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Experimental Investigation of Friction Stir Welding Of Aluminum Aa6061 Alloy Joints Testing

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Abstract : *The combination of wrought aluminum-magnesium-silicon alloy confirming to aluminum AA6061 alloy widely accepted because of light weight fabrication structures, high strength to weight ratio and good corrosion resistance. Friction Stir Welding(FSW) process is an emerging solid state joining process in which the material that is being welded does not melt and recast when compared to fusion welding process that are routinely used for joining structural aluminum alloys. In this FSW process a non consumable tool is used to generate frictional heat in the abutting surfaces. Experiments for surface roughness, Rockwell hardness and tensile tests are carried out and reported in this paper. The base material used for friction stir welding is aluminum AA 6061 alloy. Surface roughness values decreases with the increase in speed of the tool and also there exists an optimum speed to have the good surface finish. Hardness increases with decrease in speed of the tool but increases after reaching a certain value. Tensile strength increases with the increase in speed of the tool and also there exists an optimum values for particular feed of the tool.*

Keywords *- Friction Stir Welding (FSW), Aluminum AA6061 alloy, Surface roughness, Hardness and Tensile strength.*

I. Introduction

The friction stir welding (as shown in figures 1 & 2) is relatively new joining technique invented by The Welding Institute (TWI) in 1991 [1] in which a specially designed rotating pin is inserted first into the adjoining edges of the sheet to be welded with proper tilt angle and then moved all along the joint [2,3,5]. Unlike other traditional fusion welding technique there is no liquid state for the pool [4-8].

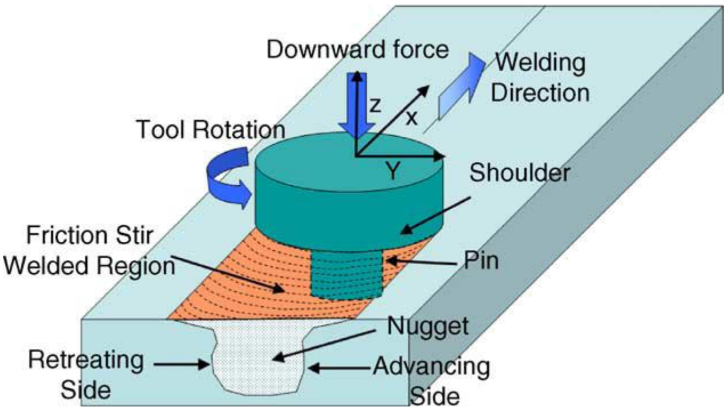

Fig.1. Schematic drawing of FSW process.

Heat treatable wrought Aluminum-Magnesium-Silicon alloys conferring to AA6061 of moderate strength but possessing excellent welding characteristics over the high strength alloys are used [1]. Hence, alloys of this class are extensively employed in pipelines, storage tanks, marine frames and aircraft applications. Although Al-Mg-Si alloys are readily weldable, they suffer from severe softening in the heat affected zone (HAZ) because of reversion (dissolution) of Mg_2Si precipitates during weld thermal cycle [9]. This type of mechanical impairment presents a major problem in engineering design. It will be more appropriate to overcome or minimize the HAZ softening to improve mechanical properties of weldment [10].

In friction stir welding process the material that is being welded does not melt or recast compared to many of the fusion welding processes that are routinely used for joining structural alloys [11]. This welding is a continuous, hot shear, autogenous process involving non-consumable rotating tool of harder material than the substrate material. Good mechanical properties with defect free welds have been made in a variety of aluminum alloys, even those that are not weldable previously [12]. When alloys are friction stir welded, phase transformations that occur during cooling cycle of the weld are of solid state type. Due to the absence of parent metal melting, the new FSW process is observed to offer several advantages over fusion welding.

II. Experimental procedure

2.1 Material

The material used for this research study is aluminum AA 6061 alloy of 150 mm in length, 60 mm in width and 4 mm in thickness. The standard and experimental chemical compositions are listed in Table.1. Mechanical and Physical properties of aluminum AA6061 are presented in table.2 and table.3 respectively.

