INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume 4, Issue 4)
Available online at: www.ijariit.com

Effect of variable process parameter of MIG welding on aluminium alloy 6061-T6

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ABSTRACT

The increasing use of aluminum alloys (6061-T6) in shipbuilding, aeronautics, marine frames, railway vehicles, bridges, offshore structure topsides, and automobile industry relevance due to its light weight and high strength to weight ratio. The present investigation is designed to study the effect of various process parameters (welding current, voltage, and angle of the torch.) in metal inert gas (MIG) welding processes on a bead on the plate of aluminum alloy 6061-T6. In this alloy, the weld fusion zone has coarse columnar grains because of the unequal he, at distribution during weld metal solidification. Electrode material has selected for MIa G welding as ER4043. Taguchi's optimization technique and orthogonal array matrix were used to optimize and selection of the process parameters for better results.

Keywords: *Metal inert gasthe welding, Aluminium alloys (6061-T6), Welding current, Welding voltage, Torch angle*

1. INTRODUCTION

MIG welding is widely used in many industrial applications because it is very easy to operate, can be done automatic and semi-automatic manner & have much higher deposition rate, which allows thicker work-pieces to be welded at higher welding speeds. This is a fusion welding process in which arc is generated between the electrode and the work material filled by a continuously fed filler wire electrode. The heat produced by the arc results in melting and fusion; Shielding of the arc and the molten weld pool is often obtained by using inert gases such as argon and helium as shown in figure 1 [1]. Since non-inert gases (CO_2), are also particularly used. This is the most widely used arc welding process for aluminum alloys. Shielding gas feeds through the welding gun, which shields the process from contaminants in the air. As a matter of fact, lots of difficulties are associated mainly persistent oxide layer on the surface of the material, high thermal conductivity, high coefficient of thermal expansion, solidification shrinkage and, above all, high solubility of hydrogen, and other gases, in the molten state [2]. Aluminum alloys are very much used in industries due to its lightweight, high strength and excellent corrosion resistance. It is said that aluminum is preferred next to steel in industries. An alloy of aluminum AA6061-T6 (solutionized and artificially aged) developed in 1935 Originally called "Alloy 61S" is a precipitation-hardened aluminum alloy which containing Mg and Si as its major alloying elements. It is the most widely used medium strength Al alloy & has good mechanical properties, exhibits good weldability, easily available, cheap and has high strength to weight ratio. Welding of the aluminum alloys have remains a challenging task before and nowadays. On the way of Welding, the unequal distribution of heat may be developed the hot cracking in weld zone can be a severe problem as a during solidification. [3]. Diganta Kalita et. al asserted the effect of three process parameters of MIG welding, welding current, voltage and shielding gas flow rate on the tensile strength of welded joints having Grade C20 Carbon Steel as parent metal and ER70S-4 electrode Mahadzir Ishak et al. explicated the weldability of aluminum alloy 6061 by MIG welding using ER5356, ER4043 (ER5356 filler contains 5.5% of magnesium and ER4043 contain 6% silicon) as filler metal. Javier A. et.al. conferred the analysis of heat input effect on the mechanical properties of Al-6061-T6 alloy weld joint Plates (thickness 4.8mm) welded with an ER4043 electrode (1.19 mm in diameter) using the typical simple butt joint to investigate the effect on the mechanical properties of aluminium alloy 6061-T6 due to the Gas Metal Arc Welding (GMAW) process. Elsadig O. et. al. find out the effects of corrosion and mechanical properties of MIG welding on aluminum alloy AA 6061 T6. Filler wire used for the experiment is A404. Vineeta Kanwa et. al. investigated the Parametric optimization of MIG welding for Hardness using Taguchi method. Welding Speed, Welding Current, and Welding Voltage were chosen as welding parameters. The materials dimensions (75x60x6) mm were used for butt welding of aluminum alloy 6061 and 5083. Argon was used as a shielding gas. Filler wire 4043 of diameter 1.2 mm was used. A lot of researchers have optimized the process parameters like welding current, voltage, welding speed, gas flow rate during welding of AA6061T6 but not included the effect of the angle of the torch. So in this paper, we have included the effect of various parameters with torch angle on microstructure and penetration on welding of aluminum alloys (6061-T6). The composition of alloying element in 6061-T6 and Mechanical property of material has been shown in table 1, & 2 respectively.

