International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 04, April-2016

Experimental Investigation on Weldability Aspects of Aluminium 6063 Alloy using Friction Stir Welding and Gas Tungsten ARC Welding

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Abstract- **In the present study aluminium 6063 plates were used to evaluate its weldability properties by using two different welding processes such as Friction stir welding (FSW) and Gas tungsten arc welding (GTAW). For both base metal and weld bead tensile properties and Vickers hardness values were evaluated as per ASTM standards. It is found that the ultimate tensile strength in both welding processes significantly decreased as compared to base metal. The Vickers hardness values of welded samples in both welding processes increased marginally. The above mechanical properties were correlated by using optical microscopy.**

Keywords-Aluminium 6063 alloy; tensile strength; Vickers hardness

I. INTRODUCTION

Aluminium alloys known to possess excellent corrosion resistance and significant lower density than other competing alloys of similar mechanical performance. To take advantage of these promising features in structural applications, methods of joining aluminium alloys must be thoroughly investigated and understand to maximize this structural capabilities of these aluminium alloys.

Welding is a process of joining two similar or dissimilar metals (usually metals) through localized coalescence resulting from a suitable combination of temperature, pressure and metallurgical conditions [1]. Depending upon the combination of temperature and pressure, a wide range of welding processes, like-gas welding, arc welding, resistance welding, solid state welding, thermo-chemical welding and high energy beam welding, have been developed. All these welding processes result different weld bead profiles and angular distortions to weld-pieces as governed by the inherent characteristics of process and processing parameters. Al-Mg-Si alloys have been used extensively in the fabrication of aerospace, automotive and marine components due to their superior mechanical properties such as low density, high strength/weight ratio, excellent weldability [2]. Amongst Al alloys, Al-Mg-Si (6XXX) alloys have got further preference in industrial applications as these alloys contain very fewer amount of alloying elements (0.4 to 0.9 wt.% Mg and 0.2 to 0.6wt.% Si) which makes them cheaper than other series like AlCu (2XXX) and Al-Zn (7XXX) alloys [3]. Al alloys of the 6000 series are known to have good formability, corrosion resistance, weldability, and high strength-to-weight ratio.[4-6].Still worldwide research and continous efforts are going on to increase the weldability properties of aluminium alloys. It is well known that 46% of aluminium alloys used for various applications is in the form of sheets and plates [7].

GTAW is one of the most important joining technologies in welding of aluminium alloys. High-quality weld joints without spattering and slags qualify this welding technology for the major part of metals. As the filler-metal supply is separated from the arc, the molten pool can be controlled in the best way possible - an advantage which ensures the quality of the execution of the weld but entails a relatively low deposition rate and welding speed [8].

Friction stir welding (FSW) is one of the solid-state joining technique and widely applied to aluminium alloys [9, 10]. During FSW process, the material undergoes intense plastic deformation at elevated temperature, resulting in generation of fine and equiaxed recrystallized grains [11-15]. As FSW has been widely used to join aluminium alloys, it may be developed as a viable route to join especially high strength non-weldable series (AA2xxx, AA6xxx, and AA7xxx), which are susceptible to solidification cracking in the weld zone and liquation cracking in the heat affected zone (HAZ) [16].

II. EXPERIMENTAL

A. Materials:

In the present investigation, plates of 6 mm thick aluminium 6063 were used as base material. The spectroscopy analysis was performed on the samples to know the basic chemical composition is silicon (0.26%), ferrous (0.34%), copper (0.009%), manganese(0.017%),magnesium (0.60%), chromium (0.006%), zinc (0.028%), titanium (0.024%), aluminium (98.76%).

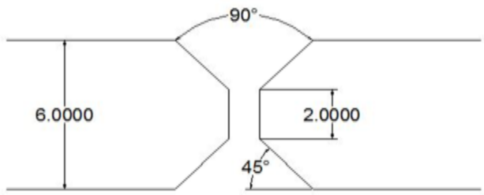

Fig. 1. Double V groove used for GTAW(all dimensions are in mm)

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B. Specimen preparation:

The test specimens of 6mm thickness were welded using GTAW with a double V groove as shown in the figure 1. The non-pulsed GTAW was used on both the specimens with the same filler material. The filler material have melting point less than that of the parent metal and are more elastic than the parent metal therefore they prevent cracking. The as received samples were directly used for FSW.

