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FRICTION STIR WELDING OF DISSIMILAR ALUMINUM ALLOYS AA6061 - AA7075

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Abstract:

Friction Stir Welding (FSW) is a successful solid state welding technology for Aluminum and many other materials. FSW produces low cost and high quality joints without a need of filler materials by eliminating welding defects such as crack and porosity. FSW is widely adopted in different industry field to join different metallic alloy that are hard to weld by conventional fusion welding. The process is also very robust, being insensitive to environmental conditions unlike many traditional welding processes. In this study, the dissimilar joining of Aluminum alloys AA6061 and AA7075 by frictionstir welding process is discussed. Experimental study was done by selecting different process parameters such as tool speed of 1000 rpm, 1500rpm and different traverse speeds of 25mm/min, 50mm/min in dissimilar joints. Microstructural and mechanical properties of the welded samples were investigated and arrived at optimized process parameters for the better weldmentof dissimilar aluminum alloy plates of thickness 6mm.

Key Words: Frictionstir Welding, Dissimilar Aluminum Alloys & Optimized Process Parameters

Introduction:

FSW has proved to be successful solid state welding technology for Aluminum and many other materials.FSW was invented by The Welding Institute (TWI),Cambridge, UK in 1991 [14, 15].FSW produces low cost and high quality joints without a need of filler materials by eliminating welding defects such as crack and porosity. FSW is widely adopted in different industry field to join different metallic alloy that are hard to weld by conventional fusion welding. The process was first used at NASA to weld the super light weight external tank for the space shuttle [16]. FSW offers a variety of advantages over traditional welding process, such as applied to all major Aluminum alloys it avoids problems of hot cracking, porosity, element loss etc. which are common to Aluminum alloys. No shielding gas or filler wire is required for Aluminum alloys. The application suitable for rail, marine, aerospace as well as automotives. The process is also very robust, being insensitive to environmental conditions unlike many traditional welding processes. It is used for applications where the original metal characteristics must remain unchanged as far as possible.

