Investigating Mechanical Properties of FSW Dissimilar Joints of AA6061 and AA6063 utilizing Taguchi method

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Abstract—
In this study, friction stir welding is a solid-state thermo-mechanical joining technique. Friction stir welding uses butt welding to examine fusing different aluminium alloys like AA6061 and AA6063. These welding processes employ various speeds and feeds. We can weld metals as needed by controlling speed and feed. We must first put the metals' advancing and retreating sides on a vice. The tool is placed at one end of the metal plate first. We must offer the metal plate 6 mm depth. High-speed tool steel (H13) feeds 40, 60 mm/min and speeds 800, 1000, 1200, and 1400 rpm at the end of the operation. Then the metals will be fully welded. To measure tensile, impact, and surface roughness at various distances from the joint weld bead centerline. The joint's tensile and impact strengths were maximum when welding (FSW) with the highest welding speed and tool rotating speed and AA6061 plates on the advancing side. Metal welding is utilized in aerospaceship construction and manufacturing..

Index Terms— *Friction Stir welding (FSW);*

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I. INTRODUCTION

It is a solid-state joining process (the metal is not melted) which uses a third body tool to join two facing surfaces. Heat is generated between the tool and material which leads to a very soft region near the FSW tool. Friction Stir welding (FSW) is a welding technique invented by the welding Institute (TWI) in 1991 (Cary H.B., 1979) [1] FSW true welding process. FSW is a derivative of conventional friction welding. The FSW process involves the translation of a rotating cylindrical tool along the is actually a solid state joining process that is a combination of extruding and forging and is not a interface between two plates. The weld is formed by the deformation of the material at temperatures below the melting temperature. The properties of the metal in the joined area are higher than those from any other known welding process and distortion is virtually eliminated (WeisheitA at all,1998, Juttner, 1998). FSW uses a cylindrical, shouldered tool with a profiled pin that is rotated and slowly plunged into the joint line between two pieces of sheet or plate material, which are butted together. The plates comprising the work piece are held in compression and are rigidly fixed to the machine bed during welding. Friction stir welding uses rotating tool that is cylindrical in shape with a cylindrical pin of smaller diameter extending from the tool shoulder. Initially, the rotating tool is plunged into the joint until the shoulder contacts the top surface of the work piece. Heating is caused by rubbing of the tool faces against the work piece and by viscous-plastic dissipation of mechanical energy at high strain rates developed through interactions with the tool. During welding, the material along the joint is heated to a softened condition transferred around the periphery of the tool and subsequently recoaleseed along the back surface of the pin to produce the weld. The depth of penetration is controlled by the length of the probe below the shoulder of the tool. The initial plunging friction contact heats the adjacent metal around the probe as well as a small region of material underneath the probe, but once in contact with the top surface of the job, the shoulder contributes significant additional heat to the weld region.

