Characterization of Friction Stir Welded Aluminium Alloy (5083) Joints

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Abstract – By using friction stir welding process 5mm thickness of aluminium alloy plates the experimentation was done. The tests are conducted at different tool rotational speeds 710rpm, 900rpm, 1120rpm, the welding speed is at 20mm/min, 30mm/min, and 40mm/min respectively were taken. The investigation is made with the conical tool profile made up of high speed steel. Specimens for tensile testing, impact testing, Rockwell micro-hardness measurements and microstructure analysis were prepared. It was notice that the high-quality mechanical properties were achieved at moderate tool rotational speed, and microstructure consists of grains with inter metallic compounds in aluminium matrix and free from eutectic melting. No micro porosity, stringers and segregation are seen.

Key Words: Friction stir welding, AA 5083, conical profile tool, rotational speed, welding speed, mechanical properties (tensile testing, impact test, micro hardness), microstructure Analysis.

1. Introduction:

Friction stir welding is becoming an essential joining process because it makes high quality welds for number of materials as compared to the conventional welding techniques. In FSW process, a non-consumable welding tool is used to produce the frictional heat between the tool and the work piece as shown in figure 1. This facilitates the tool movement along the joint line. As a result, the plasticized material is changed from the leading edge of the tool to trailing side. Subsequently, it produces a high quality joint between the two plates by the translation movement of the work piece along with applied pressure of the tool. The 5083 aluminium alloy is exhibits good oxidization resistance to seawater, better mechanical properties. It has good formability, machinability and weld ability. The 5083 aluminium alloy is used for providing of welded components for ship building and railway vehicles.

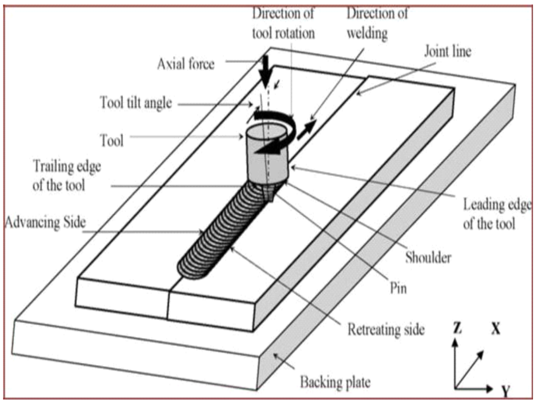


Fig1.Working principal of FSW

2. Literature review:

M.K. Bilici et al, in this present research work focus on the effects of tool geometry and properties of friction stir spot welding on polypropylene sheets. In his examination four dissimilar tool pin geometries with varying different shoulder angles and shoulder diameters and pin angles, pin lengths were used for friction stir spot welding. The Normal room temperature was used for the entire welding process and weld strength outcome are studied from the experiments of the effect of tool geometry and the lap shear tensile trials were carried out to find the weld static strength. The most favorable tool geometry for 4mm thickness polypropylene sheets was determined. The straight cylindrical pin given the lowest lap shear fracture load and largest lap shear fracture load is obtained at taper cylindrical pin.

T. Deb Royet et al (2010) was analyzed the mechanical properties of friction stir welds while varying process parameters in 5083-H111 aluminium alloy. The used tool had a shoulder diameter of 20 mm, and a pin with a length of 4.5 mm and diameter of 5.0 mm respectively. And the tool was made from SK tool steel, tilted at 2 degree. Welding was done at the tool rotational speed of 500 rpm, 900rpm, 1800rpm and welding speed is 40mm/min to 120 mm/min. tensile tests were performed on the all welds. The welding process was performed at 500 rpm and 900 rpm showed a decrease in quality when the transverse feed increased. At 1800 rpm, all weld speeds formed defects. In turn, the welds were exhibited extremely low quality of mechanical properties. Every fractures during tensile tests occurred in the stir welding zone. So the optimum FSW parameters for this research were 900 rpm and 120 mm/min which had an ultimate tensile strength around 250MPa.

