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Evaluation of Mechanical Properties of FSW Al 2014 T4 & Al 6061 T6 Alloys

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***Abstract* – Friction Stir Welding (FSW) is fairly a recent technique that uses a non-consumable rotating welding tool to generate frictional heat and plastic deformation at the welding location while the material is in solid state. The principal advantages are low distortion, absence of melt related defects and high joint strength. Tool design and material plays a vital role in addition to the important parameters like tool rotational speed, welding speed and axial force. Friction Stir Welding (FSW) is a solid state welding process to join materials by generating frictional heat between a rotating tool and materials being welded. It was invented at The Welding Institute (TWI), Cambridge (U.K.) in 1991. Since then FSW has become a major joining process in the aerospace, railway and ship building industries especially in the fabrication of aluminium alloys. It is difficult to weld the aluminium alloys, using arc welding, gas welding and other welding processes. Friction Stir Welding on the other hand, can be used to join most Al alloys and better surface finish is achieved. Although the work piece does heat up during friction stir weld, the temperature does not reach the melting point. In this research work, rotational speed and traversing speed was considered for friction stir welding butt joint of Al alloy 2014 T4 & 6061 T6 alloys and further mechanical properties such as tensile strength, Vickers hardness and micro structure was studied.**

***Keywords:* Friction Stir Welding, Aluminium alloys, Microstructure, Tensile strength, Vickers hardness.**

I. Introduction

Friction stir welding is a solid state joining technique invented in 1991 by the Welding Institute [1],[2]. Welding is highly reliable and efficient metal joining process [3]. FSW is a new joining process, which used frictional heat generated between rotational tool and material. It allows metals, including aluminium, lead, magnesium, steel, titanium, and zinc copper and metal matrix composites to be welded [4]. The process of Friction Stir Welding has been widely used in the aerospace, shipbuilding, automobile industries and in many applications of commercial importance[6]. FSW joints have improved mechanical properties and are free from porosity or blowholes compared to conventionally welded materials. Aluminium alloys are the alloys in which aluminium is the base material and elements like Mg, Zn, Cu, Ti, Si and Fe are the alloying elements which improve and enhance the mechanical properties of the alloy. Today aerospace concepts need reductions in both the weight as well as cost of production of materials. So in these conditions, welding processes play an important role and programs have been set up to study their potential [7]. FSW is solid state joining process with encouraging results in several industrial fields. Applications of this process are being used in the automotive, aerospace, ship building, and railroad industries [8]. This process of the tool traversing along the weld line in a plasticized tubular shaft of metal results in severe solid state deformation involving dynamic recrystalization of the base material [9]. FSW method is gorgeous for joining high strength aluminium alloys since there is far lesser heat input throughout the process compared with conventional welding processes such as TIG or MIG [11], [12], [13] which include being a single step course, use of simple and reasonably priced tool, no more time consuming, no finishing process requirement, less processing time, use of accessible and readily available machine tool equipment, suitability to automation, flexibility to robot use, being energy efficient and environmental friendly [14].

II. Preparation Of Sample

Aluminium Al 2014 T4 and Al 6061 T6 alloys are mostly used in industrial applications due to its moderately high strength, light weight and very good resistance to corrosion makes it highly suitable in various structural, building, marine, machinery, process-equipment applications. Theoretical and actual chemical composition of Al 2014 T4 and Al 6061 T6 are shown in Table I. FSW of dissimilar aluminium alloys Al 6061 & Al 2014 with transverse and rotational speed 45mm/min, 60 mm/min and 1650 rpm, 1950 rpm respectively for the tool have been undertaken in the present study. The aim of present work is to investigate on the mechanical and micro structural properties of dissimilar 2014 and 6061 aluminium alloys joined by FSW. In the present work, the effect of welding parameters on the micro structure and mechanical properties of friction stir welded butt joints of dissimilar aluminium alloys has been undertaken.

Table I Chemical Compositions of Al 2014 & Al 6061

	Al	Cr	Cu	Mg	Mn	Si	Zn	Fe	Ti
Al 2014 (Theo.)	90.4-95	0.1	3.9-5	0.2-0.8	0.4-1.2	0.5-1.2	Max. 0.25	Max. 0.7	Max. 0.15
Al 2014 (Actual)	95.1	0.002	2.88	0.31	0.4	0.86	0.15	0.18	0.12
Al 6061 (Theo.)	95.8-98.6	0.4-0.35	0.15-0.4	0.8-1.2	0.5	0.4-0.8	Max. 0.25	Max. 0.7	Max. 0.15
Al 6061 (Actual)	97.5	0.038	0.14	0.67	0.35	0.91	0.18	0.12	0.10

The plates were prepared with 100×50×6.5 mm dimensions with chemical compositions. The friction stir welding process was performed on a CNC universal milling machining. The specially designed fixture was clamped on bed of CNC universal milling machining. The tool was mounted on the vertical spindle. Then two prepared aluminium pieces were clamped into the fixture. Then the rotating tool was made to penetrate into the butt joint. Then after some time, when there was sufficient heating was produced due to friction between tool and plates, the bed was given automatic feed, along the joint direction. Thus the welding was achieved. After that the pieces were cut into the samples of required dimensions for performing the tensile tests, micro structure and Vickers hardness tests.

