

Influence of Current on Microstructure and Hardness of Butt Welding Aluminium AA 6082 Using GTAW Process

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Abstract

Aluminum and its alloys have excellent corrosion properties owing to the tenacious oxide layer, ease of fabrication. In the construction of pressure vessels and storage tanks, the weld ability play unique role in selection of materials from the various materials. Aluminum alloy 6082 is a medium strength alloy with excellent corrosion resistance. It has the highest strength among the 6000 series alloys. The preferred welding process of aluminum alloy is Tungsten Inert Gas (TIG) welding due to its comparatively easier applicability and better economy. In this paper welding parameter current was optimized for Alloy 6082. The wide range of current was selected by performing the trial runs. As per results of trial butt joint of Alloy 6082 was welded by TIG welding process. Microstructure and hardness were analyzed and optimum current was found.

Keywords

Microstructure, Hardness, Alloy 6082, TIG

I. Introduction

Aluminium is the most abundant metal in nature. Some 8% by weight of the Earth's crust is Aluminium. Unfortunately, Aluminium does not occur in nature in the metallic form. In rocks, Aluminium is present in the form of silicates and other complex compounds. The ore from which most Aluminium is presently extracted, Bauxite, is a hydrated Aluminium oxide [1]. Aluminium is the most difficult metal to weld. Aluminium oxide should be cleaned from the surface prior to welding. AA6082 FSW joints were produced by employing different welding parameters by P.Cavaliere, [2]. A.Kumar's[3] work pertains to the improvement of mechanical properties such as hardness of AA 5456 Aluminum alloy welds through pulsed tungsten inert gas (TIG) welding process. The behavior of the welded joints at the optimum condition of process parameters was attributed to increase an amount of Mg_2Al_3 precipitates that are formed in the aluminum matrix examining microstructure and micro hardness of different joints.

A. Cabello Mun [4] investigated the comparative microstructural and mechanical characteristics of fusion welds (TIG) and solid-state welds (FSW) of Al-4.5 Mg-0.26 Sc heat-treatable aluminium alloy. The effect of different shoulder geometries on the mechanical and microstructural properties of a friction stir welded joints of 6082 T6 aluminium was analysed by A. Scialpi [5]. Mechanical properties of welded joints of 6082-T6 Al alloy with Gas Metal Arc Welding (GMAW), under the experienced welding conditions, undergoes a remarkable reduction of the initial value i.e. about 60% of the parent metal [6] In the HAZ both tensile strength and hardness reduce to a minimum at a distance from the weld fusion line of about 6 mm, presumably due to over-aging consequent to the transformation of the strengthening metastable precipitate [7]. The preferred welding process of aluminium alloy is frequently Tungsten Inert Gas (TIG) welding due to its comparatively easier applicability and better economy [8]. In the present study an effort has been made to find best setting of input parameters current of TIG welding for better strength of Aluminium AA6082. The

joint thickness of 6mm has been selected with conventional AC mode on TIG welding. Investigation has been made to study the influence of AC on hardness and metallurgical characterization of TIG welded butt joints of aluminium alloy AA6082-T6.

I. Experimental Work

The specimens used in the investigation were extracted from butt joints of AA6082.

A. Brief on Base Material and Filler Road Material

The AA6082 are generally in the form of strips and thickness of sheet used for this purpose is 6mm. For welding of sheet of this thickness, manufactures have recommended use of filler wire of 4043 material [6]. Table 1 shows the composition of base material and filer wire.

Table 1: Chemical Composition of Base Material and Filler Wire [6]

Elements	Composition %(AA6082) Base material	Composition %(4043) Filler Wire
Manganese (Mn)	0.40-1.00	0.05
Iron (Fe)	0.00-0.50	0.08
Magnesium (Mg)	0.60-1.20	0.05
Silicon (Si)	0.70-1.30	5.0
Copper (Cu)	0.00-0.10	0.3
Zinc (Zn)	0.00-0.20	0.1
Titanium (Ti)	0.00-0.10	0.2
Chromium (Cr)	0.00-0.25	-
Aluminium (Al)	Bal	Bal

B. Preparation of Test Specimen

Before conducting the final experimentation the pilot experiment was conducted to finalize the values of welding parameter (Current). Sample of AA6082 plate of 6mm thickness was cut in the shape of smaller section, having 300 mm X 75mm area. Each such strip was machined to obtain V-groove, having an angle 65°, root face was kept 2mm, as per B.I.S standard, No. 813-1961. Edge preparation of specimen was shown in fig. 1.