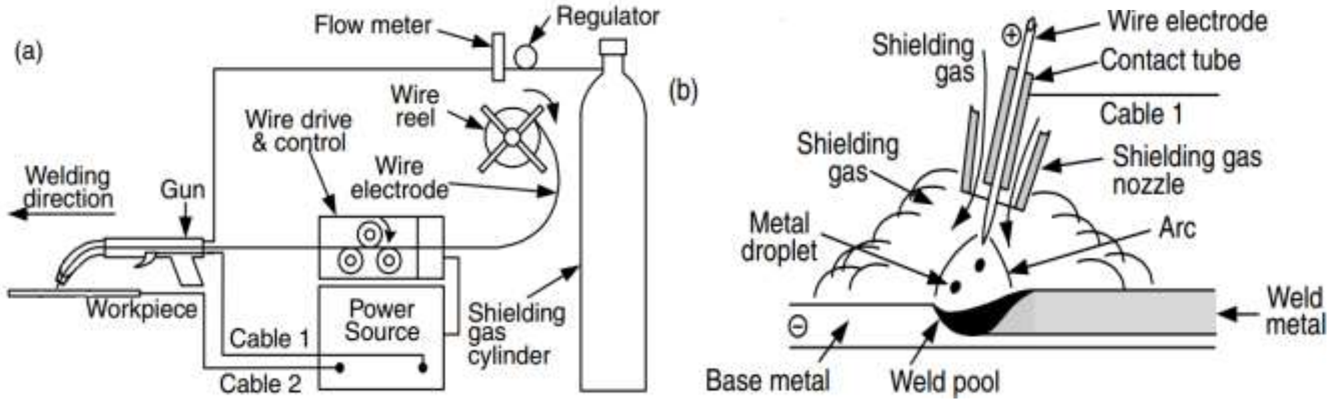


Fig. 1: Gas–metal arc welding: (*a*) overall process; (*b*) welding area enlarged

Table 1: Chemical composition of Al alloy 6061-T6

Component	Mg	Si	Fe	Cu	Cr	Mn	Zn	Ti	Al
Wt. %	0.9	0.62	0.33	0.28	0.17	0.06	0.02	0.02	Bal.

Table 2: Mechanical properties of Al alloy 6061-T6

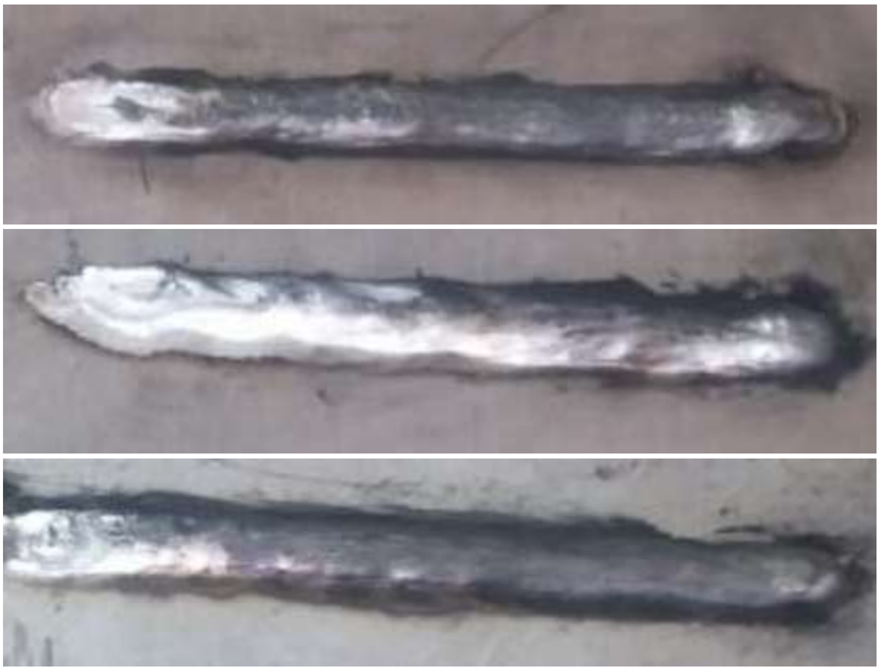
Yield Strength (MPa)	**Ultimate Tensile Strength (MPa)**	**Elongation (%)**	**Reduction in cross sectional area (%)**	**Hardness (VHN)**
302	334	18	12.24	105

