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MECHANICAL ASPECTS OF FRICTION STIR WELDED AA1100 ALUMINUM ALLOY JOINT

Engineering

KEYWORDS: Friction Stir Welding, Tool pin profile, Rotational speed, Tensile strength, Hardness

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ABSTRACT

In this experimental work an investigation was carried out on FSW butt joint to measure its tensile strength and hardness. The welded joints were made on AA1100 grade aluminum strips of 5mm thick having chemical composition as Al 99.0%, Si + Fe 1.0%, Zn 0.1%, Sn 0.05%, Mo 0.05%,Cu 0.05%, other elements 0.05% with mild steel tool of different pin profiles. Two different pin profiles viz. straight cylindrical and square were used to fabricate the joints at rotational speed of 2000 rpm. Transverse tensile properties of the weld were evaluated at room temperature of 27°C. Some welded specimens failed in the regions corresponding to HAZ and some failed in the base metal and demonstrated good yield and ultimate strength. Of the two tool pin profiles used in this investigation to fabricate the joints, square pin profile give better weld as compare to straight cylindrical pin profile. Of the 2 joints fabricated in this investigation, the joint fabricated at a rotational speed of 2000 rpm with square pin profile showed better tensile strength than joint welded with cylindrical pin profile. It shows as the contact surface area of pin profile decreases strength of the weld also decreases. Improvement in hardness of friction stir zone is noticed due to refinement of grain size in both the joints.

I. INTRODUCTION

The Friction Stir Welding (FSW) is a solid state joining process invented at The Welding Institute (TWI) in 1991. The ability to produce high quality welds in high strength aluminum alloys sets FSW apart from fusion welding techniques. The process is solid state in nature and relies on the localized forging of the weld region to produce the joint. The plates comprising the work piece are held in compression and are rigidly fixtured to the machine bed during welding. Friction stir welding uses a non consumable, rotating tool that is cylindrical in shape with a cylindrical pin of smaller diameter extended from the tool shoulder. The rotating tool is plunged into the joint until the shoulder contacts the top surface of the work piece. Figure 1 explains the working principle of FSW process. The rubbing of the tool face against the work piece causes heating. During welding the material along the joint is heated to a soften condition, transferred around the periphery of the tool and subsequently recoalesced along the back surface of the pin to produce the weld.

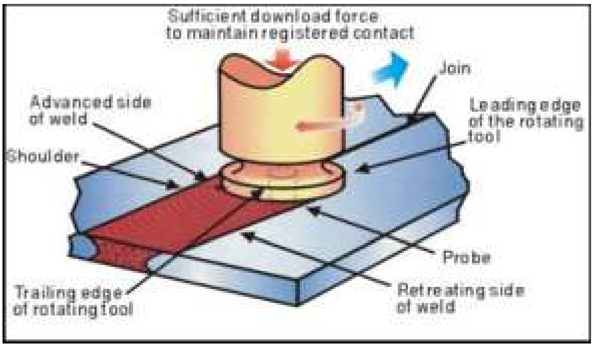


Fig. 1 Schematic representation of FSW principle

Aluminum alloys have gathered wide acceptance in the fabrication of light weight structures requiring a high strength to weight ratio. The preferred welding processes for aluminum alloys are frequently gas metal arc welding (GMAW) and gas tungsten arc welding (GTAW) due to their comparatively easier applicability and better economy. For most of the aluminum alloys, many difficulties are associated with the traditional welding, such as high solubility of gases in the molten state, solidification shrinkages, crack sensitivity and presence of oxide inclusions. It also suffers from poor welded joint strength. The loss of strength is due to the melting and quick re-solidification, which renders all the strengthening precipitates to dissolve and the material is as good as a cast material with solute segregation and large columnar grains.

Compared to many of the fusion welding processes that are routinely used for joining aluminum alloy, friction stir welding (FSW) is an emerging solid state joining process in which the material that is being welded does not melt and recast. The welding parameters and tool pin profile play a major role in deciding the weld quality.

TWI has patented the friction stir welding process and very less information is available. So the present investigation is an attempt to understand the influences of rotational speed and pin profile of the tool on friction stir processed (FSP) zone formation in aluminum alloy.