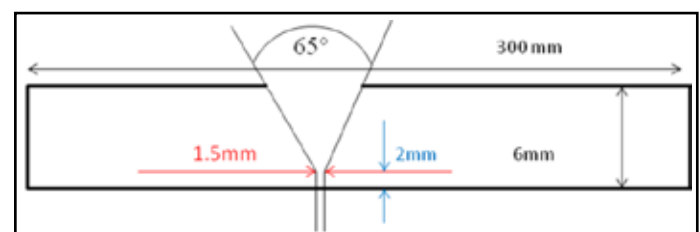


Fig. 1: Edge Preparation of Specimen

Prior to welding, the groove was thoroughly cleaned with wire brush, followed by cleaning with acetone, to remove the oxide

layer, if any; and dirt or grease adhering to the groove surface. Weldment was prepared by using commercial Aluminium filler wires, different welding condition. The pilot experimentation has been performed by using commercial settings of TIG welding apparatus and as per hand book (Welding Aluminium a designers and user). Shielding Gas used was argon (99.97% pure) with electrode Tungsten (99.75% pure) having diameter 3mm and filler rod of diameters 2.4 mm. It was observed that with gas flow rate 20 lit/min below 80 Amp the welding joint was not properly made and around 250 Amp burning of specimen started. As per this observation different set of current were decided, values given in table no 2. Sixteen sample of AA6082 plate of 6mm thickness were cut in the shape of smaller section, having 300 mm X 75mm area. Each such strip was machined to obtain V-groove, having an angle 65°. Root face was kept 2mm, as per B.I.S standard, NO 813-1961.

C. Welding of Test Pieces

All general precautions and procedure were adopted for TIG welding of Aluminium with output current of up to 500Amp. Since welding was to be done in open and not in closed chamber. Adequate precaution was taken to prevent welding zone from atmospheric contamination.



Fig. 2: Welded Specimens at Different Current Keeping gas Flow Rate Constant 20 lit/min

Before commencing welding arc air around welding zone was purged with argon from 10 to 15 second. Angle between electrode and work piece was maintained at 60° to 80° and angle between electrode and filler wire was maintained between 80° to 90° as per B.I.S. standard, No.813-1961. Sixteen weldments were prepared (eight are shown in fig. 2), keeping the gas flow rate constant (20lit/min) two specimen of each set as per parameter in Table 2.

D. Hardness Test

The fig. 3 shows the standard specimens for micro hardness test. The standards are taken from ASTM Internationals, Designation E 92. First of all, the required size was cut from the welded pieces after this these were made smooth by filing followed by smoothen with help of emery papers. Then to get more smoothness, polishing machine was used. The alumina powder and then diamond powder were used for polishing the surface. Microhardness of fusion zones of the weldments was measured using Vickers's micro hardness testing machine with a load of 0.5kg.

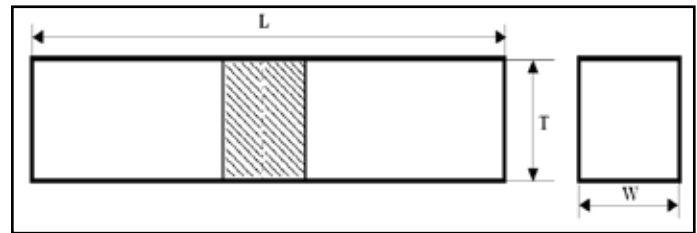


Fig. 3: Standard Specimen Size for Micro Hardness Testing (L= 30mm, W= T= 6mm)

E. Metallography

In order to observe the micro structural changes that take place during welding, corresponding to each current input; specimens were machined out from the weld pads as shown in fig. 2. The specimens were suitably sectioned, mounted in transverse direction of the welding, polished according to standard metallographic procedures and etched using modified Keller's reagent (5 ml HF, 15 ml HCl, 5 ml HNO₃ and 8 ml H₂O). After polishing and macro etching the cross sections of the joints were captured with the help of Image analysis software coupled with a stereo zoom microscope at a magnification of 10X to facilitate measuring of the details like cross sectional areas of the fusion zone. Standard polishing procedures were used for general microstructure observations [9]. An electrolytic oxalic acid etch was used with the conditions (Electrolyte used: Oxalic acid (10 gms) + distilled water (100 ml), Cell voltage: 6 V, Etching time: 1min). Microstructures of fusion zones of weld metal under different current combinations were viewed and captured with an optical microscope.

