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Experimental Evaluation of Mechanical Properties and Microstructure of Friction Stir Welded 5083 Aluminium Alloy

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ABSTRACT

In present work friction stir welds produced in 4 mm thick plates of AA 5083 Aluminium alloy, with different speeds and feeds, were analyzed and compared concerning the mechanical properties. A study has been made of the FSW of 4mm thickAluminium alloy 5083 plates. By considering the two different tool rotation speeds and by changing the transverse feeds,the mechanical properties vary. A study was made of the weldability of 4-mm-thick Aluminium-alloy 5083 plates using friction-stir welding.The microstructure was prepared for observation on a light microscope under a polarized light source.The tool-rotation speed varied from 710r/min to900r/min the Welding speed from 40 mm/min to 160 mm/min, and there is no tool tilt angle used.In this review the process parameters,microstructural evolution, and effect of friction stir welding on theproperties of weld specific to aluminum alloys have been discussed.

Introduction

Friction stir welding (FSW) may be a comparatively new technique developed by The Welding Institute (TWI) of Britain in 1991. It's at the start applied to the joining of aluminum, and extended to copper alloys, magnesium alloys, steel alloys and titanium alloys. The fundamental thought of FSW is remarkably straightforward. A non-consumable rotating tool with a specially designed pin and shoulder is inserted into the adjacent edges of sheets or plates to be joined and traversed along the line of joint.

The two primary functions of tool:

(a) Heating of work piece, and
(b) Movement of material to produce the joint.

The schematic diagram of friction stir welding is shown in Fig.1.1.

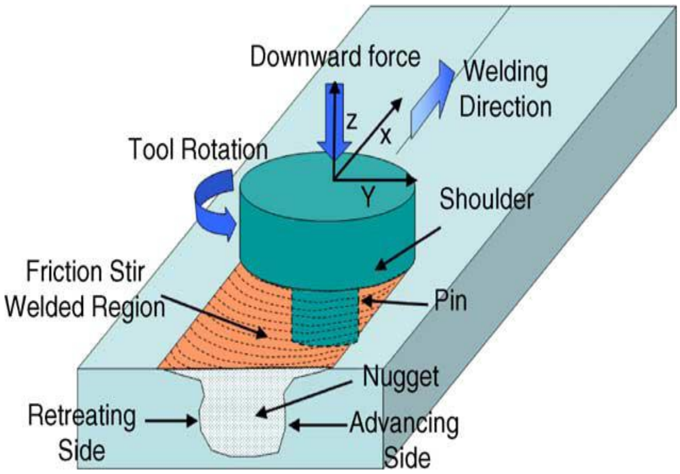

Figure 1.1 Schematic diagram of friction stir welding

Objective of research work:

In this study the tool rotation speed was taken as 710rpm and 900rpm. Eight samples of Al 5083 alloy were experimented using the travel speeds 40mm/min, 80mm/min, 125mm/min and 160mm/min. The reasons for taking these are to understand the mechanical properties and microstructure from lower speeds to higher. Within the earliest journals for 3 completely different tool rotation speeds i.e., 500rpm, 800rpm and 1250rpm, the properties were smart at 800rpm and poor at 1250rpm. Thus therein case at some tool rotation speed higher strengths are achieving and whereas by increasing the rotation speeds the poor strengths are determined owing to the improper interchangeable atoms within the metal whereas friction stir process. Thus to

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conclude the tool rotation races to what extent the strengthening improves, we are able to observe clearly during this study.

EXPERIMENTAL PROCEDURE

The main material utilized in the experiments was5083 (Si zero.122%, Fe 0.250%, Cu 0.024%, Mg 4.528%,Cr0.076%, Zn 0.023%, Ti 0.011%, Al Bal. mass fraction)Al alloy, the foremost usually used material for vesselconstruction among the 5000-series of Al alloys.The experimental study includes the butt joining of 4mm AA 5083 plates. The welding method is applied on a vertical miller (Make HMT FM-2, 10hp, 3000rpm) as shown in fig 4.1.

Tool is held in tool arbor as shown in fig 4.7. Special welding jigs and fixtures are designed to carry 2 plates of 150mm X 75mm X 4mm thickness as shown in fig. shows the combos of the tool rotational speed (rpm), welding speed (mm/min) and tool geometry and diameter of the tool shoulder to the diameter of the tool pin (Ds/Dp). These combos are chosen supported the literature survey and also the capability of the miller used for the experimental study.

Work material dimensions:

The work material is aluminum 5083 plate having 65 mm X 60 mm X 4 mm thickness dimensions.