II. Literature Review

This joining technique is energy efficient, environment friendly and versatile. In particular, it can be used to join high-strength aerospace aluminum alloys and other metallic alloys that are hard to weld by conventional fusion welding. FSW is a solid-state process which produces welds of high quality in difficult-to-weld materials such as aluminium, and is fast becoming the process of choice for manufacturing lightweight transport structures. **[**2**]** Revealed that the position of the materials affects the dissimilar material properties and quality, which mainly depends on properties of two materials and the welding parameters. It is reasonable to believe that the location of the materials in FSW of dissimilar alloys could lead to more severe temperature asymmetry. This asymmetry in temperature, stress and materials flow between the advancing and retreating sides could significantly affect the dissimilar joint quality and properties, which mainly depends on the properties of the two materials and the welding parameters such as tool rotation speed, travel speed and positions of the materials. It was reported that only a portion of material transported from the leading edge undergoes chaotic flow and sound joints without defects can only be obtained when the weld interface is on the advancing side. **[**3] Investigated the effects of various process parameters including tool pin profile, tool rotational speed, and welding speed on mechanical properties of the dissimilar joints between AA2024 and AA5083 Al alloys. They reported that dissimilar joints fabricated using tapered hexagon tool pin profile have the highest tensile strength and tensile elongation, whereas the straight cylinder tool pin profile have the lowest tensile strength and tensile elongation. However, the increase in the tool rotational speed or welding speed led to increase in tensile strength initially and then decrease after reaching a maximum value. [4] investigated Dissimilar AA6061 and AA7075 alloy have been friction stir welded with a variety of different processParameters. In particular, the effects of materials position and welding speed on the material flow, microstructure, micro hardness distribution and tensile property of the joints were investigated. It was revealed that the material mixing is much more effective when AA6061 alloy was located on the advancing side and multiple vortexes centres formed vertically in the nugget. Three distinct zones with different extents of materials intercalations were identified and the formation mechanism of the three zones was then discussed. Grain refinement was observed in all three layers across the nugget zone with smaller grains in AA7075 Al layers. All the obtained joints fractured in the heat-affected zone on the AA6061 Al side during tensile testing, which corresponds very well to the minimum values in micro hardness profiles. It was found that the tensile strength of the dissimilar joints increases with decreasing heat input. The highest joint strength was obtained when welding was conducted with highest welding speed and AA6061 Al plates were fixed on the advancing side. To facilitate the interpretation, the temperature history profiles in the HAZ and at zones close to TMAZ were also measured using thermocouple and simulated using a three-dimensional computational model. [5]deals with the development of an empirical relationship to predict tensile strength of friction stir welded AZ61A magnesium alloy. The process parameters such as tool rotational speed, welding speed, axial force and tool pin profile play a major role in deciding the tensile strength. The response surface method (RSM) was used to develop the empirical relationship. The four-factor, five-level central composite design was used to minimize the number of experimental conditions. The developed empirical relationship can be effectively used to predict tensile strength of friction stir welded AZ61A magnesium alloy joints at 95 % confidence level. Friction stir welding of AZ61A magnesium alloy joints shows lower tensile strength at slower rotational speed. **[6]**carried out experiment in FSW to join aluminum alloys AA6061 and AA5052 at various combinations of tool rotation speeds and tool transverse speed. Tensile testing of the specimen was also carried out which showed the good mechanical properties (Tensile properties of the friction stir welded AA5052AA6061 were found better than the properties of the softest of the similar friction stir welded AA6061). It was seen that the interdiffusion of the alloying elements and development of similar orientations in the nugget could have contributed of the better tensile properties of the friction stir welded AA5052-AA6061 specimen. [8] studied that when FSW was performed for dissimilar materials of AA5086 and AA6061 showed that more efficient material mixing was obtained when AA6061 on retreating side and AA5086 on advancing side. [11] studied on friction stir welds between AA 5052 and AA 6061 Al alloys sounds promising, having demonstrated excellent weld ability and performance characteristics. Cylindrical threaded pin has rendered excellent bondage between both alloys (AA 5052 and AA 6061) by effective friction stir joining. Taguchi is a useful technique which, specify the effectiveness of involved parameters. It reduces the repeated experimentation process [12]. The mechanical and metallurgical characterization has shown good agreement which is clearly evident from result obtained.

III. EXPERIMENTATION

FSW Experimental setup is a vertical milling machine 3T capacity. The aluminum alloy plates of 6 mm thickness, AA6061 & AA6063, have been cut into the required size (60x250mm) by power hacksaw cutting. The direction of welding is normal to the rolling direction. Single pass welding procedure has been followed to fabricate the joints. Non-consumable tool made of H13 steel have been used to fabricate the joints. A Friction Stir Welding Machine has been used to fabricate the dissimilar welded joints. Total 8 types of joints were prepared by varying the tool rotational speed with two different weld speed and same tool profile.

Fig.1. Friction stir welding machine setup

The tool is plunging and passing in between the two work piece joint. The two work pieces are arranged in a straight line. The below figure shows the tool is passing in between the work piece. The experimentation was conducted by utilizing Taguchi method.

Table: 1. Level and Factors L8- (4^1 2^4):

Factors/Levels	1	2	3	4
Speed N RPM	800	1000	1200	1400
Feed F mm/min	40	60		

Table: 2.Experimentation Process Taguchi table:

S.No	Material	Speed 'N' Rpm	Feed 'F' Mm/Min
1	AA 6061- AA 6063	800	40
2		1000	40
3		1200	40
4		1400	40
5		800	60
6		1000	60
7		1200	60
8		1400	60