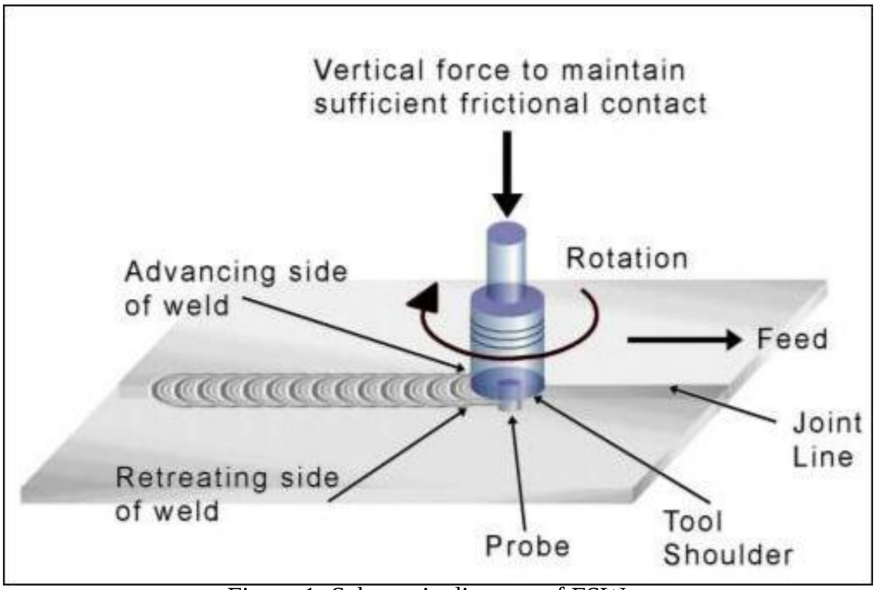

Figure 1: Schematic diagram of FSW

The principal features are shown in Fig.1. A rotating tool is pressed against the surface of two abutting or overlapping plates. The side of the weld for which the rotating tool moves in the same direction as the traversing direction, is commonly known as the advancing side, the other side, where tool rotation opposes the traversing direction, is known as the retreating side. An important feature of the tool is a probe (pin) which protrudes from the base of the tool (the shoulder), and is of a length only marginally less than the thickness of the plate. Frictional heat isgenerated, principally due to the high normal pressure and shearing action of the shoulder. Friction stir welding can be thought of as a process of constrained extrusion under the action of the tool. The frictional heating causes a softened zone of material to form around the probe. This softened material cannot escape as it is constrained by the tool shoulder. As the tool is traversed along the joint line, material is swept around the tool probe between the retreating side of the tool (where the local motion due to rotation opposes the forward motion) and the surrounding unreformed material. The extruded material is deposited to form a solid phase joint behind the tool. The process is by definition asymmetrical, as most of the deformed material is extruded past the retreating side of the tool. The process generates very high strains and strain rates, both of which are substantially higher than found in other solid state metalworking processes like extrusion, rolling, forging, etc.

Chemical Composition of AA6061 and AA7075:

Table1: Chemical composition of AA6061and AA7075

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
AA6061	0.8	0.7	0.40	0.15	1.2	0.35	0.25	0.15	Bal
AA7075	0.06	0.18	1.3	0.04	2.5	0.18	5.9	0.07	Bal

Methodology:

A rotating cylindrical tool with a profiled probe is fed into a butt joint between two clamped workpieces, until the shoulder, which has a larger diameter than the pin, touches the surface of the work pieces. The probe is slightly shorter than the weld depth required, with the tool shoulder riding atop the work surface. After a short dwell time, the tool is moved forward along the joint line at the pre-set welding speed. Frictional heat is generated between the wear-resistant tool and the work pieces. This heat, along with that generated by the mechanical mixing process and the adiabatic. Heat within the material, cause the stirred materials to soften without melting. As the tool is moved forward, a special profile on the probe forces plasticized material from the leading face to the rear, where the high forces assist in a forged consolidation of the weld. 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 recrystallization of the base material. A non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of sheets or plates to be joined and traversed along the line of joint. The tool serves two primary functions: (a) heating of work piece, and (b) movement of material to produce the joint. The heating is accomplished by friction between the tool and the work piece and plastic deformation of work piece. The localized heating softens the material around the pin and combination of tool rotation and translation leads to movement of material from the front of the pin to the back of the pin. As a result of this process a joint is produced in 'solid state'. Because of various geometrical features of the tool, the material movement around the pin can be quite complex. During FSW process, the material undergoes intense plastic deformation at elevated temperature, resulting in generation of fine and equiaxial recrystallized grains. The fine microstructure in friction stir welds produces good mechanical properties.

Tool Selected:

Table 4: Tool Specification

Material	Shoulder Diameter	Pin Length	Pin Diameter
Di- Steel	30mm	6mm	6mm

Welding Parameters:

Table 5: Welding Parameters

S.No	Material	Transverse Speed (mm/min)	Rotation Speed (RPM)
1	AA6061+AA7075	25	1000
2	AA6061+AA7075	50	1000
3	AA6061+AA7075	25	1500
4	AA6061+AA7075	50	1500

Experimental Setup:

Friction Stir Welding can be done in 3-Axis or 5-axis setup. Friction Stir Welding of AA6061 and AA7075 were done with a 3 axis FSW setup. Aluminum 7075 was selected as advancing side and Aluminum 6061 as retreating side of two abutting metal plates for the selected tool and welding parameters.

