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ANALYZING MECHANICAL PROPERTIES OF FRICTION STIR WELDED JOINTS OF SIMILAR AND DISSIMILAR ALUMINIUM ALLOYS

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ABSTRACT: The structural application demands reduction in both the weight and as well as cost of the fabrication and production of materials. Aluminium alloys are the best choice for the reduction of weight, cost and replacing steels in many applications and Friction Stir Welding (FSW) process efficient and cost effective process. FSW is solid state welding process in which material is not melted during welding process so it overcomes many welding defects compared to conventional fusion welding process which is initially used for low melting materials. This process is initially developed for low melting materials like Aluminium, Magnesium, and Zinc but now process is useful for high melting materials like steel and also forcomposites materials. The present study describes the effect of FSW process involving butt joining of similar Aluminium alloy combinations of AA6351 with AA6351 and dissimilar Aluminium alloy combinations of AA6351 with AA5083 on the tensile, hardness and impact behavior.

KEYWORDS: Friction Stir Welding, Tensile, Hardness, Impact strength, Aluminium alloy AA6351 and AA5083.

1 INTRODUCTION

Friction Stir Welding (FSW) is a solid state welding process developed and patented by The Welding Institute (TWI) in 1991. It is emerged as a novel welding technique to be used in high strength alloys that were difficult to join with conventional welding techniques [1]. The process were initially developed for aluminium alloys [2-10], but since thenFSW was found suitable for joining other materials like magnesium [11, 12], steel [13,14], titanium [15], copper [16,17] and also composites [18]. Instead of a conventional welding torch, friction stir welding uses a non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edged of the two parts to be welded and traversed along the line of the joint as shown in Fig.1. The pin and shoulder of tool can be modified in number of ways to influence material flow and microstructural formation.

Fig.1. Friction Stir Welding Experimental Setup

2 EXPERIMENTAL PROCEDURE

2.1 MATERIAL

The materials used for this investigation are aluminium alloys AA6351 and AA5083 of size 100 X 50 X 5 mm. The standard chemical composition and base materials used for this experiment chemical composition are listed in table no.1 and 2 respectively. A vertical CNC milling machine is converted in to friction stir welding machine for welding process. Mechanical properties of aluminium alloy AA6351 and AA5083 are represented in table 3.

Table 1. STANDARD CHEMICAL COMPOSITION (ALUMINIUM ALLOY AA6351)

Element	Standard
Si	0.8
Fe	0.5
Cu	0.1
Mn	0.4
MG	0.4
Zn	0.2
Ti	0.2
Al	Balance

Table 2. STANDARD CHEMICAL COMPOSITION (ALUMINIUM ALLOY AA5083)

Element	Standard
Si	0.2
Fe	0.35
Cu	0.15
Mn	0.15
MG	5
Zn	0.25
Ti	0.1
Al	Balance

Table 3. MECHANICAL PROPERTIES OF ALUMINIUM ALLOY AA6351 AND AA5083

Aluminium alloy	AA5083	AA635
Hardness Brinell	97	85
Hardness Rockwell A	43	39
Hardness Rockwell B	62	55
Yield Strength Mpa	283	250
Tensile Strength Mpa	310	320
Elongation at break	14	10

Workpiece Specification: Plate Length=100mm, Plate Width=50mm, Plate Thickness=5mm. Raw material was cut into the specified dimensions, then machined at the sides in order to make them flat to ensure accurate face-to-face contact at weld joint as shown in Figure2.

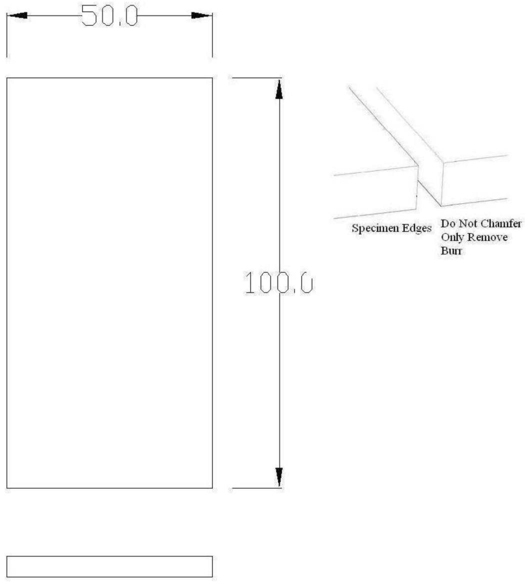

Figure 2: Workpiece Dimensions

2.2 TOOL MATERIAL

In this study FSW specimens are prepared at 30mm/min feed rate and at 1200 rpm spindle speed. The plate size of aluminium alloys are same and having 100 mm length, 50 mm width and 5 mm thickness. HSS material is used to manufacture the tools.