III. Results and Discussion

A. Effect of Current on Micro Hardness

The hardness was measured for all the specimens made at different value of AC (100, 120, 140, 160, 180, 200, 220 and 240 Amp). Corresponding behaviors for the indenter traverses outwards from the center of weld zone was observed as shown in figures 4.

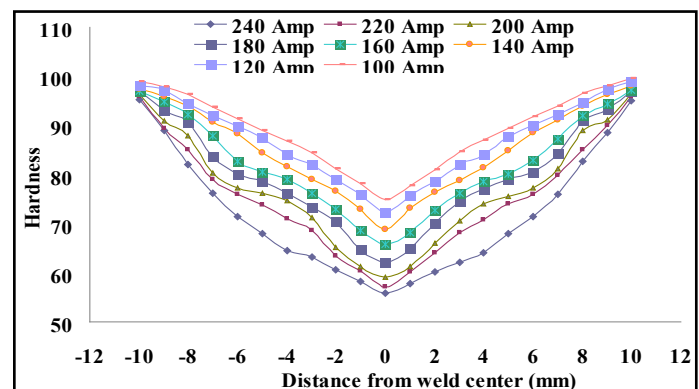


Fig. 4: Effect of AC (from 100 to 240 Amp) on Micro Hardness

The micro hardness for specimen made at low current 100 Amp varied from 75 to 99.6 VHN and at high current 240 Amp varied from 55.8 to 95.2 VHN, showing increasing trend from center of nugget to base metal. This trend was followed in all the conditions, the Table 2 shows the values of lowest hardness and highest hardness for all the conditions. The hardness for low current is high, which is due to the fact that cooling rate is higher in compare to high current where high heat. The hardness of the nugget zone was found to be significantly lower than the base alloy for all the conditions. The reason for this trend may be due

to the high cooling rate due to steeper thermal gradients near the base metal forming fine grained and towards the center of the nugget cooling rate is low due to low thermal gradient and may lead to coarse grained [10].

Table No. 2 Lowest and Highest Hardness for All Conditions

Current	240 Amp	220 Amp	200 Amp	180 Amp	160 Amp	140 Amp	120 Amp	100 Amp
Lowest Hardness (VHN)	55.8	57.1	59.1	62.1	65.9	68.9	72.4	75
Highest Hardness (VHN)	95.2	96	96.5	97	97.2	98	99	99.6

B. Effect of Current on Micro Structure

Microstructures of weld metal under different current inputs were viewed and captured with an optical microscope coupled with an image analyzing software. Optical micrographs showing the microstructures of weld zone for different current input are presented from fig. 5 to fig. 11. It is observed from these optical micrographs that as heat input increases the dendrite size and inter dendritic spacing in the weld metal also increase. This dendrite size variation can be attributed to the fact that at low heat input, cooling rate is relatively higher due to which steep thermal gradients are established in the weld metal, which in turn allow lesser time for the dendrites to grow, whereas at high heat input, cooling rate is slow which provides ample time for the dendrites to grow farther into the fusion zone [8].

