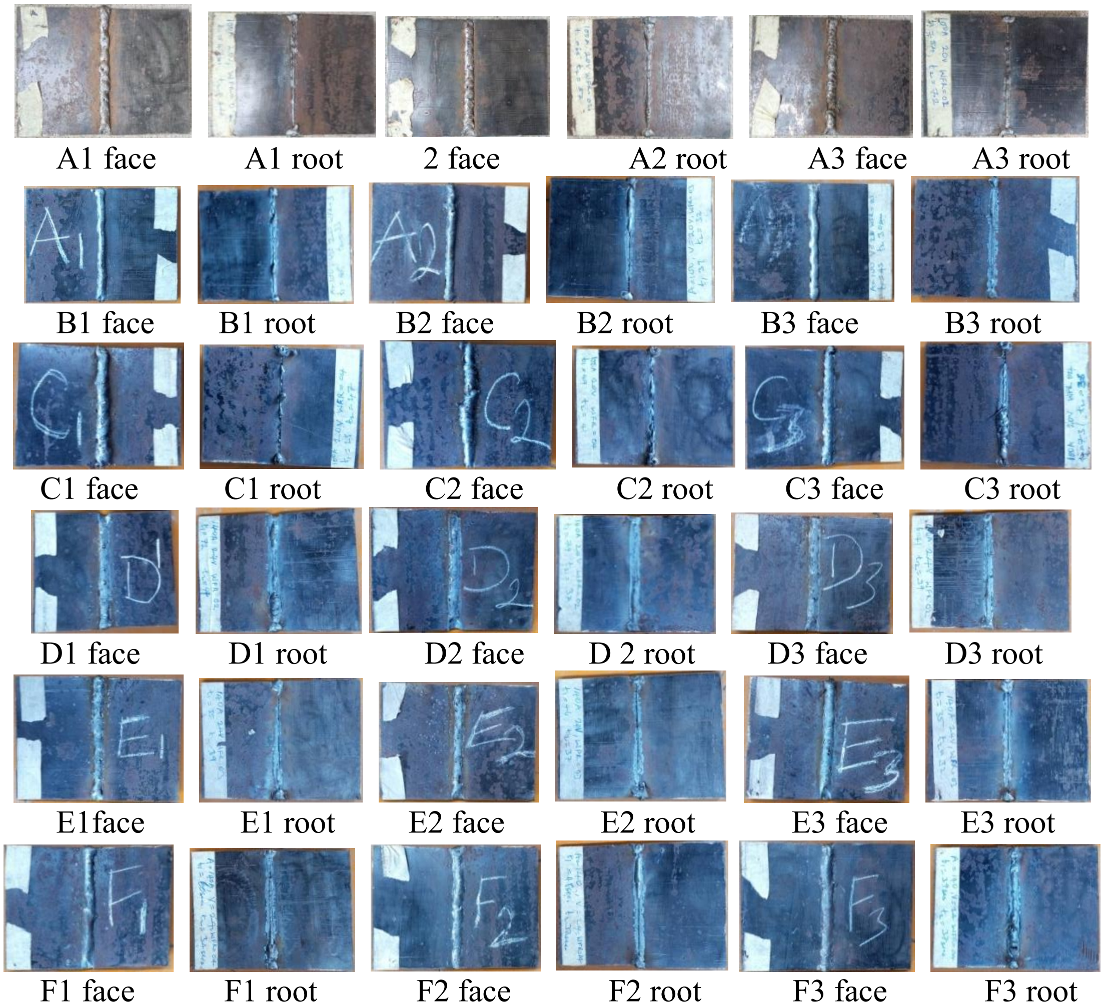

Figure 5: Samples A, B, C, D, E and F welded in triplicates showing their face and root passes.

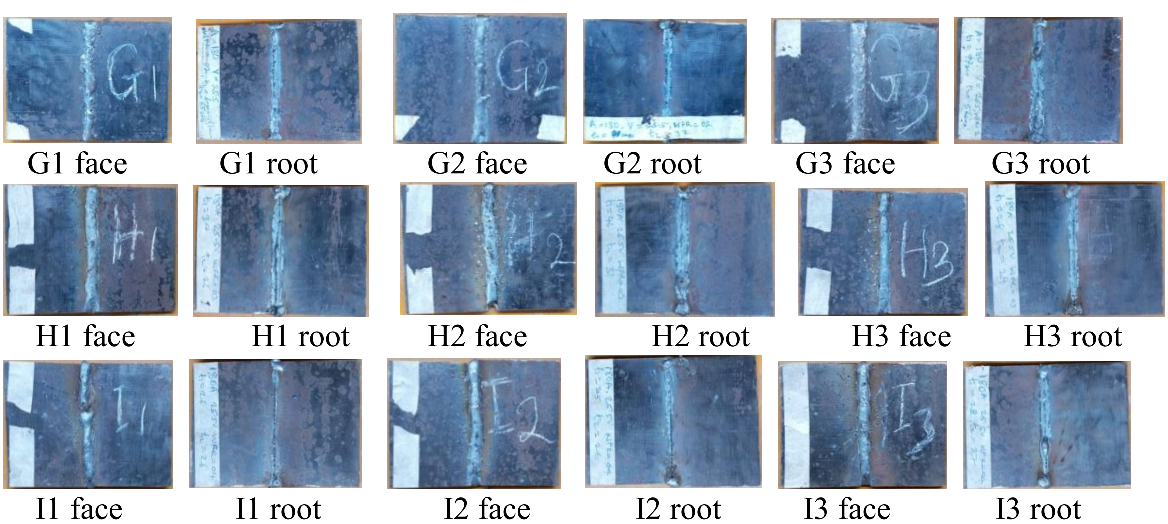

Figure 6: Samples G, H, and I welded in triplicates, showing their face and root passes.

4. CONCLUSIONS

The effect of welding current on gas metal arc welded bead of AISI 1020 steel was investigated in this study. Welding current is directly proportional to the heat input during welding and the heat input significantly influence the geometry of the weld beads formed during welding operation. The heat input also influences some welding defects in addition to manipulative skill capability of the welding technician. This study revealed that the overall width of the weld beads increases as the welding current increases. The ability of the welding technician to adequately manipulate and control the welding speed is also crucial to the formation of good weld beads. The geometry of the weld beads is highly significant to the performance and the durability of the welded component. Hence adequate care should be taken when selecting welding current and if possible fully automatic welding process can be adopted where this not possible, the welding technician manipulative skill capability need to be on the top notch in order to obtain good weld beads with minimal welding defects.

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