Table.1 Chemical composition (%) of aluminum AA6061 alloy

Element	AA 6061	
	Standard	Experimental
Si	0.4-0.8	0.56
Fe	0.7max	0.413
Cu	0.15-0.4	0.301
Mn	0.15	0.34
Mg	0.8-1.2	0.8
Cr	0.04-0.35	0.04
Zn	0.2	0.094
Ti	0.2	0.014
Al	Remaining	Remaining

Table.2 Mechanical Properties of aluminum AA6061 alloy

Brinell Hardness	95
Knoop Hardness	120
Vickers Hardness	107
Ultimate Tensile Strength	310 MPa
Tensile Yield Strength	276 MPa
Elongation at Break	17 %
Modulus of Elasticity	68.9 GPa
Poissions Ratio	0.33
Shear Modulus	26 GPa
Shear Strength	207 MPa

Table.3 Physical Properties of aluminum AA6061 alloy

Density	2.7 g/cm^3
Melting Point	582-652°C
Electrical Receptivity	3.99x10^{-6} Ω.cm
Thermal Conductivity	167 W/m.K

Aluminum AA6061 alloy is one of the most widely used alloy in the 6000 series. This standard structural alloy, one of the most versatile of the heat treatable alloy, is popular for medium to high strength requirements and has good toughness characteristics. Application ranges from transportation components to machinery and equipment applications to recreation products and consumer durables.

Aluminum AA6061 alloy has excellent corrosion resistance to atmospheric conditions and good corrosion resistance to sea water. This alloy also offers good finishing characteristics and responds well to anodizing.

It is one of the most common alloys of aluminum of general purpose use. This material is widely used for construction of aircraft structures, such as fuselages. This material is also used for yacht construction, including small utility boats, construction of bicycle frames and components and automotive parts, such as wheel spacers etc.

2.2 Welding Procedure

A vertical axis CNC milling machine is converted into a Friction Stir Welding (FSW) machine with an attachment of work holding fixture for welding. The Specifications of CNC Milling Machine: Vertical Axes CNC 3– Axes Machining Center, Model: BME-45, Spindle Range: 10-6000 rpm, Tool Material: HSS, Movement: 610 X 450 mm and Bed size: 800 X 500 mm.

The two work pieces to be welded, with square mating edges, are clamped on a rigid back plate. The fixture prevents the work pieces from spreading apart or lifting during welding process. The welding tool, consisting of a shank, shoulder and pin is then rotated to a specified speed and oriented normal with respect to the work piece. The tool is slowly plunged into the work piece material at the butt line, until the shoulder of the tool forcibly contacts the upper surface of the material and the pin is at a short distance from the back plate. A downward force is applied to maintain the contact and a short dwell time is observed to allow for the development of the thermal fields for preheating and softening the material along the joint line. At this point, a lateral force is applied in the direction of welding (travel direction) and the tool is forcibly traversed along the butt line, until it reaches the end of the weld. Upon reaching the end of the weld, the tool is withdrawn, while it is still being rotated. As the pin is withdrawn, it leaves a keyhole at the end of the weld. Friction stir welding was used to control local properties in structural metals including aluminum and other nonferrous and ferrous alloys. The pin may have a diameter one-third of the cylindrical tool and typically has a length slightly less than the thickness of the work piece. The pin is forced or plunged into the work piece until the shoulder contacts the surface of the work piece. As the tool descends further, its shoulder surface touches the top surface of the work piece and creates heat. As the temperature of the material under the tool shoulder elevates, the strength of the material decreases.

2.3 Surface Roughness Testing

Roughness is a measure of texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small the surface is smooth. Roughness is typically considered to be the high frequency, short wave length component of a measured surface. Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have high friction co-efficient than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component since irregularities in the surface may form nucleation sites for cracks or corrosion. Although roughness is usually undesirable, it is difficult and expensive to control in manufacturing. Decreasing the roughness of a surface will usually increase exponentially its manufacturing costs. This often results in a tradeoff between the manufacturing cost of a component and its performance in application.

The surface roughness tests were conducted to determine the surface roughness values of aluminum AA6061 alloy friction stir weldments at different rotational speeds and feeds of the tool in a Surface Roughness Tester.

2.4 Rockwell Hardness Testing

The Rockwell scale is hardness scale based on the indentation hardness of material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by preload.

The Rockwell hardness tests were conducted to determine the hardness values of aluminum AA6061 alloy friction stir weldments at different rotational speeds and feeds of the tool in a Rockwell Hardness Tester.