2. EXPERIMENTAL PROCEDURE

Aluminum alloy 6061-T6 is selected as a material because of huge application in daily life which has diminished as (120mm*70mm*10mm) for conducting an experiment. Before the welding, the workpiece had removed dirt particle and sharp edge on the surface of the workpiece by the use of high grain emery paper and acetone. The workpiece had been placed on the fixture and set the parameters which have investigated throughout the previous study of literature survey. Welding torch angle fixture had fixed on the carriage to successfully welding on the job for the different angle of the torch. Then set up the process parameter after trail and same procedure applied on different fixed parameters. In MIG welding the filler rod used as ER4043 grade having diameter 1mm. Taguchi's L9 orthogonal array had been used. The workpieces had been polished up to mirror finish in the polishing machine with the help of different grades of emery paper and velvet cloth with alumina and silica gel. Etched using the etchant (6.25ml Methanol + 6.25ml of HCl + 6.25ml HNO_3 + three drops of HF) for 13s to observe different zones of welding. A Reichert MEF4 A/M (Leica Corp.) optical microscope was used for the optical microscopy. Micro-hardness samples were prepared in exactly the same way as the optical metallographic sample. Vickers micro hardness measurements were taken using a Shimadzu digital micro hardness tester, using a load of (1N) applied for 10 seconds.

3. RESULT & DISCUSSIONS

A Few of welded bead on plate workpiece material have shown in figure 2. The oxidation is formed during the welding on an aluminum plate which shown as black on the top layer of weld bead structure.



On 100 A and 23 Volt
Oxide formation more than the 110A because less current provide.

On 110 A and 23 Volt
Little oxide formation because adequate current provide.

On 120 A and 23 Volt
More oxide formation due to more current.

Fig. 2: MIG welding on a bead on a plate of Al 6061-T6 alloy

The value of the penetration, reinforcement and weld bead width are measured with an optical microscope. The values obtained are in the following table:

Table 3: Values of depth of penetration (P), Reinforcement (R), and weld bead width (W) of the samples welded by MIG welding

S. No.	Current (A)	Voltage (V)	Torch Angle (^{0})	P (mm)	R (mm)	W (mm)
1	100	22	90	4.5	2.2	7
2	100	23	70	3.6	2.1	6
3	100	24	50	4.5	3.3	8
4	110	22	50	3.4	3.7	7
5	110	23	90	5.5	3.5	8
6	110	24	70	5.9	5.4	7
7	120	22	50	3.5	3.6	7
8	120	23	70	5.2	4.5	8
9	120	24	90	6.3	3.8	8

3.1 Effect of current, Voltage, and torch angle on penetration

Penetration is larger the better quality characteristics. Therefore higher value of penetration is considered to be optimal. It is clear from the table (1) that penetration is maximum when the Current is 120A, Voltage is 24V, and Torch angle kept at 90 º. Penetration increases when the current increases from 100A to 120A.When the voltage is increased from 22V to 24V the penetration increases. The penetration first decreases with the increase in torch angle and then slightly increases.

3.2 Effect of current, Voltage, and torch angle on reinforcement

Penetration increases when the current increases from 100A to 120A.When the voltage is increased from 22V to 24V the penetration increases. The penetration first decreases with the increase in torch angle and then slightly increases. The reinforcement decreases with increase in current. The increase in voltage the reinforcement first increases and then decreases. and increase in torch angle the reinforcement decreases.

3.3 Microhardness testing results

Microhardness testing is done on Vicker's hardness tester. A load of 100gf is applied dwell for 10 seconds. Hardness test result shows that the hardness of the samples welded by keeping torch angle 50º is less as compared to the specimens welded by keeping torch angle 90º. If we consider one specimen if we go away from the weld center the hardness increases.