II. EXPERIMENTAL WORK

The rolled plates of 5 mm thickness, AA1100 aluminum, were cut into the required size (120 mm x 150 mm) by power hacksaw. The composition of the aluminum AA1100 grade is given in Table 1. Butt joint configuration was prepared to fabricate the joints. The initial joint configuration was obtained by securing plates in position using mechanical clamps. The work piece sheets were held on a supporting bar of mild steel having a flat surface with the help of T-bolt clamps and packings on the bed of the machine.

Rotational speed of 2000 rpm for two different tool pin profiles and in total 2 joints (2 x 1) were fabricated by passing the tool pin through the joint. The material used for welding tool is mild steel. Two different tool pin profiles viz. straight cylindrical (SC) and Square (SQ) were used to fabricate the joints. The specifications of the tools are given in Table 2. An initial depression of 0.1 mm to the shoulder of the tool was given to provide sufficient axial pressure. The various process parameters used for the experimentation are given in Table 3 and the process is shown in Figure 2.

TABLE 1 WORK PIECE COMPOSITION

Elements	(<,>,=)	Percentage
Aluminum	>=	99.0
Silicon + Ferrous	<=	1.0
Zinc	<=	0.10
Tin	<=	0.05
Molybdenum	<=	0.05
Copper	<=	0.05
Other Elements	<=	0.05

TABLE 2 TOOL MATERIAL AND DIMENSIONS

Specifications	Values
Tool Material	Mild Steel
Length of tool	60 mm
Tool shoulder diameter	20 mm
Pin diameter	5 mm
Pin length	5.8 mm

TABLE 3 WELDING PROCESS PARAMETERS

Parameters	Values
Rotational Speed	2000 rpm
Welding Speed	20 mm/min
Tool inclined angle	0°
Shoulder deepness inserted into the surface of base metal	0.1 mm

TABLE 4 WELDED SPECIMENS

Sr. No.	Specimen No.	Rotational Speed (RPM)	Tool Pin Profile
1.	S-1	2000	Straight Cylindrical
2.	S-2	2000	Square

Figure 2 Welding Process

The tensile test specimens were prepared according to the guidelines of American Society for Testing of Materials (ASTM) as shown in Figure 3. Tensile test was carried out in 600 KN; electro-mechanical controlled Universal Testing Machine at a room temperature of 27°C. The specimen was loaded at the rate of 1.5 KN/min as per ASTM specifications, so that tensile specimen undergoes deformation. The specimen finally failed after necking and the load versus displacement was recorded. The yield strength, ultimate tensile strength, percentage elongation and joint efficiency were evaluated.

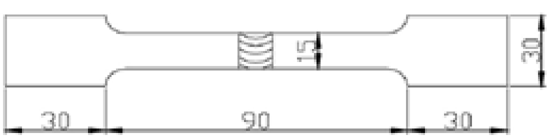


Figure 3 Dimensions of Tensile Specimen

The results of tensile loading of the base metal and welded specimens are shown in Table 5 and Table 6 respectively. The variation of yield strength; ultimate tensile strength, percentage elongation and joint efficiency are shown in Graphs 1- 4 respectively.

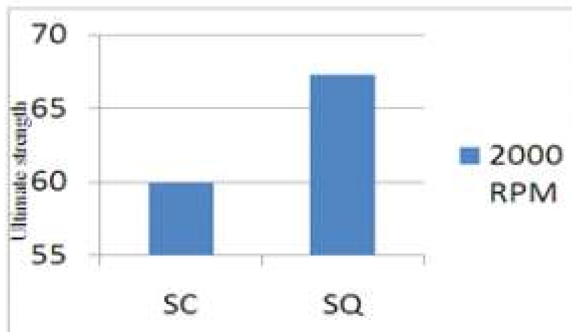
TABLE 5 TENSILE TEST RESULTS OF BASE METAL

Yield Strength	Ultimate Tensile Strength	Percentage Elongation			
Load (KN)	Stress (N/mm^2)	Load (KN)	Stress (N/mm^2)	Breaking Length (mm)	% Elongation
22.8	76	30.6	102	67	34