Puneet Rohilla et al., (2013) in this paper, Aluminium alloy 6061 as gathered broad approval in the production of the light structures essential to high strength. Compared to the fusion welding operations that are used for joining structural aluminium alloys, friction stir welding (FSW) process is an emerging solid state joining process in which the substance that is being welded does not melt and recast. In this investigational work, an extensive investigation has carried out on FSW butt joint. Welded joints were prepared with the help of tool made of high speed steel (HSS) alloy steel. Tools were of two dissimilar pin profiles viz. straight cylindrical, and square. The welded joints were made on aluminium grade AA 6061 plates of 6mm thick. Tests were conducted to find out the tensile strength, percentage of elongation and micro hardness. In this examination, tool rotation and traverse speeds are kept constant i.e., 2000 rpm and 20mm/min. the variables are profile of the tool and having passes one sided and both sided. Cylindrical tool pin shape exhibited greater tensile properties compared to other joints, irrespective of tool rotational speed in double pass. The joints made-up by single pass have shown lesser tensile strength and also percentage of elongation compared to the joints fabricated by double pass and this tread is general for every tool profiles.

3. Experimental Procedure:

A. Work Piece Material: Aluminium alloy 5083 contains 5.2% magnesium, 0.1% manganese and 0.1% chromium. In the tempered state, it is strong, and retains superior formability due to outstanding ductility.5083 has high resistance to corrosion and is used in marine applications. It has the low density and good thermal conductivity general to all aluminium alloys. It has the peak strength of the non-heat treatable alloys with an ultimate tensile strength of 317 MPA or 46000 psi and tensile yield strength of 228 MPA or 33000 psi. It is not recommended for use in temperatures in excess of 65 degree c.

The plates of 5mm width AA5083 were cut into size of 150mm*60mm and machined with square butt joint type. The first configuration was come out by securing the plates in butt arrangement using specially designed and fabricated fixture. Here the non consumable high speed steels are used for welding. The chemical composition of the AA5083 material used in the current study is given in table1.

Table1: Chemical Composition of AA5083 in WT%:

Material	AA5083
Aluminium	Balance
Chromium	0.05-0.25% max
Copper	0.1% max
Iron	0.4% max
Magnesium	4 to 4.9% max
Manganese	0.4 to 1% max
Silicon	0.4% max

Titanium	0.15% max
Zinc	0.25% max

B. Friction Stir Welding:

Friction stir welding (FSW) is a solid state joining method that involves joining of metals without fusion or filler materials. The frictional heat is created from a rapidly rotating non-consumable high strength tool pin that extends from a cylindrical shoulder. The process is particularly applicable for aluminum alloys but can be extended to additional products also. Plates, sheets and hollow pipes can be welded by this technique. The process is also suitable for automation. The weld produced is of finer microstructure and superior in characteristics to that used welding process in latest times.

The welding was carried out in a universal milling machine by varying the tool speed. Conical profile tool is used in this process. Based on the study, with the availability of speeds on the machine, three different rotational speeds (710 rpm, 900rpm, and 1120 rpm) and three different welding speed(20mm/min,30mm/min,40mm/min)were preferred to carry out the experiment. The process parameters and tool dimensions are as shown in table 2.

Fig2.While the plates under Fsp

Table2: FSW process parameters:

Process parameters	**Values/types**
Tool rotational speed(rpm)	710,900,1120
Welding speed(mm/min)	20,30,40
Axial load	Constant(5kn)
Pin length(mm)	5.6mm
Tool shoulder diameter(mm)	20mm
Pin diameter(mm)	8/6mm
Tool material	High speed steel
Tool Profile	Conical
Thickness of the material(mm)	5

Fig3.Conical tool profile

4. Results and Discussions:

For every specimen the following tests are conducted and the samples are prepared with the friction stir welding of aluminium alloy 5083,

I. Tensile test
II. Impact test
III. Rockwell micro-hardness test
IV. Microstructure analysis

Tensile Test:

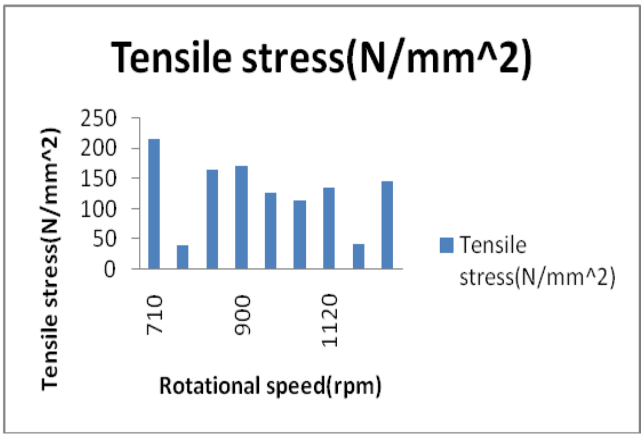
After friction stir welding the entire specimens were Tested to get the ultimate tensile strength.

Table3: Mechanical Properties at Various Tool Rotational Speeds and Welding Speeds:

Tool Rotational Speed(rpm)	Welding Speed	Tensile Stress(N/mm^2)	Impact Strength(joules)	Hardness
710	20	216.709	8	56.5
	30	150.305	2	59.25
	40	165.779	4	61.75
900	20	172.519	42	62.25
	30	126.709	32	68.75
	40	113.490	39	65
1120	20	135.920	34	73.25
	30	100.364	42	63.5
	40	146.866	18	70.5

Fig4.Tensile test samples

Tool Rotational Speed (rpm) vs Tensile Stress (N/mm^2):



Charpy Impact Test:

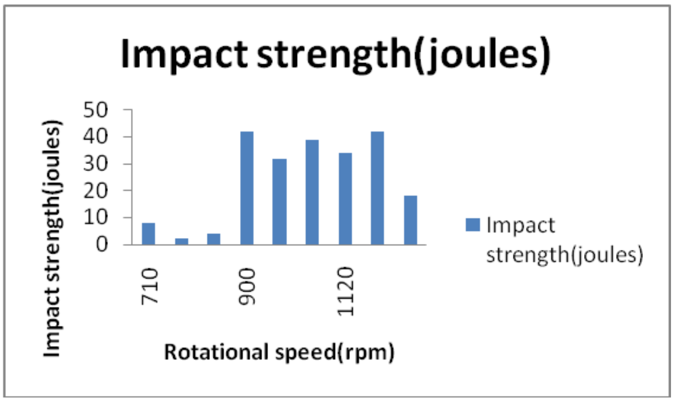
The charpy impact, also well-known as the charpy v-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. Absorbed energy is a measure of the materials notch toughness.

Fig5.Impact test samples

Table4: Results showing Impact strength values:

Tool Rotational Speed (rpm)	Welding speed(mm/min)	Impact strength
710	20	8
	30	2
	40	4
900	20	42
	30	32
	40	39
1120	20	34
	30	42
	40	18

Tool Rotational Speed (rpm) vs Impact Strength (Joules):



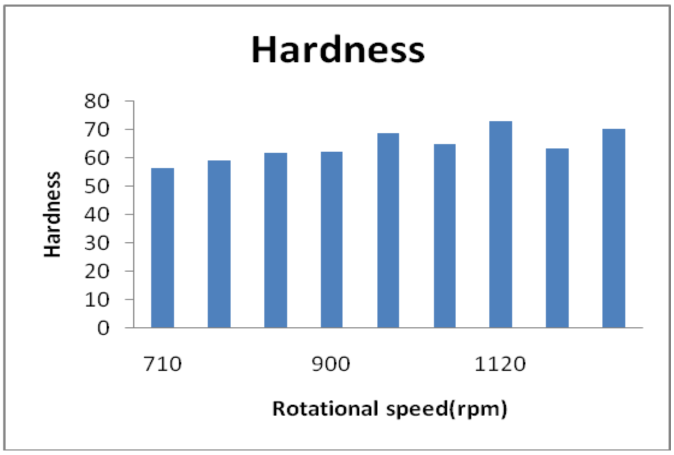
Rockwell Micro Hardness Test:

Rockwell micro hardness analysis is made to verify the hardness of the welded specimens. The micro hardness of Rockwell is achieved great at 1120 rpm and the welding speed is 20mm/min and the value is 73.25 and it is extremely closer to 1120 rpm and the welding speed is 40mm/min with the value of 70.5

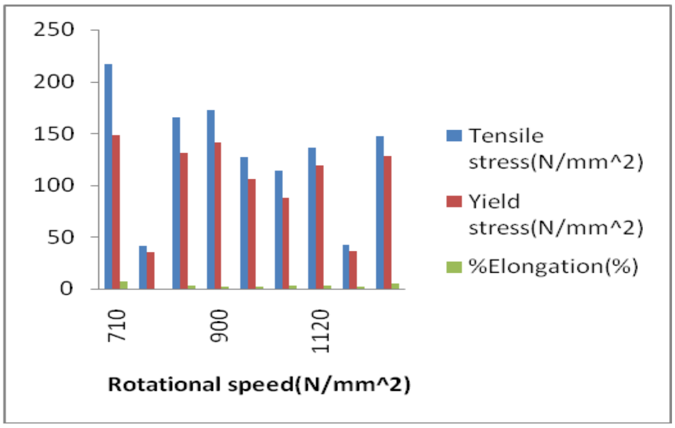
Table5: Results Showing Micro-Hardness:

Tool Rotational Speed (rpm)	Welding Speed	Hardness Values
710	20	56.5
	30	59.25
	40	61.75
900	20	62.25
	30	68.75
	40	65
1120	20	73.25
	30	63.5
	40	70.5

Tool Rotational Speed (rpm) vs Hardness:



Tool Rotational speed vs Tensile Stress, Yield Stress, % Elongation:



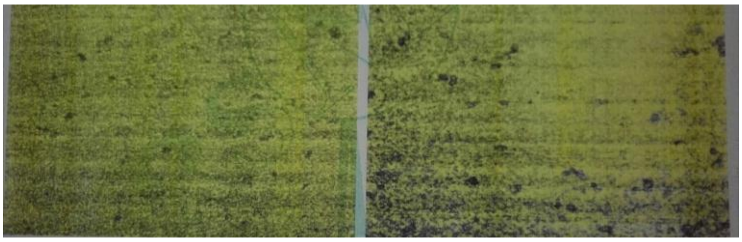
Microstructure Study:

The tool rotation speed is essential aspect because it can control the microstructure grain size.

Microstructure Results: Microstructure consists of grains with intermetallic compounds in aluminium matrix and free from eutectic melting. No micro porosity, stringers and segregation are seen.

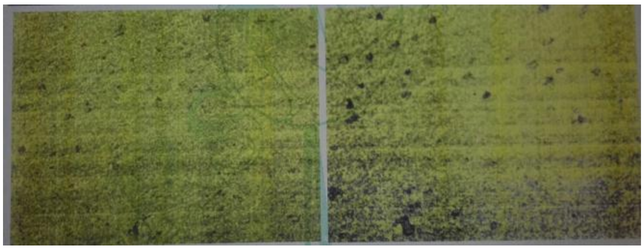
Tool Rotational Speed 710rpm, Welding Speed 20mm/min:

200X **400X**



Tool Rotational Speed 900 rpm Welding Speed 20mm/min:

200X **400X**



5. CONCLUSIONS:

For Aluminium alloy 5083 at 710 rpm by using conical profile tool the mechanical properties obtained were best.

It has been notice that the varying in tensile strength occurs for different tool rotational speeds. The tensile strength is found to be greater at 710 rpm and less at 1120rpm.

The uppermost hardness value is 73.25 at a rotational speed of 1120 rpm and welding speed 20 mm/min due to the excess frictional heat generated at this state.

Microstructure consists of grains with intermetalic compounds in aluminium matrix and free from eutectic melting. No micro porosity, stringers and segregation are seen.

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