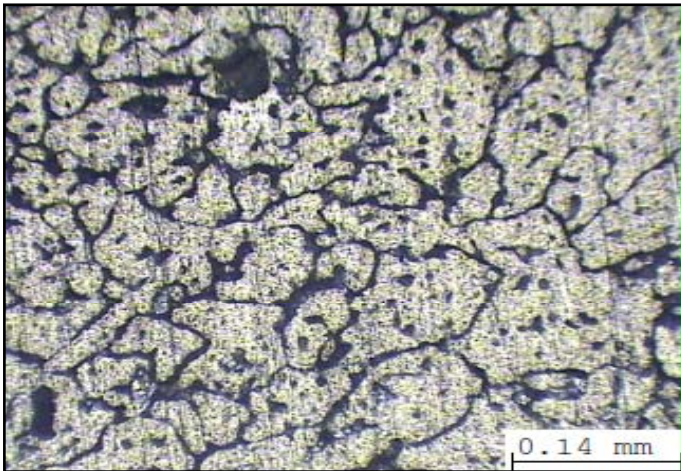


Fig. 5: Effect of AC (100 Amp) on Microstructure of Weld Metal

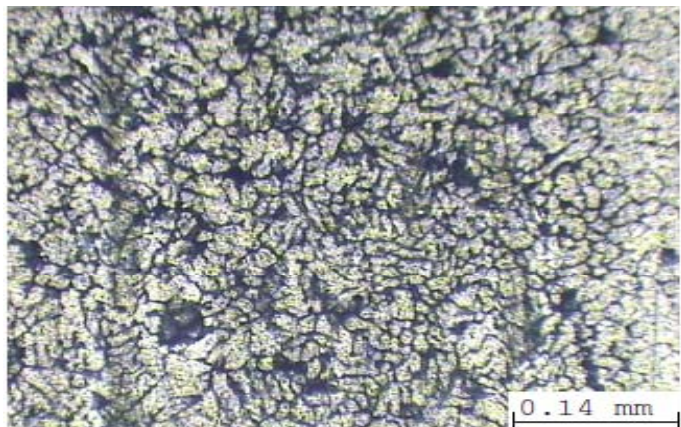


Fig. 6: Effect of AC (120 Amp) on Microstructure of Weld Metal

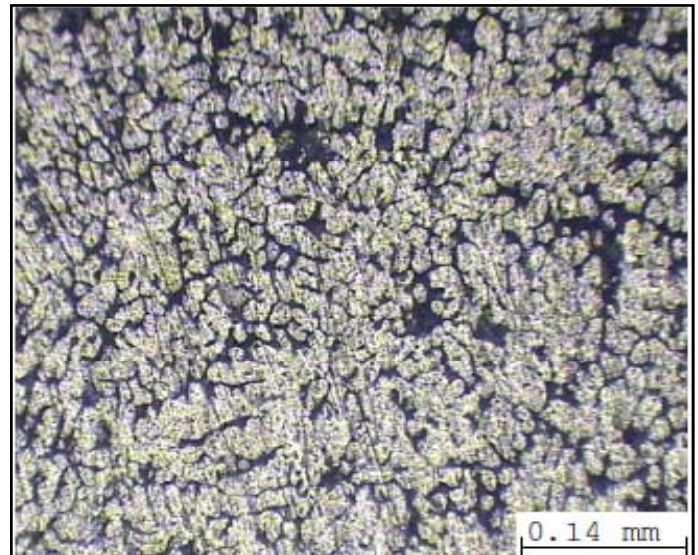


Fig. 7: Effect of AC (140 Amp) on Microstructure of Weld Metal

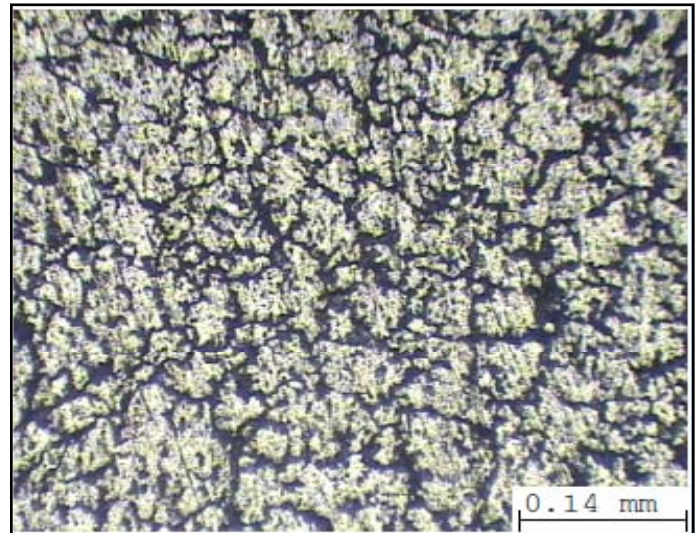


Fig. 8: Effect of AC (160 Amp) on Microstructure of Weld Metal

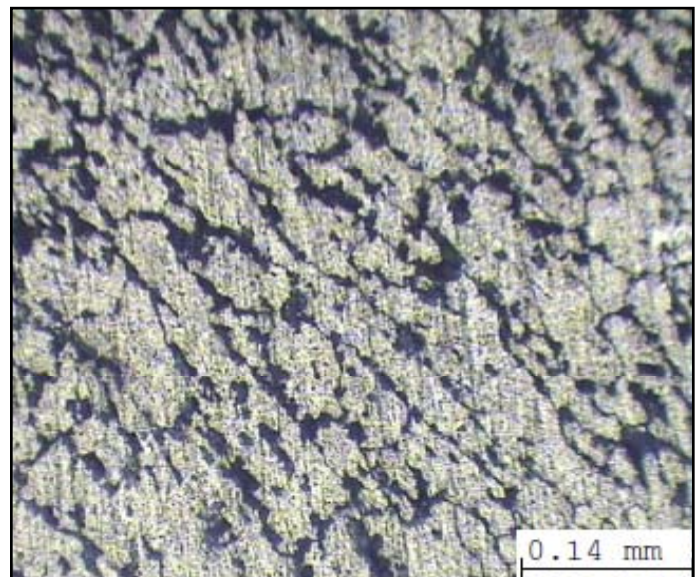


Fig. 9: Effect of AC (180 Amp) on Microstructure of Weld Metal

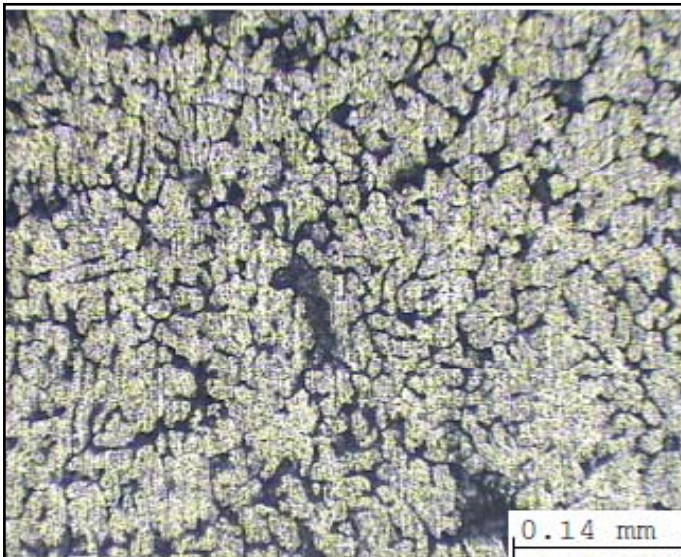


Fig. 10: Effect of AC (200 Amp) on Microstructure of Weld Metal

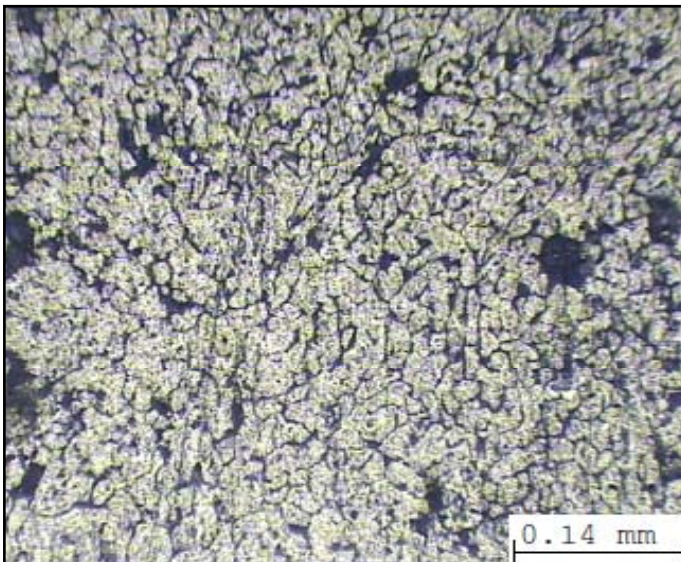


Fig. 11: Effect of AC (220 Amp) on Mof Weld Metal

IV. Conclusion

1. It was also observed that a fine interdendritic network of aluminum with much of the Mg_2Al_3 eutectic (dark) precipitates near grain boundaries were present. Similar trends have been observed in the literature.
2. Micro structure and SEM of the specimen with current 140 A is the evidence of higher tensile strength due to fine grain and uniform dimples.
3. The hardness at low current was high and as it decreases as the current increases, more over hardness was low at nugget and towards base metal it increases.
4. Based upon the present study it is recommended that 140 Amp current best for TIG welding of 6082 aluminum alloy.

References

- [1] Gene Mathers, "The welding of aluminium and its alloys".