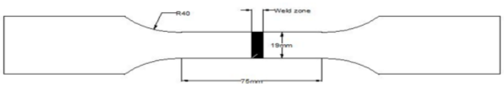

Fig. 2. Specimen geometry for tensile test

C. Mechanical property evaluation

1) Tensile test:

All the tensile properties were evaluated as per the ASTM standard A370-2013. The tensile test specimen configuration is shown in Fig. 2 .The specimens were carefully machined using a wire cut electrical discharge machine. The test was carried out using a MCS 60 UTE-60 universal testing machine. The properties like ultimate tensile strength, percentage of elongation, proof stress and load were determined by using load displacement data obtained during the test.

2) Microstructure

In order to identify the variation of properties in base metal, weld regions both in FSW and GTAW, microstructure analysis was carried out as per the ASTM standard E 407. For both the welded specimen the microstructure analysis were carried out at the fracture zone.

3) Hardness

The standard Vickers hardness test was conducted on both weld regions as well as parent metal according to the standard specified by IS 1501:2002.This test was carried out using diamond indenter and load applied is equal to 5 kgs.

III. RESULTS AND DISCUSSIONS

A. Tensile test

The tensile strength was evaluated for all the materials i.e. Al 6063 grade 'O' base material, weld bead specimens of GTAW and FSW. Table I clearly shows that the base material is having significantly high ultimate tensile strength as compared to that of weld bead specimens. This value is 67% high as compared to GTAW specimen and nearly 120% higher than FSW specimen.

Load vs displacement data of base metal are given in Fig 3. The graph clearly reveals that after attaining peak load, a stable crack extension takes place before the failure of the specimen. In the case of GTAW and FSW weld beads the material fails immediately after attaining peak load. This clearly shown in fig4 and 5, a sudden load drop took place immediately after the ultimate load. The sudden failure of both the weld beads is due to the brittle nature of material at weld bead.

TABLE I. TENSILE TEST DATA OF SPECIMENS

SPECIMEN	**ULTIMATE LOAD KN**	**ULTIMATE TENSILE STRENGTH N/mm^2**	**ELONGATION %**	**0.2% PROOF STRESS N/mm^2**
BASE	9.480	124.852	25.700	75.837
GTAW SPECIMEN	8.520	74.145	--------	--------
FSW SPECIMEN	6.480	57.764	--------	--------

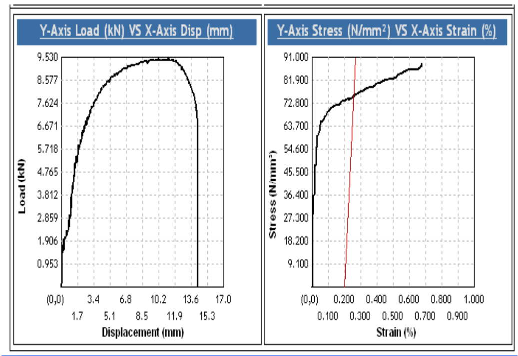

Fig. 3. Load vs displacement and stress vs strain data of base metal

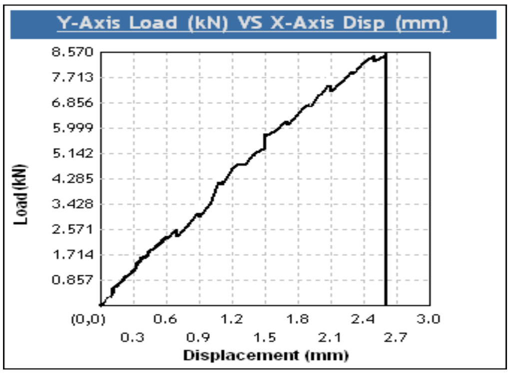

Fig. 4. Load vs displacement data of GTAW weld bead

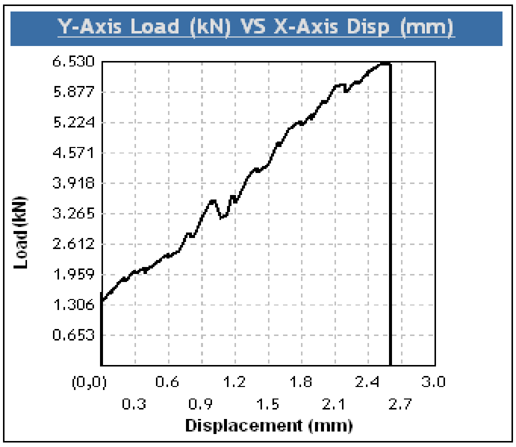

Fig. 5. load vs displacement data of FSW weld bead

B. Hardness

Vickers hardness values are evaluated for all the three specimens (base metal, GTAW weld bead,FSW weld bead).The result shows that GTAW weld bead hardness is marginally higher as compared to that of base metal and FSW weld bead.The hardness values are presented in Table II.