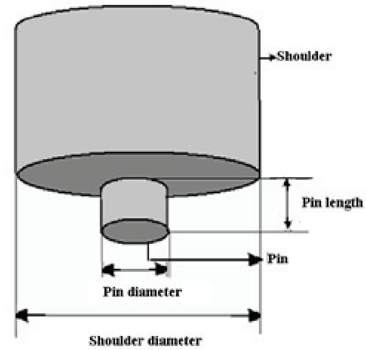
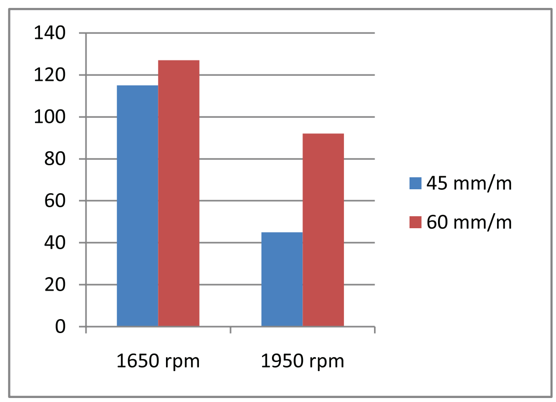


Fig. 1 Tool Geometry

III. Result

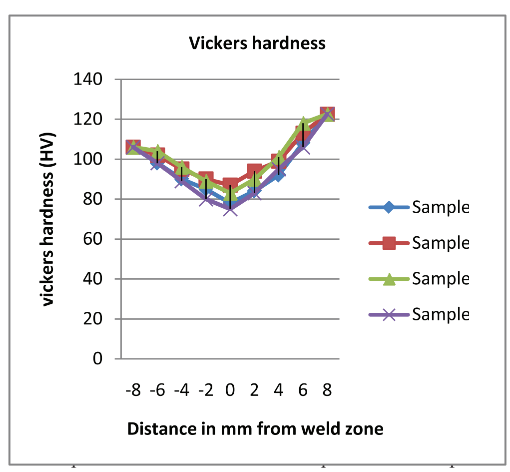
Tensile Strength

Tensile strength (in N/mm^2) of samples is shown in following graph 1.



Vickers Hardness

Vickers hardness of samples at various points is shown in graph 2.



Microstructure

Welding parameters have significant effect on microstructure. At low rotational speed heat generated is less, which is not sufficient to make plastic flow of metal in the weldment causing poor mechanical properties. With the increase in tool rotation speed, high heat is generated, which increases the width of HAZ and reduces the cooling rate. This results in coarse microstructure. However with increase in traversing speed, heat input decreases and cooling rate increases, which produce fine microstructure, as shown in following figures.

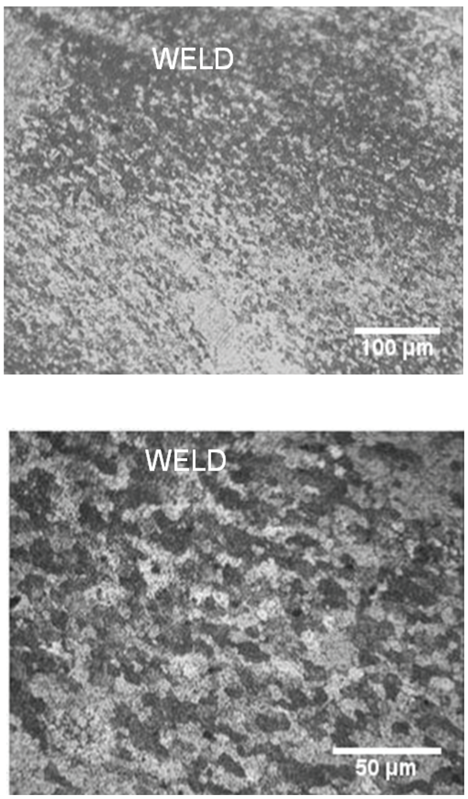
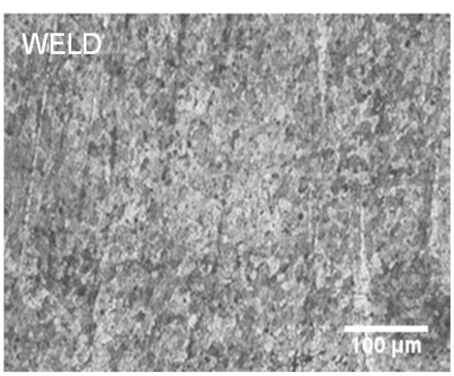
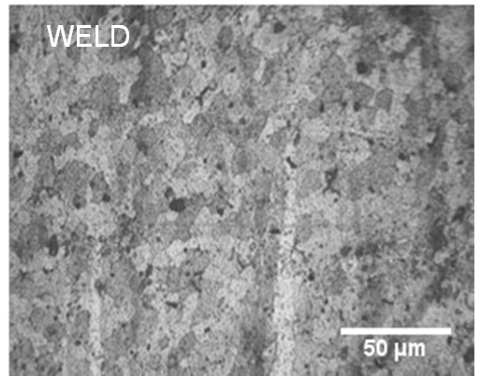