3.4 Microstructure of welded sample

The microstructure of all the joints was examined at different locations, but most of the tensile specimens failed in the weld metal region, and the optical micrographs taken at the weld metal region alone are displayed in Fig. 3 for comparison purpose. The base metal contains coarse and elongated grains with uniformly distributed very fine precipitates (Fig. 3a). The fusion zone of GMAW (Fig. 3b) originated dendrite structures.

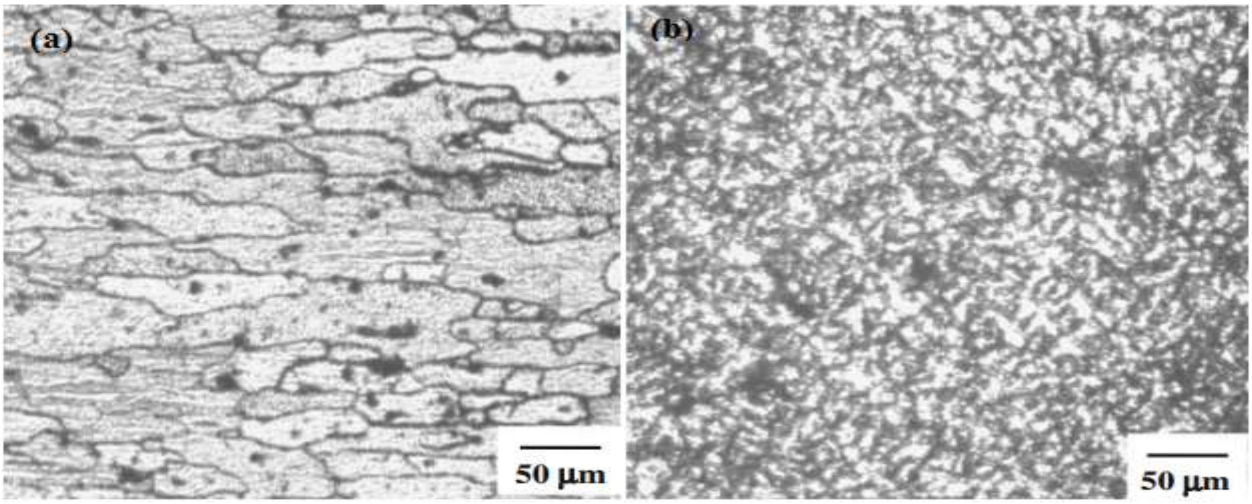


Fig. 3: Optical micrographs of weld metal region 3(a) Base metal 3(b) fusion zone of GMAW[11]

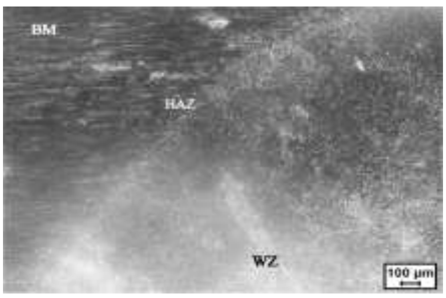


Fig. 4: The microstructure of the WZ, HAZ, and BM of welded sample

In fusion welding, the dilution of base metal in weld metal is a common phenomenon. Even though a large amount of silicon is available (available in base metal and filler metal) for precipitation reaction, the available magnesium (available in base metal alone) in the molten weld pool for the precipitation reaction is very low. Hence, the weld region of AA6061 aluminum alloy welded with AA4043 filler metal usually contains a lower amount of Mg_2Si precipitates compared to the base metal region [11].

4. CONCLUSION

In this paper, the mechanical properties of MIG welding of the AA6061 aluminum alloy were evaluated. From this investigation, the following important conclusions have been derived

- The process parameters & angle of the torch is found to be a most influencing parameter for defect-free welding.
- Based on Taguchi's analysis for optimized & concluded that for defect-free MIG welding in aluminum alloy AA6061-T6 the welding current range between 100A to 120A, the voltage must be 23V, and torch angle must be 90º.

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