- [2] P.Cavaliere, A.Santis, F.Panella, "Thermoelasticity and CCD analysis of crack propagation in AA6082 friction stir welded joints", *International Journal of Fatigue* 31, 2009, pp. 385–392.
- [3] A.Kumar, S.Sundarrajan, "Optimization of pulsed TIG welding process parameters on mechanical properties of

AA 5456 Aluminium alloy weldments", *Journal of Materials and Design* Vol. 30, 2009, pp. 1288–1297.

- [4] A. Cabello Munoz, G. Ruckert, B. Huneau, X. Sauvage, S. Marya, "Comparison of TIG welded and friction stir welded Al–4.5Mg–0.26Sc alloy", *Journal of materials processing technology* Vol. 197, 2008 pp. 337–343.
- [5] A. Scialpi, L.A.C. De Filippis, P. Cavaliere, "Influence of shoulder geometry on microstructure and mechanical properties of friction stir welded 6082 aluminium alloy", *Journal of materials and design* Vol. 28, 2007, pp. 1124–1129.
- [6] S.Missori, A.Sili, "Mechanical Behavior of 6082-T6 aluminium alloy welds", *Journal of Metallurgical science and technology*, Vol. 18, 2000, pp. 12–17.
- [7] P.Cavaliere, A.Squillante, F.Panella, "Effect of welding and microstructural properties of AA 6082 joints produced by friction stir welding", *Journal of materials processing technology* 200 (2008) pp. 364–372.
- [8] T. Senthil Kumar, V. Balasubramanian, M.Y. Sanavullah, "Influences of pulsed current tungsten inert gas welding parameters on the tensile properties of AA 6061 aluminium alloy", *Journal of Materials and Design* Vol. 28, 2007, pp. 2080–2092.