2.5 Tensile Testing

Tensile strength (TS) or Ultimate Tensile Strength (UTS), is the maximum stress that a material can withstand while being stretched or pulled before necking, which is when the specimen’s cross section starts to significantly contract.

The tensile tests were conducted to determine the tensile strength values of aluminum AA6061 alloy friction stir weldments at different rotational speeds and feeds of the tool in Universal Testing Machine (UTM).

III. Results and Discussions

3.1 Surface Roughness Observations

The variation of surface roughness with FSW tool speed by changing the feed rate for aluminum AA 6061 alloy are shown in Fig. 2. From this figure it is clear that at lower rotational speed (800 rpm) surface roughness of the FSW joint is higher. When the rotational speed is increased from 800 rpm, correspondingly the surface roughness also increased and reaches good surface finish (minimum) at 950 rpm. If the rotational speed is increased above 950 rpm, the surface roughness of the joint increased.

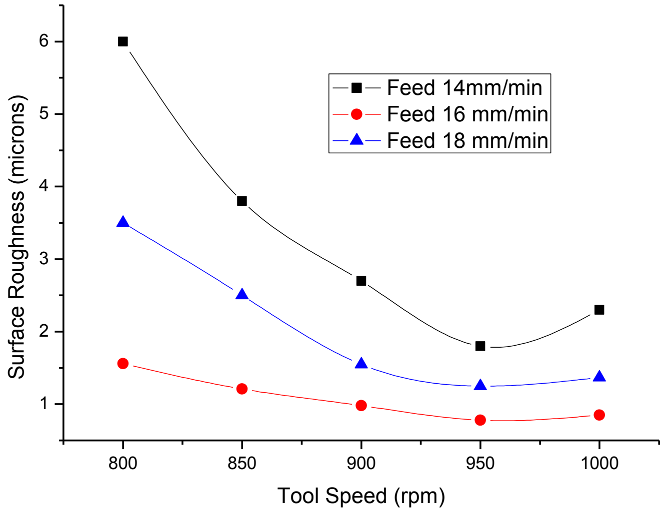

Fig.2. Tool Speed Vs Surface Roughness.

3.2 Rockwell Hardness Test Observations

Fig. 3 reveals the effect of tool speed on hardness of friction stir welded aluminum AA6060 alloy. At lower tool speed (800 rpm) hardness of the FSW joints is lower. When the tool speed is increased from 800 rpm, correspondingly the hardness also increased and reaches maximum at 950rpm. If the tool speed further increased above 950rpm, the hardness of the joint decreased.

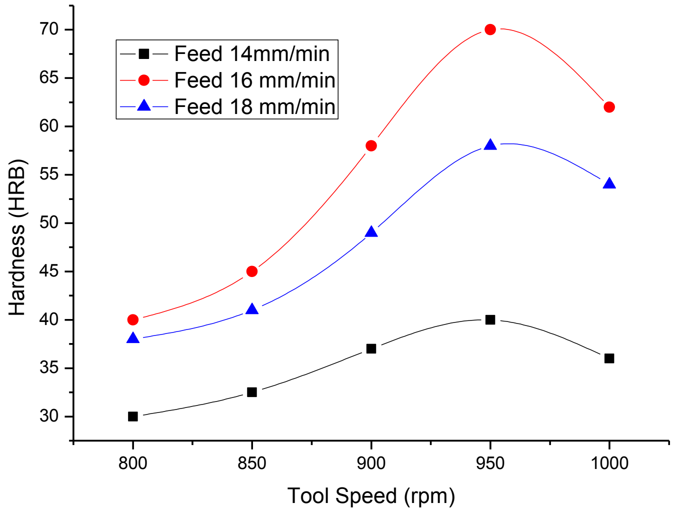

Fig.3. Tool Speed Vs Hardness (HRB)

3.3 Tensile Test Observations

The tensile strength of all the joints is lower than that of the base material, irrespective of the rotational speeds used to fabricate the joints. Out of the five rotational speeds used to fabricate aluminum AA6061 joints, the joint fabricated at a rotational speed of 950 rpm yielded superior tensile properties. Fig. 4 reveals the effect of tool rotational speed on tensile strength of friction stir welded aluminum AA6061 alloy. At lower rotational speed of the tool (800 rpm) tensile strength of the FSW joints is lower. When the rotational speed is increased from 800 rpm, correspondingly the tensile strength also increased and reaches a maximum at 950 rpm. If the rotational speed is increased above 950 rpm, the tensile strength of the joint decreased.