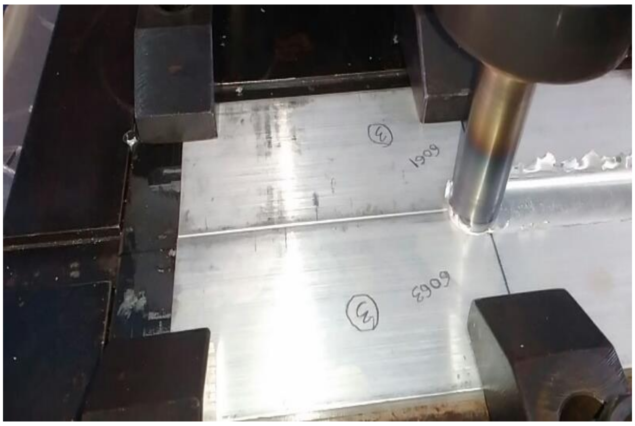

Fig.2.Fsw Tool Is Moving On Fsw Sample Given By CNC Commands

IV. RESULTS AND DISCUSSIONS

1. Tensile Test:

American Society for Testing of Materials (ASTM-E8) guidelines is followed for preparing the test specimens. Test has been carried out in 1 KN, Universal Testing Machine.

Fig.3 Tensile test specimens before testing

Fig.4 Tensile Test Specimens After testing

Table: 3.Tensile Test Results:

S.No	Material	Speed Rpm	Feed Mm/Min	Load Kgf	area mm^2	tensile strength N/mm^2
1	AA 6061-AA 6063	800	40	525	36	143.06
2		1000	40	580	36	158.05
3		1200	40	875	36	238.43
4		1400	40	710	36	193.47
5		800	60	855	36	232.98
6		1000	60	515	36	140.33
7		1200	60	445	36	121.26
8		1400	60	715	36	194.83

From the tensile Test results rotational speed of 1200 rpm and 40 mm/min Feed rate get high tensile strength i.e. 238.43N/mm^2. From the tensile Test results rotational speed of 1200 rpm and 60 mm/min Feed rate get low tensile strength i.e. 121.26N/mm^2.

From the results feed rate increases the tensile strength of the specimen decreases.

2. Surface Roughness Test:

Surface roughness is gauged by the deviations from the normal vector of an actual surface compared to its theoretical framework. When these deviations are substantial, the surface is classified as rough; conversely, minor deviations denote a smooth surface. The evaluation of surface roughness employs the Taly-Surf Experiment setup, which quantifies the roughness of the weld bead in Friction Stir Welding (FSW). Analysis of the outcomes reveals that optimal surface smoothness, at 1.24 micrometers, is achieved under specific conditions: a low rotational speed of 800 rpm and a reduced feed rate of 40 mm/min.

S.NO	MATERIAL	SPEED	FEED	TILT ANGLE	SURFACE ROUGHNESS
1	AA6061-AA6063	800	40	1°	1.24
2		1000	40	1°	5.72
3		1200	40	1°	5.11
4		1400	40	1°	5.08
5		800	60	1°	4.03
6		1000	60	1°	5.22
7		1200	60	1°	6.04
8		1400	60	1°	5.45

Table: 4.Surface Roughness Test Results

S.No	Material	Speed Rpm	Feed mm/min	Resistance recorded without specimen a (N-m)	Resistance recorded with specimen b(N-m)	impacresistance a-b(N-m)
1	AA6061-AA6063	800	40	207.5	194.4	8.5
2		1000	40		191.7	15.8
3		1200	40		192.7	12.5
4		1400	40		195	13.1
5		800	60		194.4	13.1
6		1000	60		178.2	29.3
7		1200	60		179.2	28.3
8		1400	60		196.4	13.6

Table: 5 . Impact Test Results

3. Impact Test:

The ASTM standard method for determining the impact resistance of materials. Various welded of AA (6061 &6063) were tested for impact resistance under charpy testing equipment (i.e., Angle of hammer is of 90 degrees).

The result obtains from charpy test for different alloys are as follows:

6061AA-6063AA: The best magnitude of impact resistance i.e. 29.30 j was obtained at a speed of 1400 rpm and feed rate of 40 mm/min.

V. Conclusions

Aluminium alloys AA6061 and AA6063 are welded in this experimental investigation employing Friction Stir Welding at both room temperatures. These alloys are welded at various rates, including 800, 1000, 1200, and 1400 rpm. To achieve the best results, the parameters speed and feed rate are adjusted.

Based on the above findings and discussions, the following conclusions are reached:

1. When the AA6061 was placed on the advancing side and distinct vortex profiles generated vertically in the nugget core, the material flow became significantly more effective.
2. The welded zones in the friction stir welded joints were greatly softened. The speed of the tool increased from 800 to 1400 rpm.
3. Tensile strength of the weld bead increased with tool speed for dissimilar FSW of AA alloys, and as compared to the placement of AA 6061 on the advancing side, greater tensile strength was reached.

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