- [9] ASTM International E407-07, "Standard practices for microetching metal and alloys".
- [10] Subodh Kumar, A.S. Shahi, "Effect of heat input on the microstructure and mechanical properties of gas tungsten arc welded AISI 304 stainless steel joints", *Journal of Materials and Design*, Vol. 32, 2011, pp. 3617–3623.
- [11] ASM Committee, "Metal Handbook –properties and selection of metals".
- [12] A.Squillac, A.De Fenzo, "A comparison between FSW and TIG welding technique modification of microstructure and pitting corrosion resistance in AA 2024-T3 butt joints", *Journal of Materials Processing Technology*, Vol. 152, 2004, pp. 97–105.
- [13] A. Loukus, G.Subhash, "Mechanical properties and micro structural characterization of extrusion weld in AA6082-T4", *Journal of Materials science*, Vol. 39, 2004, pp. 6561–6569.
- [14] P.M.G.P.Moreria, T.Santos, S.M.O.Tavares, "Mechanical and Metallurgical Characterization of friction stir welding joints of AA6061 with AA6082-T-6", *Journal of Materials and Design* Vol. 30, 2009, pp. 180–187.
- [15] R.K. Gupta, S.V.S. Narayan Murty, "Analysis of crack in aluminium alloy AA2219 weldment", *Engineering Failure Analysis* 13, 2006, pp. 1370–1375.
- [16] Wang Rui, Liang Zhenxin, Zhang Jianxun, "Experimental Investigation on Out-of-Plane Distortion of Aluminum Alloy 5A12 in TIG Welding", *Journal of Rare Metal Materials and Engineering*, Vol. 37, 2008, pp. 1264–1268.