Non consumable tool fabricated from High speed steel (Typical chemical composition is shown within the table4.5) is employed to fabricate joints, and diameter of shoulder and pin used were 24 and 8mm and also the length of the pin 3.7mm (depend on the plate thickness).

The tool used for this study is round shape pin with shoulder. Aconstant axial force is applied for the whole friction stir Welding (FSW) experiments.

The welding parameters are conferred in Table4.1. Joints were made-up using totally different mixtures of rotational speed and welding speed and different tool profile.

Table 4.1 FSW process parameters of rotation Speeds, Traversing Speed, and pin profiles.

Process parameters	values
Tool rotation speed (rpm)	710, 900
Welding speed (mm/min)	40, 80, 125, 160
Pin length (mm)	3.7
Tool shoulder diameter (D), Tool pin diameter (d) [mm]	2 4, 6
D/d ratio of tool	4
Tool pin geometry	Tapered conical profile
Tool material	High speed steel [H-13]

Experiments conducted at deferent combination tool rotating speed, welding speed and tool profile. The combinations of conducted the experiments as shown in table4.2.

Table 4.2Welded conditions

Condition	Tool rotation speed (rpm)	Welding speed (mm/min)	Tool profile	Joint status
1	710	40	Tapered conical	welded
2	710	80	Tapered conical	welded
3	710	125	Tapered conical	welded
4	710	160	Tapered conical	welded
5	900	40	Tapered conical	welded
6	900	80	Tapered conical	welded
7	900	125	Tapered conical	welded
8	900	160	Tapered conical	welded

Figure 4.5Welded plate at condition 1

Figure 4.6Welded plate at condition 2

Tool geometry

Non consumable tool made of HSS tool steel (Typical chemical composition is shown in the Table 4.5) is used to fabricate joints, and diameters of shoulder 24, and pin used were 6 mm and the length of the pin 3.7 mm (depend on the plate thickness). The tools used for the present study are tapered conical pin profiles with shoulder as shown in Fig4.5. A constant axial force is applied for the entire friction stir welding (FSW) experiments.

Figure 4.7 Schematic drawing of the FSW tool

Micro hardness Test procedure:

To examine local variations in the mechanicalproperties that occur in andaround the friction stir weld zone, the hardness of the welding zone was testedwith a Micromet micro hardness tester. AKnoop indenter was used with a load of200 g and dwell of 15 s. The Knoop hardnesswas measured across the centerlineof the welded plate.All compression tests and hardnesstests were performed at room temperature,approximately 22°C.

Tensile strengthtest:

The tensile tests were conducted to determine the breaking load and yield strength of Aluminum AA5083 alloy friction stir weldments at different rotational speed of the tool in a Universal Testing Machine (UTM) as per ASTM standards[B 557:2006].

Charpy impact test procedure:

Sub size (3mm thick) Charpy V-notch impact specimens were prepared and tested in accordance with BS EN 10045-11990. The specimens were prepared with the same orientations and notch tip positions (stirred zone) as the corresponding fracture toughness.

RESULTS AND DISCUSSIONS

Effect of process parameters on mechanical properties of FSW of AA5083

The welding speed, the tool rotational speed, the vertical pressure on the tool, the tilt angle of the tool and the tool design are the main independent variables that are used to control the FSW process. The heat generation rate, temperature field, cooling rate, x-direction force, torque, and the power depend on these variables. Generation of temperature increases with increasing rotational speed and decreasing with increasing welding speed. Peak temperature also increases with increase in the axial pressure.The welded joints were sliced using power hacksaw and then machined to the required dimensions to prepare tensile, microstructure, hardness tests.

Effect of tool rotational speed

In FSW, tool rotation speed results in stirring and mixing of material around the rotating pin which in turn increase the temperature of the metal. It appears to be the most significant process variable since it tends to influence the translational velocity. In order to find the effect of tool rotational speed on the mechanical properties, two different speeds (710rpm, 900rpm) were selected keeping in view of the speeds available in the retrofitted vertical milling machine at traversing speeds of 40mm/min , 80mm/min , 125mm/min , 160mm/min. At rotating speed 710rpm and traversing speed 125mm/min the joint was too good compared to other combinations

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as shown in Fig 4.3. The combinations of used process parameters are shown in Table4.1.