Figure 2: (a) & (b)

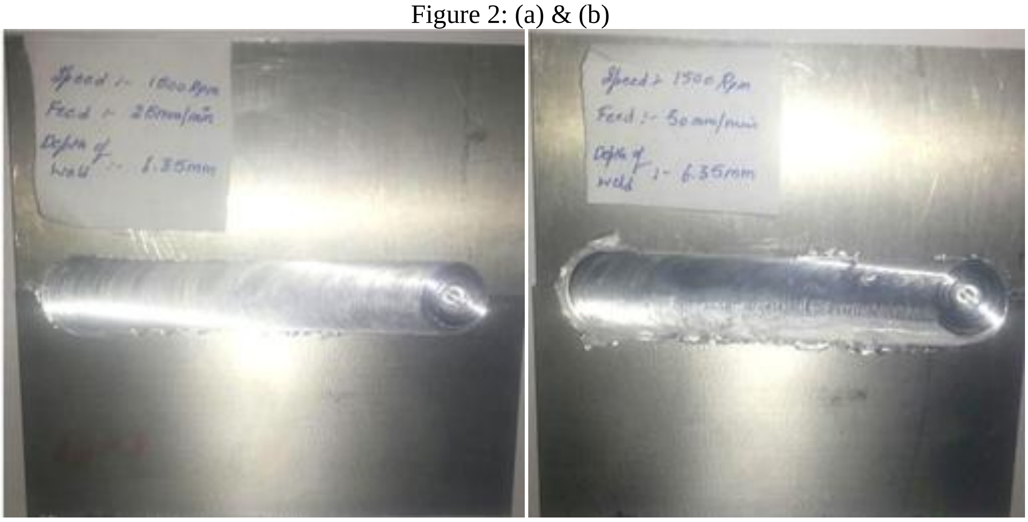

Figure 2: (c) & (d)

Figure 2: (a) 1000rpm, 25mm/min (b) 1000rpm, 50mm/min (c) 1500rpm, 25mm/min (d) 1500rpm, 50mm/min welded samples

Micro Vickers Hardness Test:

Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a compressive force is applied some materials (e.g. metals) are harder than others (e.g. plastics). Macroscopic hardness is generally characterized by strong intermolecular bonds but the behavior of solid materials under force is complex. Indentation hardness is one kind. The Vickers test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness. The basic principle, as with all common measures of hardness, is to observe the questioned material's ability to resist plastic deformation from a standard source. The Vickers test can be used for all metals andhas one of the widest scales among hardness tests. The unit of hardness given by the test is known as the Vickers Pyramid Number (HV).

Scanning Electron Microscopy:

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the sample's surface topography and composition. The electron beam is scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image. SEM can achieve resolution better than 1 nanometer. Specimens can be observed in high vacuum in conventional SEM, or in low vacuum or wet conditions in variable pressure or environmental SEM and at a wide range of cryogenic or elevated temperatures with specialized instruments.

Sample Preparation:

Aluminum plates that are welded are cut into 30mm*7mm*7mm that covers weld region as well as heat affected zone. These metal pieces are well polished using polishing paper of 1000p, 1200p, 1500p, 2000p, in the same order. The final polishing is done using velvet cloth. To view the clear grain structure in black and white etching is done using Keller’s Etching Reagent.

Keller's Etching Reagent:

Table 6: Keller's etching reagent

S.No	**Chemical**	**Quantity**
1	Methanol	50ml
2	Hydrochloric acid	50ml
3	Nitric acid	50ml
4	Hydrofluoric acid	1 drop

After the etching reagent is prepared, the specimens are dipped in the reagent for approx. 6-7 seconds with the polished surface facing up. Soon after the specimen are washed carefully and completely using distilled water and dried using dryer. And carefully wrapped in aluminium foil to avoid oxidation. Then SEM is carried out.

Results and Discussions:

Micro Vickers Hardness Test:

The hardness of the weld specimens were tested using Vickers hardness testing machine across and at the cross section of the weld. The results are obtained and the average value gives the Vickers pyramid number (HV) of the specimen.

Table 7: Vickers Hardness number for welded specimens

S.No	Welding Parameter	Vickers Hardness Number
1	1000RPM & 25mm/min	154
2	1000RPM & 50mm/min	161
3	1500RPM & 25mm/min	92
4	1500RPM & 50 mm/min	183

Scanning Electron Microscope (SEM):

The Scanning electron microscopy is conducted for the specimens that are treated with etching reagent (Keller's reagent). The results obtained are given below.