Tool dimensions: Shoulder Diameter- 20mm, Pin Diameter- 5mm.

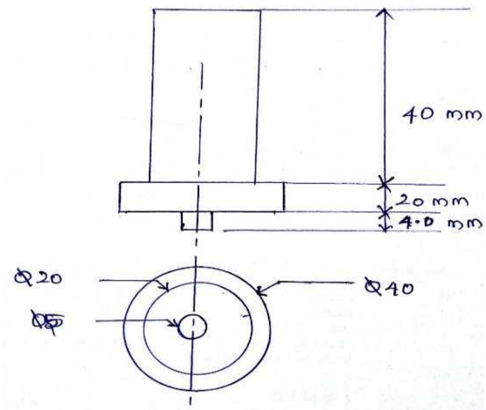

Figure 3: Tool Dimensions

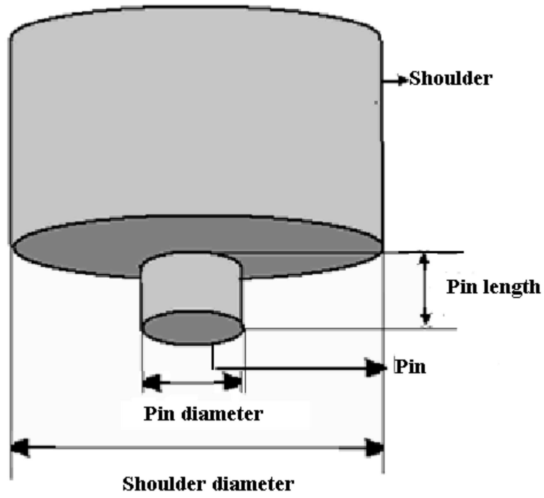

Figure 4: Tool Geometry

2.3 WELDING PROCEDURE

Aluminium alloys of AA6351 and AA5083 were chosen for in this experimental work. Similar aluminium alloy combinations of AA6351 with AA6351 and dissimilar combinations of AA6351 with AA5083 friction stir welded in this experiment. Specially designed tool was used in this friction stir welding process. The tool material used in this work was high speed steel (HSS) with cylindrical shaped probe without threads. The FSW tool was subjected to heat treatment process to improve hardness, the hardness of tool after heat treatment process is 55 HRC. A vertical CNC milling machine is converted in to friction stir welding machine to carry out welding process. The two plates are partitioned in the fixture which is prepared for fabricating FSW joint by using mechanical clamps so that the plates will not separate during welding process. Two aluminium alloy plates of size 150X60X5 mm were perfectly clamped in CNC milling machine bed on a backup plate. The axial force of 3.5 KN is applied during welding process. The FSW tool is inserted into the tool holder. Tool is plunged into the joint in the downward direction with a feed rate of 30 mm/min in clockwise direction. Higher tool rotation generates temperature because of higher frictional heating and results more intense stirring of mixing material.

2.4 TENSILE TESTING

The tensile tests were conducted to determine the tensile properties of similar aluminium alloys of AA6351 withAA6351 and dissimilar aluminium alloy of AA6351 with AA5083 friction stir weldments at rotational speed of the tool (1200 rpm) in a Universal Testing Machine (UTM) as per ASTM standards.

2.5 HARDNESS TESTING

Rockwell hardness tests were performed to determine hardness of FSW weldments of similar alloy combinations and dissimilar alloy combinations at rotational speed of the tool i.e., from 1200 rpm.

2.6 IMPACT TESTING

The Charpy impact test was performed to determine the impact energy of similar aluminium alloys combinations ofAA6351 with AA6351 and dissimilar aluminium alloy combinations of AA6351 with AA5083 friction stir weldments at rotational speed of the tool (1200 rpm) as per ASTM standards.