Effect of Welding Speed

The metal flow phenomenon in friction stir welding (FSW) comprises two modes of metal transfer. The first mode of metal transfer takes place layer by layer and is caused by the shearing action of the tool shoulder, while the second mode is caused by the extrusion of the plasticized metal around the pin. The rate of heating of thermal cycle during FSW is a strong function of the welding speed, To understand the effect of traversing speed on the weld quality and mechanical properties two different welding speeds were used to fabricate the joints as shown in Table 4.2. As the welding speed is increases the mechanical properties will be very poor, due to the insufficient heat generation. The best mechanical property was achieved at 125mm/min.

Mechanical properties

Tensile Properties

The tensile strength was observed i.e., 175.895 MPa and the yield was 138.437 MPa at the fusion zone of aluminum welds at tool rotation speed of 710rpm and a welding speed of 125mm/min with (D/d ratio 4) tool pin profile. This is due to the fact that with increase in tool rotation speed coarse grain structure produced which results in low ultimate tensile strength.

Graph 1: Mechanical property by varying the welding speeds with 710 rpm:

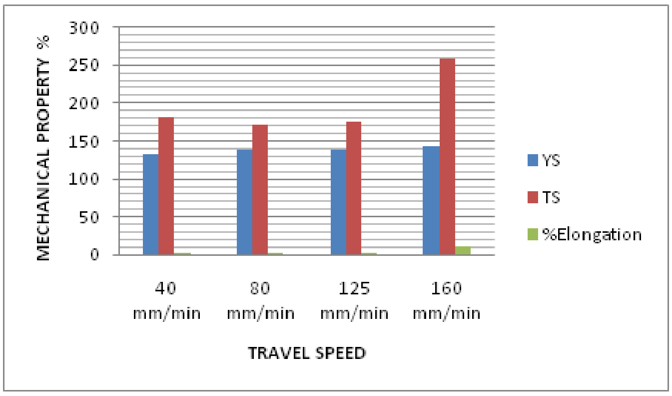

Fig 6.1Mechanical property for base metal at various travel speeds and 710 r/min rotational speeds

Impact Strength

Impact toughness was observed at the fusion zone of aluminium welds with pin profile at 710 rpm and constant welding speed 125mm/min was 14,whereas the Toughness is higher due to the presence of fine grain size. Result of impact test showed that samples welded at lowest rotational speed had maximum impact energy as compared with those welded at higher tool rotational speed.

From the Table 6.3 it is observed that, at 710rpm and 125mm/min gives better mechanical properties. This is due to sufficient heat obtained at this condition.

Hardness

The hardness values for experimental samples are very impressive in which for the sample no.5 i.e, at speed 900rpm and feed 40mm/min given greater value.

Elongation

Elongation depends on the generated heat input, but heat input is dependent on welding parameters such as toll rotation speed, welding speed and tool shoulder diameter.

The tensile behavior and hardness values from the experiments show that there is an increase in the samewhen the rotational speed and axial force is increased by keeping the weld speed constant. There is a decrease in the same when the weld speed is increased keeping the other parameters constant. However, when the axialforce is increased the tensile strength is increased. This behavior is due to the increased frictional heat andinsufficient frictional heat. Higher weld speeds resultsin poor heat generation and plastic flow of thematerial.

This may have resulted in a week interface at the joint. Higher the weld speeds lower the heatgeneration which results in fasters cooling of the welded joints. It can also be inferred that when thewelding speeds are higher there exists lower metallurgical transformations and lower strengths.

Table 6.3 Welded conditions at constant rotational speed of 710 & 900rpm:

Run order	Tool rotation speed (rpm)	Travel speed or Feed(mm/min)	UTS (MPa)	% of elongation	Hardness (BHN)	Impact strength	YS(MPa)
1	710	40	181.719	2.86	76.5	12	131.805
2	710	80	171.522	2.58	72.97	10	139.691
3	710	125	175.895	2.44	70.20	**14**	138.437
4	710	160	**259.769**	**9.2**	78.10	12	143.142
5	900	40	138.753	2.8	**84.27**	8	133.07
6	900	80	209.395	3.92	76.87	10	**148.37**
7	900	125	228.159	5.34	77.9	8	147.332
8	900	160	147.865	2.5	75.77	12	136.89