Fig. 2 Microstructure of weld zone (sample 1)



(b)

Fig. 3 Microstructure of weld zone (sample 2)



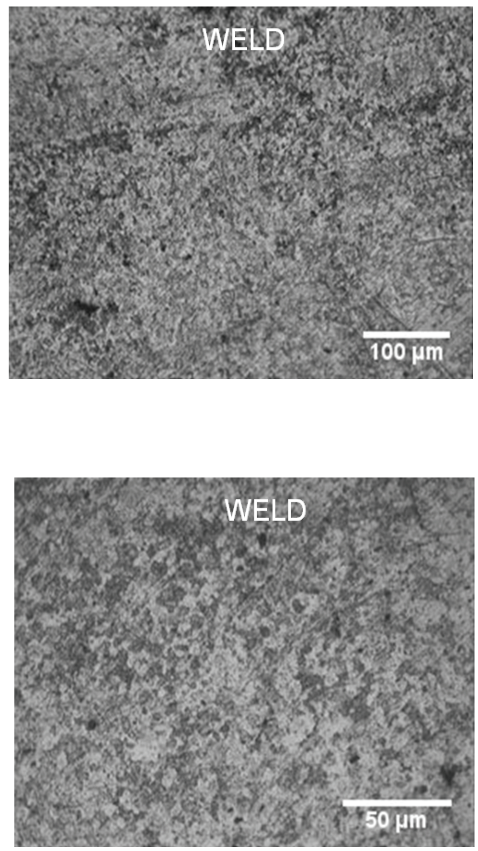
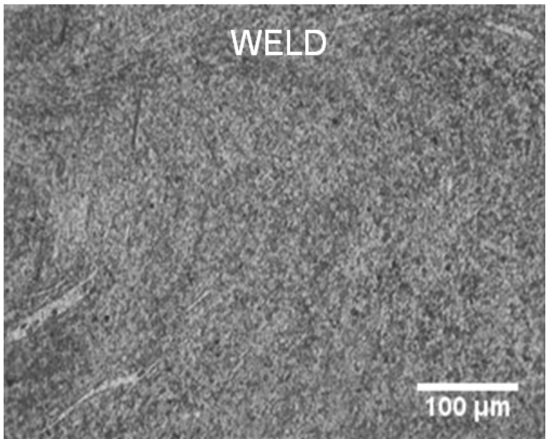
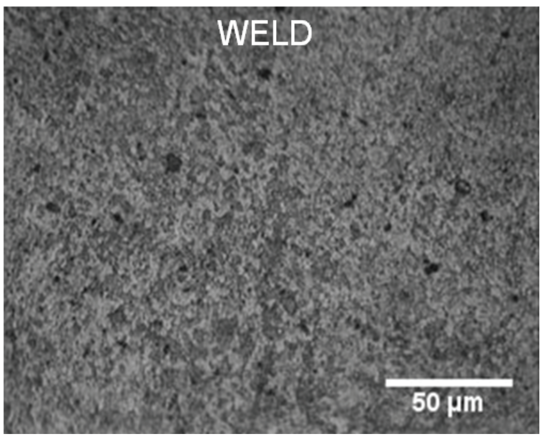


Fig. 4 Microstructure of weld zone (sample 3)

(a)





IV. Conclusion

Following are the conclusions for the study:-

- Base metals Al 2014 T4 and Al 6061T6 were successfully welded by Friction Stir Welding without any breakage and deterioration of the tool.
- The developed Microstructure of the stir zone shows uniform fine grains but in the base metal grains were bit elongated.
- The Tool rotational speed was found to be the most important parameter affecting mechanical and metallurgical properties of the dissimilar weldment.
- With the increase in tool rotational speed, heat input increases resulting in larger heat affected zone and coarse grain structure, which resulted in low ultimate tensile strength.
- Also with the increase in rotational speed as coarse microstructure is developed a decrease in hardness is observed.
- The high welding speed results in low heat input which improves the cooling rate, leaving a fine grained structure having increased ultimate strength.
- Fine microstructure results in increased hardness.

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