3 RESULTS AND DISCUSSIONS

3.1 TENSILE TEST

Tensile tests were performed to determine the tensile properties (yield strength, tensile strength and percentage elongation) of the aluminium alloy similar alloy combination of AA6351 with AA6351 and aluminium alloy dissimilar combination of AA6351 with AA5083. The effect of rotational speed of the tool on tensile properties (yield strength, tensile strength and percentage elongation) of friction stir welded aluminium alloy AA6351 with AA6351 and aluminium alloy AA6351 with AA5083. It seen from these figures that at lower rotational speed of the tool (1000 rpm), lower tensile properties of the FSW welded joint were observed. When rotational speed increased from 1000 rpm onwards tensile properties were also increased and reaches maximum at 1300 rpm. If the rotational speed is increased more than 1300 rpm, a reverse trend has been observed i.e. the tensile properties of the welded joint has decreased. The optimum values observed at rotational speed of 1300 rpm were observed for both the cases.

The mechanical properties of the aluminium alloy combinations (AA6351- AA5083 and AA6351-AA6351) are given below,

Table 4. CHARPY IMPACT TEST

Sample ID	Thick X Width X Length (mm)	Charpy Impact Energy, Joules
AA5083-AA6351	5 X 10 X 55	6
AA6351-AA6351	5 X 10 X 55	4

Table 5. ROCKWELL HARDNESS TEST

Sample ID	Observed value, HRA			Average, HRA
	1	2	3	
AA5083-AA6351	**10**	**9**	**10**	**10**
AA6351-AA6351	**9**	**8**	**8**	**8**

TENSILE PROPERTIES OF AA5083 WITH AA6351

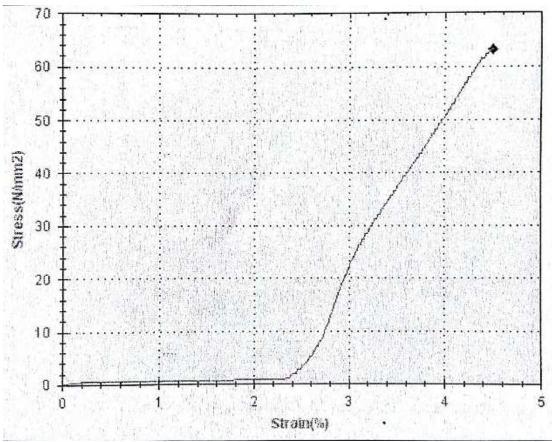

Figure 5: Stress-Strain relationship

TENSILE PROPERTIES OF AA6351 WITH AA6351

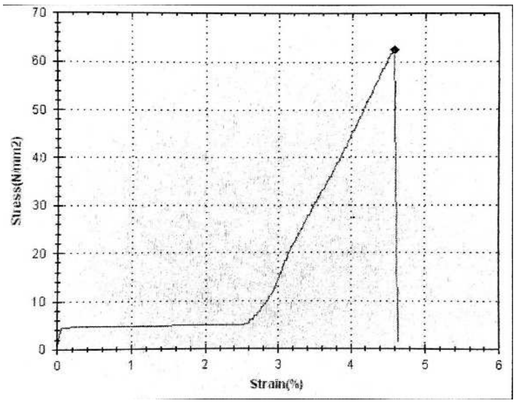

Figure 6: Stress-Strain relationship

The tensile properties and fracture locations of the welded joints are dependent on process parameters like rotational speed, welding speed and axial force of the tool, tool tilt angle etc. The lower rotational speed results lower defects like crack and pinholes in friction stir processed zone and resulted lower tensile values. On the other hand when the rotational speed increases (1400 rpm and 1500 rpm), the heat input also increases which results poor tensile properties due to rise in temperature, which increases grain growth, higher rotational speed solidification and coarsening of strengthening precipitates at the weld zone area and lowering of dislocation density [19].

4 CONCLUSION

The friction stir welding is very recent trends in metal joining processes especially for aluminum alloys. It is found that many research works are done on the aluminum alloys. Dissimilar aluminium alloy of AA6351 with AA5083 combinations has the better mechanical properties as compared to similar aluminium alloy of AA6351 with AA6351 combinations because the cylindrical tool profile, process parameters (tool rotational speed, axial downward force and feed rate) and proper mixing of material at weld location is not taking place of different melting points of AA6351 (melting point at solid state is 554 °C and at liquid state is 649 °C) and AA5083 (melting point at solid state is 591°C and at liquid state is 638°C).

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