TABLE II. VICKERS HARDNESS DATA OF SPECIMENS

Base	**FSW weld bead**	**GTAW weld bead**
53.90 HV	56.07 HV	64.53 HV

C. Microstructure

All the above mechanical properties were correlated by using optical microscopy. The GTAW weld bead microstructure clearly shows finer grains as compared to other two materials.So this is one of the prime reason for having higher hardness. The base material and FSW weld bead hardness values are almost similar due to the same grain size in both the cases .GTAW weld bead microstructure results in finer grains because of post heat treatment process, where higher cooling rates were employed. In both the materials at weld region the microstructure consists of fine and coarse intermetallic particles of Mg-Si-Fe aligned in the direction of stirring in the matrix of aluminium. The base metal microstructure fig6 consists of fine intermetallic particles of Mg-Si-Fe in the matrix of aluminium. For the purpose of comparision all the microstructural images were taken at same magnification i.e. at 200X (Fig 6, 7 and 8).

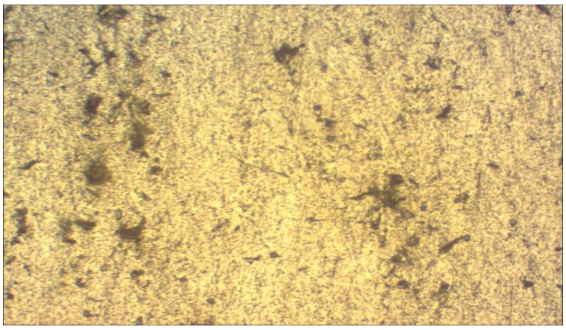

Fig. 6. Microstructure of base metal

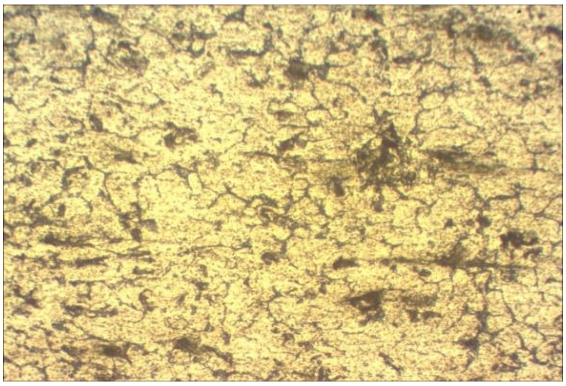

Fig. 7. Microstructure of GTAW weld bead

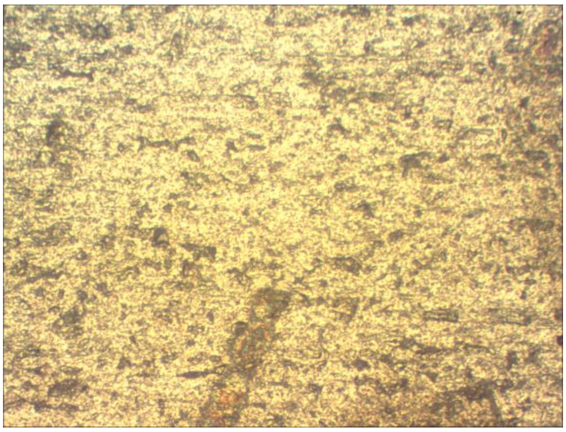

Fig. 8. Microstructure of FSR weld bead

IV. CONCLUSIONS

GTAW and FSW welding process have investigated the weldability aspects of aluminium 6063 alloy. These welding process have been used in the investigation for their effect on microstructure, hardness, tensile properties. The hardness value of GTAW bead specimen shows higher value as compared to FSW and base metal, so this may be due to the equiaxial fine grain microstructure in weld region. The base material tensile strength values are significantly greater as compared to GTAW and FSW specimens. The lower value in weld bead specimen is due to the post weld heat treatment. From this experimental investigation, it has been concluded that GTAW technique is most suitable for this aluminium 6063 alloy.

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International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 04, April-2016

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