Effect of Metal Inert Gas Welding Parameters on the Hardness and Bending Strength of Carbon Steel Plates

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Abstract. A study of the metal inert gas welding MIG process was carried out in order to evaluate the influence of welding parameters on the hardness and bending strength of welded carbon steel plates. Welds were made by MIG welding machine with different parameters that include welding current of 10-200 Amperes, arc voltage of 11-26.5 Volts, wire welding speed of 1.5-16.5 m/min and CO_2 flow rate as inert gas of 5-25 l/min. The result shows that the hardness increases with decreasing wire welding speed and increasing welding current. Moreover, increasing and decreasing arc voltage cause unstable arc which affected the bead surface and the weld penetration. Oppositely, increasing the flow rate of inert gas not affected on the hardness of welding zone. The majority of welded samples were bended successfully except the samples that welded with voltages of 11, 15, 22 and 26.5 Volt, current of 100 Amp, wire welding speed of 8.5 m/min, and CO_2 flow rate of 10 l/min were failed which appear large crack on their welded zone. Furthermore, the hardness of welded zone was increased with increasing the welding current value. The best quality of MIG welding process can be obtained at welding parameters of 100 Amp, 18 Volt, 8.5 m/min wire welding speed and 10 l/min CO_2 flow rate. The hardness was improved to be 240 HV instead of 192 HV with good bending behavior.

INTRODUCTION

Welding is one of the most common permanent joining processes that applied for assembly metals which can be considered as a bone structure of modern industry [1]. The quality of a weld joint is strongly influenced by process parameters during the welding process. A good selection of welding process should be utilized to optimizing the bead geometry and quality [2]. Metal inert gas welding is one of these processes which can be defined as an arc welding process that produces the coalescence of metals by heating them with an arc that generated between a continuously fed filler metal electrode and the work piece. The wire electrode was shielding by argon, helium and carbon dioxide gas or a mixture of gases which shields melting metal from contaminants in the atmosphere air [3, 4, 5]. Weld quality and deposition rates are affected by electrode size, welding current, arc travel speed, welding position, gas flow rate, shielding gas composition and electrode extension [6]. The key parameters that influence the quality of MIG welding are included welding current, arc voltage, welding speed and gas flow rate. It is significantly affects the properties of weldment due to the change of microstructure [1, 7 and 8]. Moreover, MIG parameters are the most important factors affecting the productivity and cost of welding [9]. Although, carbon dioxide is not an inert gas, it ionizes at welding temperatures and acts like one [5]. The current from the welding machine is changed by the rate of feeding of electrode wire [10].

High welding speed and financially attractive of MIG welding process can be considered as a key advantage of this method. A long arc time can be maintained without any frequent changing of welding electrode. It is providing the opportunity for coherent welding materials that difficult to weld [11]. In this research, the effect of welding current, arc voltage, wire welding speed and inert gas flow rate were evaluated and their effect on the hardness and bending strength of carbon steel plate were determined.

EXPERIMENTAL WORK

Material and Method

Carbon steel plates with chemical composition shown in table 1 were used to evaluate the effect of welding parameters on their hardness and bending strength. The plates with dimension of 200x100x3 mm were chamfered with single V-groove to be welded as a butt joint by using MIG welding machine.

Table 1. Chemical composition of carbon steel plates

Element	Percentage	Element	Percentage
Fe	98.70	S	0.021
Si	0.146	Cu	0.173
Mn	0.440	C	0.224
P	0.003	Others	0.293

Metal Inert Gas Machine

MIG welding machine with welding current of 10-200 Amperes, voltage of 11-26.5 Volt, wire welding speed of 1.5-16.5 m/min and Co2 flow rate of 5-25 l/min as inert gas that shown in figure 1 was used to weld carbon steel plates with thickness of 3 mm.

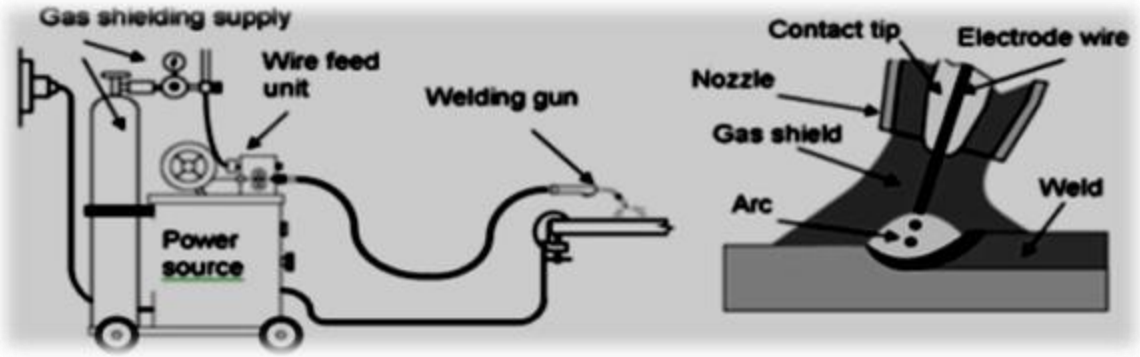


FIGURE 1. A diagram of metal inert gas welding machine [9]