In all the three cases mentioned above i.e., surface roughness, hardness and tensile strength there exist an optimum value for the particular feed rate i.e., 16 mm/min.

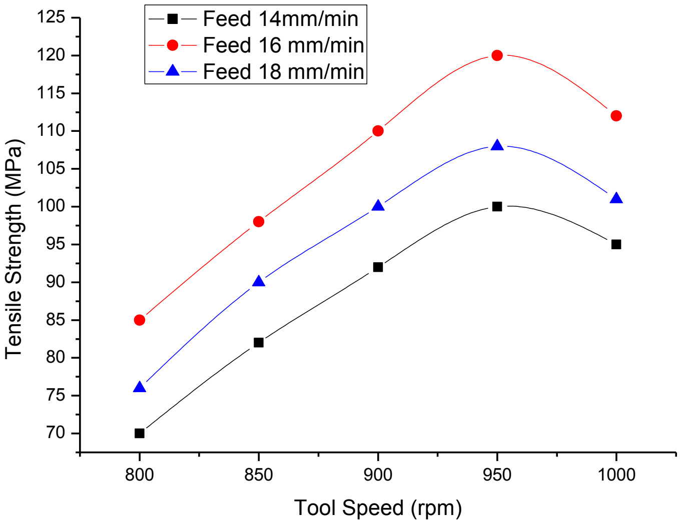

Fig.4. Tool Speed Vs Tensile Strength

IV. Conclusions

1. The results indicated that strong relation between the tool rotational speed and surface roughness values. It is observed that surface roughness decreases with the increase in speed of the tool. It is expected that there exists an optimum speed for aluminum AA6061 alloy to have the good surface finish. After reaching good surface finish value, the surface finish value increases with increase in tool speed.
2. The results related to hardness reveal that there is increase in hardness of weldment with increase in speed of the tool and the value comes down after reaching maximum value.
3. The results between tensile strength and tool speed show that tensile strength increases with increase in speed of the tool and also there exists optimum value for certain speed of the tool.
4. In all the three cases i.e., surface roughness, hardness and tensile strength optimum values exists at a tool speed of 950 rpm and also at 16 mm/min. feed of the tool.

References

[1]. W.M. Thomas, E.D. Nicholas, J.C. Needham, M.G. Murch, P.TempleSmith, C.J. Dawes, The Welding Institute, TWI, International Patent Application No. PCT/GB92/02203 and G.B. Patent Application No. 9125978.8, 1991.
[2]. H. Larson, L. Karlsson, Svensson, Proceedings of International Conference on Aluminum Alloys, vol. 3, 1998, pp. 1471-1476.
[3]. M.M Attalah, H.G Salem, Mater. Sci. Eng. A 391 (2005) 51-59
[4]. M. Peel, A. Steuwer, M. Preuss, et al., Acta Mater. 51 (2003) 4791-4801.
[5]. H.S. Park, T. Kimura, T. Murakami, et al., Mater. Sci. Eng. A, Struct. Mater.: Prop. Microstruct. Process. 371 (1-2) (2004) 160-169.
[6]. T.L Dickerson, J. Przydatek, Int. J. Fatigue 25 (12) (2003) 1399-1409.
[7]. P. Staron, M. Kocak, S. Williams, A. Wescott, Phys. B: Condens. Matter 350 (1-3) (2004) E491-E493 (Supplement).
[8]. A.P. Reyold, et al., Proceedings of the First International Conference on Friction Stir Welds, Thosand Oaks, CA, 1999.
[9]. C.J. Dawes, An Introduction to Friction Stir Welding and its Development, Weld Met Fabrication 1995:12-6.
[10]. W.M. Thomas, E.D. Nicholas, Friction Stir Welding for the Transportation Industries. Mater Des 1997; 18:269-73.
[11]. Ossterkamp A, Djapic Ossterkam L, Nordide A, Kissing bond phenomena in solid state welds of aluminum alloys, Weld J 2004:225s-31s.
[12]. Zeng WM, Wu HL, Zhang J, Effect of tool wear on microstucture , mechanical properties and acoustic emission of friction stir welded 6061 Al alloys, Acta Metall Sinica 2006:19(1):9-19.