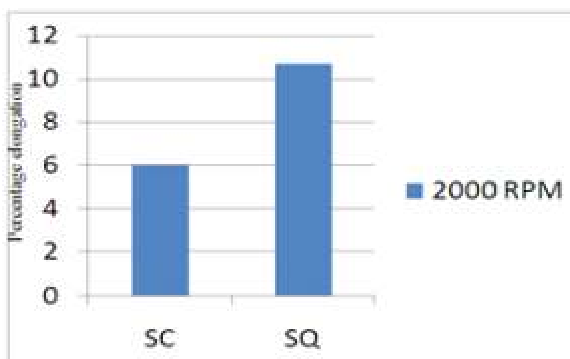
TABLE 6 TENSILE TEST RESULTS OF WELDED SPECIMENS

Specimen No.	Yield Strength		Ultimate Tensile Strength		Percentage Elongation		Joint Efficiency
	Load (KN)	Stress (N/mm^2)	Load (KN)	Stress ($N/m m^2$)	Breaking Length (mm)	% Elongation	
S-1(SC)	8.7	29	18	60	53	6	60
S-2(SQ)	10	33.33	20.2	67.33	56	10.71	67.33

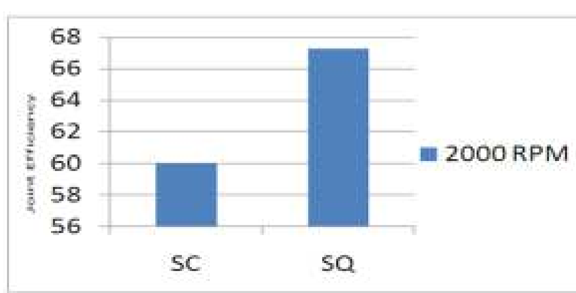
Graph 1 Variation of Yield strength



Graph 2 Variation of ultimate tensile strength



Graph 3 Variation of percentage Elongation



Graph 4 Variation of joint Efficiency

III. DISCUSSION ON TENSILE TESTING RESULTS

Transverse tensile properties of FSW joints such as yield strength, tensile strength, percentage elongation and joint efficiency were evaluated. From the graphs, it can be inferred that the tool profile and tool rotational speed are having influence on tensile properties of the FSW joints. Of the two tool pin profiles used to fabricate the joints, Square tool profile exhibited superior tensile properties compared to other joint.

The yield strength and ultimate strength of the base metal are 76 N/mm2 and 102 N/mm^2 respectively.

The maximum yield strength and ultimate strength in this experimental run are 33.33 N/mm^2 and 67.33 N/mm2 respectively which is obtained using Square pin profile.

The minimum yield strength and ultimate strength in this experimental run are 29 N/mm^2 and 60 N/mm2 respectively which is obtained using cylindrical pin profile.

IV. DISCUSSION ON HARDNESS TESTING RESULTS

Hardness value of friction stir zone is higher than the base metal. Main reason for the improved hardness of friction stir zone because the grain size of friction stir zone is much finer than that of base metal, grain refinement plays an important role in material strengthening. According to the Hall-Pitch equation, hardness increases as the grain size decreases.

V. CONCLUSIONS

In this investigation an attempt has been made to study the effect of tool pin profile and tool rotational speed on the formation of friction stir processing zone in AA 1100 aluminum alloy. From this investigation, the following important conclusions are derived:

I. Welded specimens failed in region corresponding to the THAZ and the base metal and demonstrated good yield and ultimate strength.

II. Of the two tools pin profiles used in this investigation to fabricate the joints, square pin profile tool give better weld.

III. Of the 2 joints fabricated in this investigation, the joint fabricated shows that contact area of pin with the base metal effects the strength of the weld. More the contact surface area of pin more will be the strength of weld.

IV. Also to increase the strength of the weld we can increase the rotational speed .More RPM will result in production of more heat.

V. Hardness analysis of the welded specimens shows an increase in hardness in the welded region due to refinement in grain size in stirred zone.

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