MIG Welding Procedure

Different welding parameters were applied to weld plates by using metal inert gas welding process. Manual MIG welding machine was applied for welding carbon steel plates. Coalescence was produced by heat from an arc between a metal electrode and the work piece shielded by carbon dioxide gas. MIG welding wire is fed continuously through a gun to a contact surface that imparts a current to wire. Direct current reverse polarity provides a stable arc and offers the greatest heat input at the work pieces. Twenty case studies were considered which divided into four main groups. One parameter was change and others fixed in each case study as shown in table 2. The first group of

case study includes constant welding current, arc voltage and inert flow rate with variable wire welding speed. The second group includes constant arc voltage, wire welding speed and inert gas flow with variable welding current. The third group includes constant welding current, wire welding speed and inert gas flow rate with variable arc voltage. Finally, the forth group include constant welding current, arc voltage and wire welding speed with variable inert flow rate.

TABLE 2. MIG welding parameters

Case No.	Item	Current Amp	Voltage Volt	Wire Welding Speed m/min	CO_2 Flow Rate l/min
1	1	100	18	1.5	10
	2	100	18	5.5	10
	3	100	18	8.5	10
	4	100	18	11.5	10
	5	100	18	16.5	10
2	1	10	18	8.5	10
	2	60	18	8.5	10
	3	100	18	8.5	10
	4	150	18	8.5	10
	5	200	18	8.5	10
3	1	100	11	8.5	10
	2	100	15	8.5	10
	3	100	18	8.5	10
	4	100	22	8.5	10
	5	100	26.5	8.5	10
4	1	100	18	8.5	5
	2	100	18	8.5	10
	3	100	18	8.5	15
	4	100	18	8.5	20
	5	100	18	8.5	25

RESULTS AND DISCUSSION

Visual Inspection

Figures 2-5 show carbon steel plate samples that welded by using metal inert gas welding machine. The visual inspection found that the majority of welding joint surface has smooth surface and few thinning flash surface. However, some of these samples not welded or welded with poor quality as shown in figure 4. This is due to unsuitable welding parameters that used to weld the plates. Furthermore, the width and height of welding zone line is differed from case to case and inside each case study as well.

FIGURE 2. Carbon steel plate welded with 100 Amp, 18 V, 10 l/min CO2 and different wire welding speed from 1.5 to 16.5 m/min

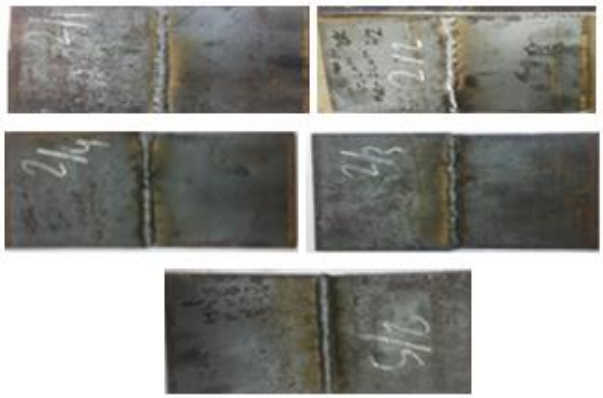


FIGURE 3. Carbon steel plate welded with 18 V, 10 l/min CO2, wire welding speed from 8.5 m/min and different current from 10 to 100 Amp

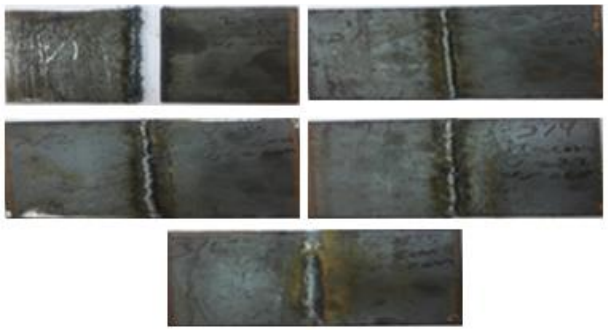


FIGURE 4. Carbon steel plate welded with 100 Amp, 10 l/min CO2 flow rate, wire welding speed from 8.5 m/min and different voltage from 11 to 26.5 volt