Microstructure study

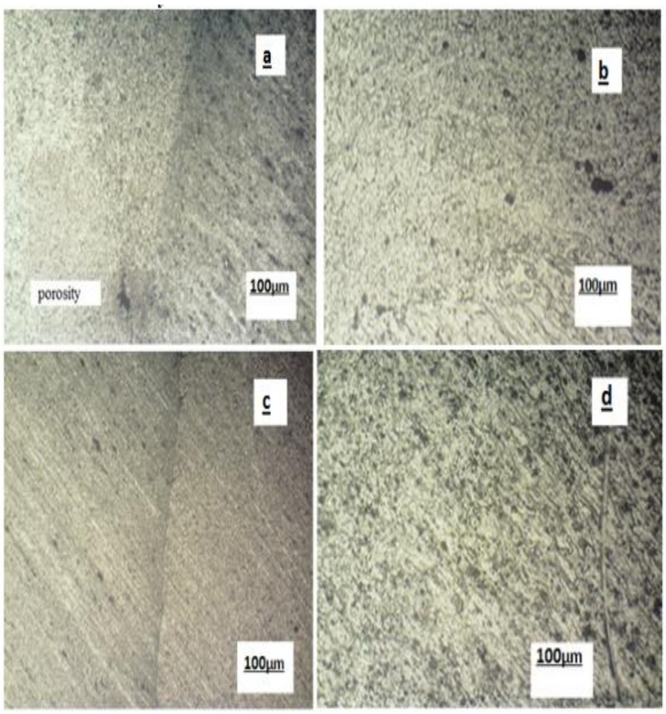

Fig 6.7 Optical microstructure at different location corresponding to locations for 710rpm rotation speed. (a) 40mm/min (b) 80mm/min (c) 125mm/min (d) 160mm/min

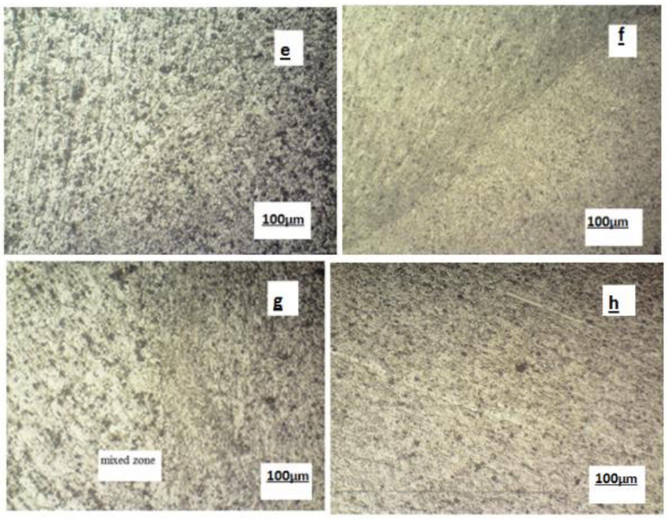

Fig 6.8 Optical microstructure at different location corresponding to locations for 900rpm rotation speed. (e) 40mm/min (f) 80mm/min (g) 125mm/min (h) 160mm/min

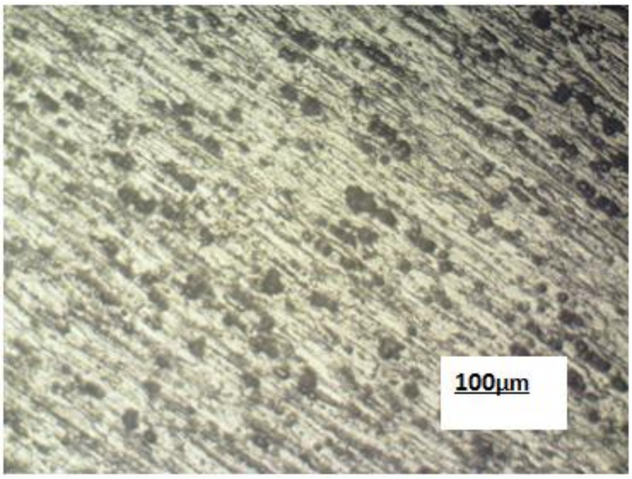

Fig6.9 Base metal of aluminum 5083

Conclusions:

Based on the analyzed results the following can be concluded.

- Among four welds of 710 rpm, weld with same rotational speed & 125 mm/min traverse speed with tapered conical profile resulted in good mechanical properties.
- Among two welds of 900 rpm, weld with same rotational speed & 125mm/min traverse speed with tapered conical profile resulted in good mechanical properties.

- It is observed that, at 710 rpm, the mechanical properties are better than at 900 rpm,this is due to sufficient heat is obtained.
- The weld with conditions of 710 rpm & 125 mm/min gives the best results as compared to the other welding conditions.
- At 710rpm and travel speed of 125mm/min the equated fine grain size obtained and the grain sizes are half of the base metal grains.
- The tensile strength decreases as the tool rotation increases. At 710rpm the strength was 175.895 M Pa. because at this condition the heat input is sufficient due to cold deformation.

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