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Preliminary experimental evaluation of friction Stir welding of dissimilar aluminium alloys

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Abstract: Friction-stir welding (FSW) is a solid-state joining process and used to join light alloy metals, which finds various industrial applications in aerospace, automotive and ship building, etc. Obtaining the required range of the parameters in friction-stir welding is essential for ensuring defect free and high strength welded joints. This paper presents the various process parameters used to find the mechanical and micro structural properties of friction stir welded components.

Keywords:FSW.microhardness, microstructure, tensile strength

Introduction

Aluminium alloy AA6061-T6 is a precipitation hardening alloy containing magnesium and silicon as its major alloying elements. [1] It has good mechanical properties and exhibits good weldability. In a conventional welding process, aluminium alloys are typically classified as 'difficult to weld' [2]. The difficulty is often attributed to the solidification process and structure – including loss of alloying elements and presence of segregation and porosities [3]. Friction stir welding (FSW) offers an alternative through solid-state bonding, which eliminates all these problems of solidification associated with the conventional fusion welding processes [4]. The different microstructural aspects include grain structure evolution, texture development, temperature distribution, recrystallization mechanisms, precipitation phenomena, etc. These factors also influence the strength and quality of the FS welds which are assessed in various environments. These works are in regard to the effects of FSW parameters on weld quality,[5,6] sheet formability after FSW,[7,8,9] and optimization of the FSW process.[9,10,12,13] On the other hand, FSW is also an excellent technique for joining the dissimilar materials. This is especially very practical in joining the dissimilar aluminium alloys to take advantage of deferent properties of deferent alloys. Fusion welding of Al alloy creates voids, hot cracking, and distortion in shape, precipitate resolution and loss of work hardening.FSW processing generates a softened region within the weld zone because of the dissolution of strengthening precipitates [14]. For non-heat treatable Al alloys, softening is not observed, when alloys are not sensitive to strain hardening [15]. Alloys exhibit softening in weld zone owing to decrease in dislocation density [16]. Most of the earlier studies on friction stir welding of similar type of Al alloys are confined in evaluating stirring zone microstructure, micro-hardness and bond strength [16, 17]. Reports are also available on the friction stir welding of dissimilar Al alloys. Shigematsu et al. joined cold rolled 5083 with 6061 Al alloy by FSW under varying rpm and traversing speed of tool [18]. Highest bond strength has been reported to be 63% of that of 6061 Al alloy. In a different endeavour, Al 2024 Plate was joined with AA2014 + 20 vol% Al2O3 composite under constant rpm and traversing speed [19]

Experimental work

For this setup, sheets of AA6061-T6 and AA5083-O 150mm long, 100mm wide and 6mm thick, were selected for butt- welding process. The chemical compositions and the mechanical properties of the base alloys are presented in table 1. The welding was carried out in load controlled friction stir welding equipment. The tools used for the process were made out of high speed steel, having a cylindrical geometry with a pin length of 5.7mm, pin diameter of 6 mm, and a shoulder diameter of 18mm.The FSW trials were carried out under variable tool rotating and traversing speeds . The different parameters of the rotation peed and the welding speeds range from 500rpm- 700rpm and 15 – 20mm/m respectively. Their profiles of the tools are tapered threaded and cylindrical threaded.

Table 1: Base metal composition

Element	**Cr**	**Cu**	**Fe**	**Mg**	**Mn**	**Si**	**Ti**	**Zn**	**Al**
AA 5083-O	0.05	0.10	0.40	4.90	0.40	0.40	0.15	0.25	Bal
AA6061-T6	0.04	0.15	0.35	0.8	0.15	0.4	0.15	0.25	Bal.

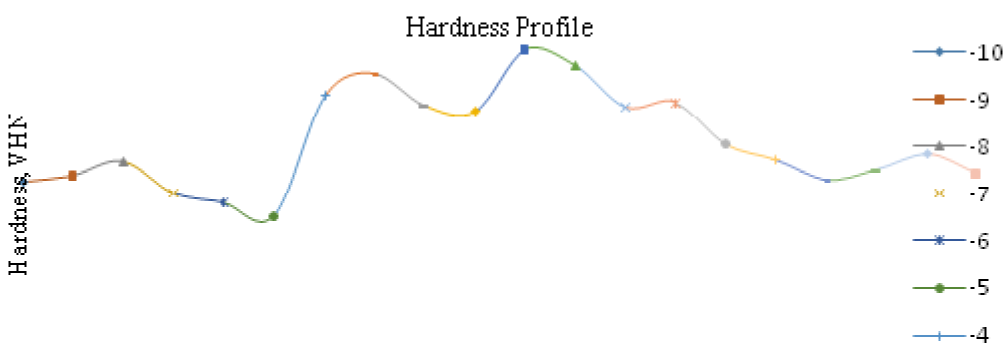
Table 2: various process parameters used for fsw

	Weld	**Tool**	**Rotation speed (rpm)**	**Welding speed (mm/m)**	**Force (kN)**
1	6061 T6- 5083-O	Tapered cylinder	500 550 600	20	4.3 3.8 3.3
2			650	20	4.6
3			700	20	5.3
4		Tapered	600	15	4.9
5	5083-O-6061 T6		600	20	5.4
6	6061 T6- 5083-O	Tapered	600	20	5.4
7	6061 T6-5083-O	Threaded	600	20	5.4
8		Threaded	700	20	5.4
9		Threaded	550	20	1.9
10			550	10	6.4
11			600	18	7
12		Tapered	600	18	4.4