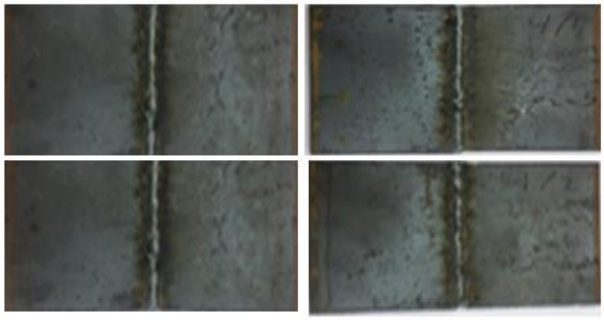


FIGURE 5. Carbon steel plate welded with 100 Amp, 18 V, 8.5 m/min wire welding speed and different current from 10 to 200 m/min and different CO2 flow rate from 5 to 25 l/min

Hardness Test

Hardness test is defined as a means of determining resistance of materials to penetration and it is a function of wear resistance. Hardness of welding zone and base metal was measured by using Vickers hardness test device and the results presented in tables 3 and figure 6-10. The result shows that the hardness decreased with increasing wire welding speed and increased with increasing welding current. Wire welding speed is inversely proportional to heat input which agrees with Harish Kumar Arya and Kulwint Singh [1]. There is a direct relationship between wire welding feed or speed and welding current. On the other hand, increasing the flow rate of inert gas Co2 not affected the hardness of welding zone. It has approximately same hardness in case of using inert gas with flow rate of 5, 10, 15, 20 and 25 l/min which agree with N. Abu Basim et al [12]. The inert gas used to form shield for excluding the atmosphere from contact with molten weld metal to avoid weld pool contamination by oxygen, nitrogen and air humidity. Furthermore, the welding arc voltage affects the width of welding joint line which leads to decrease the welding penetration. Therefore, the majority of carbon steel plats not welded due to increasing the value of arc voltage. This is because arc length is a critical variable that must be carefully controlled. The maximum hardness was obtained in case of using welding condition with welding current of 100 Amp, welding arc voltage of 18 Volt, welding wire speed of 8.5 m/min and inert gas flow rate of 10 l/min which produced hardness with value of 240 HV.

TABLE 3. Hardness value of base metal and welding zone

No. of Case Study	Base Metal Hardness (HV)	Welding Zone Hardness (HV)
1	103-192	135-222
2	103-192	146-199
3	103-192	229
4	103-192	198-240