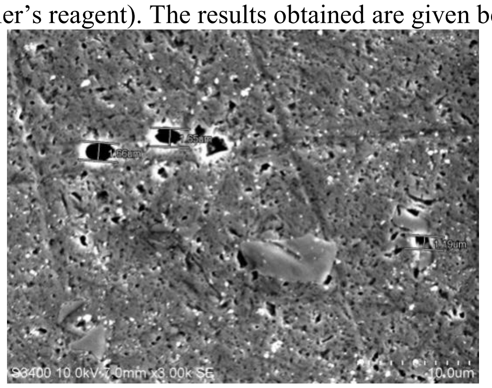

Figure 3: SEM image of 1000RPM & 25mm/min specimen

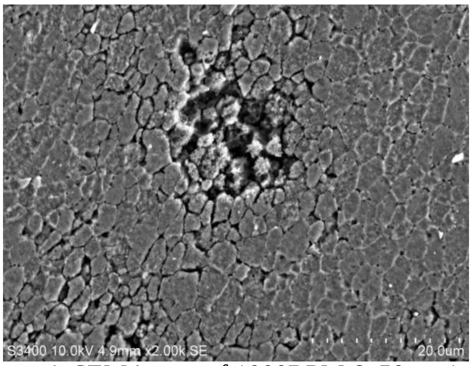

Figure 4: SEM image of 1000RPM & 50mm/min specimen

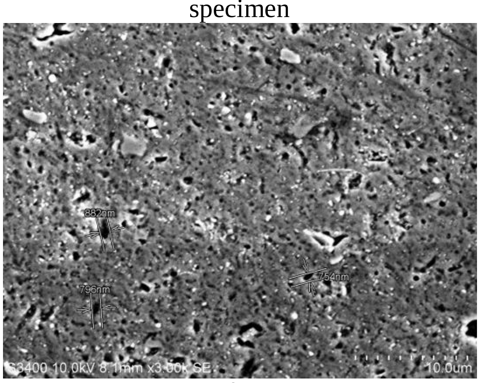

Figure 5: SEM image of 1500RPM & 25mm/min

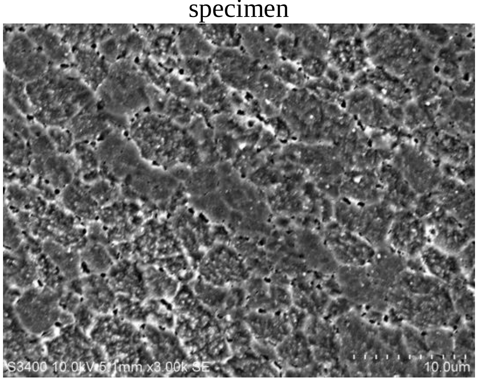

Figure 6: SEM image of 1500RPM & 50mm/min

Discussions:

Table 8: Comparison of results for different welding parameters

S.No	Welding Parameters	HV	Grain Structure
1	1000RPM,25mm/min	154	Coarse
2	1000RPM,50mm/min	161	Fine
3	1500RPM,25mm/min	92	Coarse
4	1500RPM,50mm/min	183	Fine

From various test conducted on different welded parameters, each specimen has different results in each test. But the specimens carry out for 1000RPM-50mm/min and 1500RPM-50mm/min. process high hardness value.

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Conclusion:

The current work proved that it is feasible to join dissimilar aluminum alloys of AA6061 and AA7075. It is observed that a good weldment is obtained by optimized experimental process parameters of 1000RPM-50mm/min and 1500RPM-50mm/min. It is resulted that the hardness of the welded region is better than the base metal. Furthermore very fine dispersed IMCs in Aluminium highly rich matrix was observed in the FSW joint stirred zone with a fine grain structure.

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