Results and discussions

Micro Hardness Survey

Micro hardness test was performed with a light load of 1 gram, although the majority of micro-hardness tests are performed with loads ranging 100 gram to 500 gram. The degree of accuracy can be estimated by the surface smoothness of the specimen tested. As the test load decreases, surface finish requirements become more rigid. At a load of 100 grams or less a metallographic, finish is recommended. For this investigation a smooth load of 500 gram was applied using a diamond-shaped indenter in the form of a square base pyramid having an angle of 136 degrees, without impact and was held in place for 15 seconds. Micro-hardness was measured from the weld center to the base metal on both sides. Microstructure examinations were carried out using optical microscope to quantify various the micro constituents present in the weld metal. Final polishing was done using a diamond compound having a 1µm particle size in a disc-polishing machine. Samples were etched using Keller’s reagent. Microstructure analysis was carried out using VERSAMET-3 light optical microscope with Clemex-vision image analyzing system and the resulting optical micrographs of the weld zone were recorded



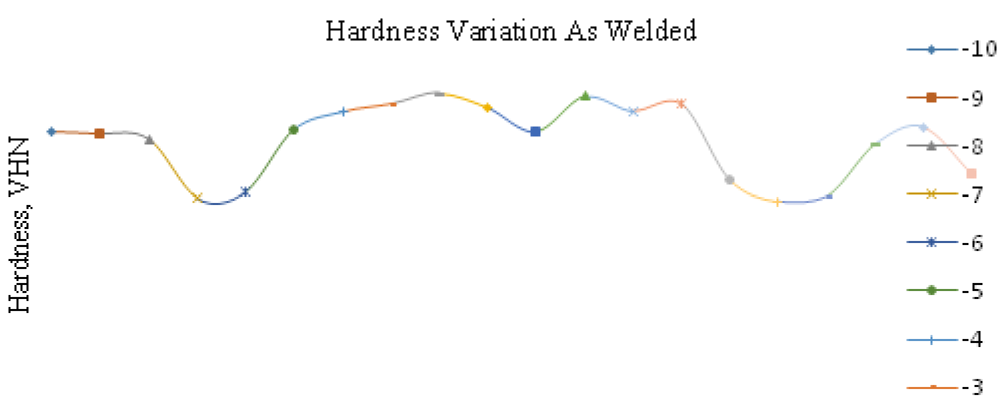
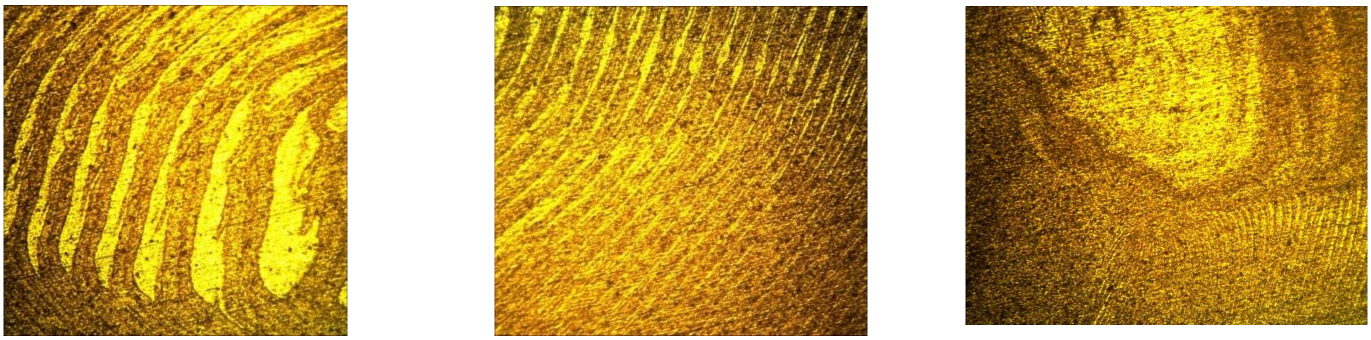


Figure 1: Hardness Profile

Microstructure

The optical micrographs of the fusion zone/nugget region of all the joints are displayed in Fig . This deformation leads to the formation of very fine equiaxed recrystalized grains with in the friction stir processed zone.Various dislocations with network structure observed in the recrystalized grains.A high density of dislocations with network structure observed in many grains.FSW process imparts a large degree of plastic deformation to the work piece by the mechanical stirring action of a rotating tool. Previous reasearchers have reported that This deformation leads to the formation of very fine equiaxed recrystalized grtains with in the friction stir processed zone.various dislocations with network structure observed in the recrystalized grains.A high density of dislocations with network structure observed in many grains.Hence, the tensile properties of FSW joints is superior.



(a) **INTERFERE ZONE 5083-O** **(b) INTERFERE ZONE 6061-T6** **(c) WELD REGION**

Figure:.2 Optical Micrograph images of Weld Zone

Conclusions

The mechanical and metallurgical properties of Friction Stri Welded joints dissimilar AA 5083-O and 6061-T6 are evaluated in detail and compared and following conclusions derived from the investigation.The tensile properties of welded joints AA 5083-O and 6061-T6 aluminium alloy joints are influenced by welding process and post weld aging treatment.A reasonable increase in tensile properties has been attained for the post weld aged joints as compared to as welded joints. Even though, the PWHT procedure is time consuming and costlier, it is advantageous to apply for the welds due to above improvements in tensile properties. Grain refinement with fine distribution of precipitates shows better strength and ductility in FSW joints.FSW joints excellent mechanical properties Micro Hardness is relativley lower in the Heat affected zone and higher in the weld region. The micro hardness values are high in the weld region of FSW joints .Moreover, the joints exhibited superior mechanical and metallurgical properties.

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