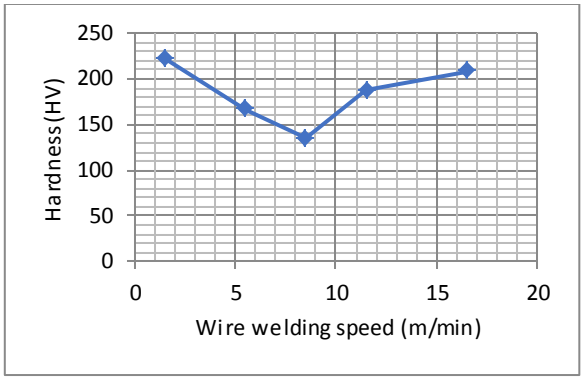


FIGURE 6. Hardness of welded zone in case of change wire welding speed

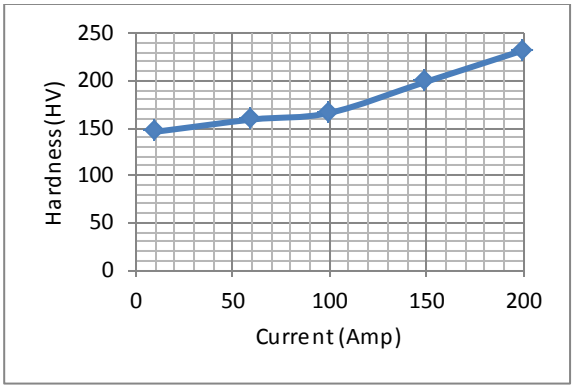


FIGURE 7. Hardness of welded zone in case of change welding current

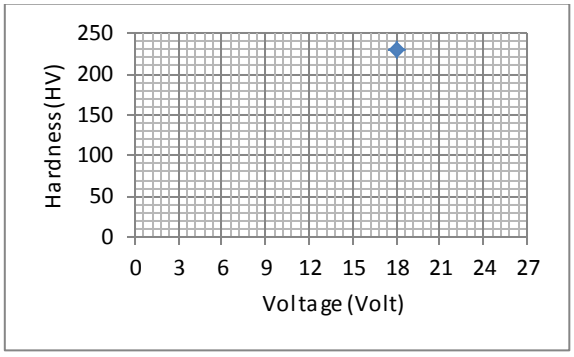


FIGURE 8. Hardness of welded zone in case of change arc voltage

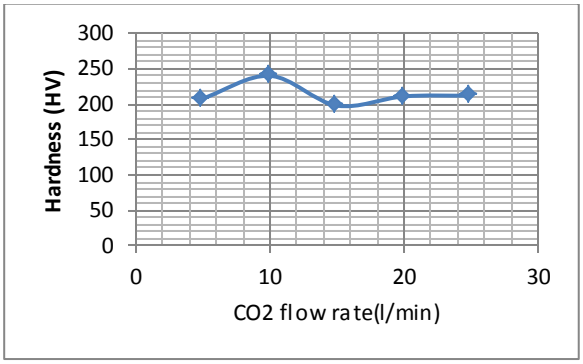


FIGURE 9. Hardness of welded zone in case of change CO_2 flow rate

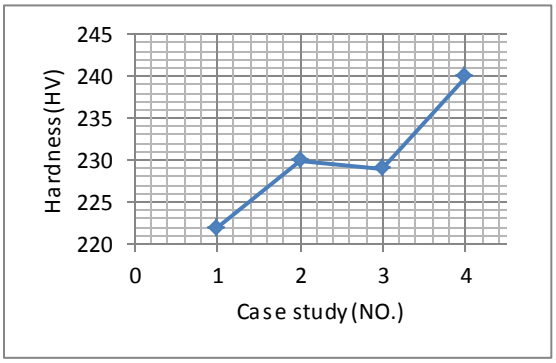
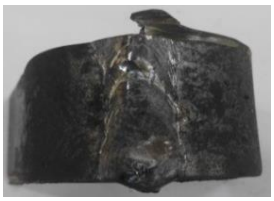


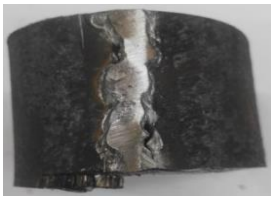
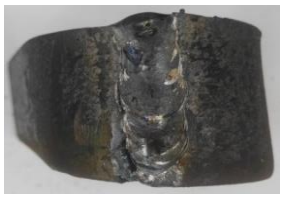
FIGURE 10. Maximum hardness of welded zone for four case studies in case of change (1) wire welding speed, (2) welding current, (3) arc voltage and (4) CO_2 flow rate

Bending Test

Bending strength is defined as the ability of materials to resist deformation under load which can be considered as a key aspect of the mechanical behavior of material. Bending test was done for MIG welded specimens and the result shows that the majority of welded plates were bended successfully without any defects as shown in figure 11. However, some of them specimens were failed in the bending test due to unsuitable welded parameters or condition that applied during welding operation and the large crack was happened at welded zone as shown in figure 12.





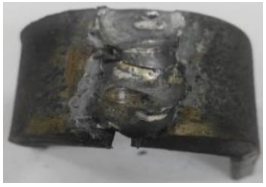


FIGURE 11. Bending test for samples without any crack for welding condition of case study number 1-1, 1-3, 2-2 and 3-5

FIGURE 12. Bending test for samples with crack for welding with condition of study number 1-2, 2-4, 3-4 and 4-1

CONCLUSIONS

An investigation has been made of the effects of metal inert gas welding parameters include welding current, welding arc voltage, wire welding speed and inert gas Co2 flow rate on the hardness and bending strength of carbon steel plates. Some concluding observations from the investigation are given below.

- The majority of carbon steel plate samples were welded successfully except four samples were failed and unwelded due to applied low efficiency of welding parameters.
- The lower efficiency of welding process happened due to using welding current of 100 Amp, welding wire speed of 8.5 m/min, inert gas CO2 flow rate of 10 l/min and welding arc voltage of 11, 15, 22 and 26.5 volt.
- The best welding parameters that produced welding with high hardness and good bending strength include welding current of 100 Amp, welding wire speed of 8.5 m/min, CO2 flow rate of 10 l/min and welding arc voltage of 18 volt. However, all case studied that applied in this research have high hardness in welded zone comparing with base metal.
- Welding parameters are not completely independent and changing one generally required changing one or more of the others to produce the desired results.
- The hardness was improved with percentage of 25% to be 240 HV in welding zone instead of 192 HV in base metal. It was increased with increasing the welding current and decreasing with increasing welding wire speed. However, it is not change with increasing inert gas flow rate.
- The majority of welded plates were bended successfully without any defects. However, some of them were failed in the bending test due to unsuitable welded parameters that applied during welding operation and the large crack was happened at welded zone.

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