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EXPERIMENTAL INVESTIGATION OF FRICTION STIR WELDING OF ALUMINIUM ALLOY AND ITS PROPERTIES

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Abstract — Friction Stir Welding process is an advanced welding technique that has more advantages than the conventional welding techniques. The advantages are – 1. Weld quality is good 2. Less power consumption 3. No flux and no filler material is used. This FSW process is taken as the research work because of its advantages and increasing use of this process in various automobile and aerospace industries. This paper reports the experimental investigations on the effects of process parameters i.e. spindle speed, travel distance and tool angle on the responses i.e. tensile strength, hardness etc. in similar welding of aluminium alloys by using the solid state welding technique Frictions Stir Welding process.

1. INTRODUCTION

Friction Stir Welding is an important manufacturing process. In recent years FSW is a widely used technique for welding especially Aluminium alloys. It produces complex configuration of parts and these are difficult to form. With the upcoming technology, the demand of producing complex parts has grown which are not possible to manufacture as single parts. In recent years, the importance of FSW has grown. It is now considered as one of the most critical welding process. FSW process is a solid state joining process. In 1991, Wayne Thomas invented this process at The Welding Institute (TWI) in UK. FSW process is an energy efficient and environment friendly process. It has more advantages than conventional fusion welding processes.

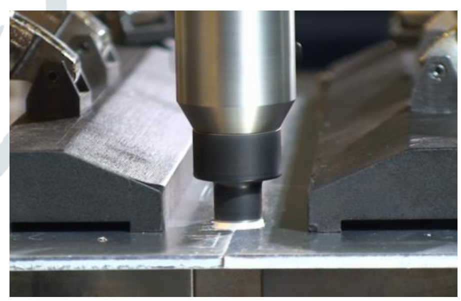

Figure 1 : Friction Stir Welding

Some of the most important of these advantages are low distortion , residual stresses, no fumes and spatters, and no flash. The process is a solid state joining process and the most significant advantage of this process is in welding of alloys difficult or impossible to wild by fusion welding techniques. And also it has a low number of defects when compared to other welding processes. But improper levels of FSW process parameters can have defective welds. Defects like voids, surface galling, tunnelling, insufficient penetration occur due to improper level of process parameters in FSW. FSW process parameters such as tool rotational speed, tool traverse speed, plunge depth, tool tilt angle, axial force, tool shoulder diameter influence the properties of welding. However, the analysis of parameter interactions with their levels in the FSW process is to be carefully studied for the efficient joint mechanical strength.

This process is an autogenous process and it does not require any kind of filler metal or shielding gases. Hence, friction stir welded joints are free from any kind of filler or slag inclusions. FSW can be performed in almost any weld position except fillet joints. FSW and its variants are considered the latest development in materials joining.

The process has commercial applications in several industries, such as aviation industry and space technology, Marine and ship building, and automotive industry. [1]

2. EXPERIMENTAL SETUP

To carry out the experiment Milling machine setup has been used.

Figure 2 : Milling Machine

TOOL PIN :
The design of the tool is a critical factor, as a good tool can improve both the quality of the weld and maximal possible welding speed.

Tool Geometry :

Diameter of small screw pin = 5mm
Height of small screw pin = 5.9mm
Small diameter of the tool = 18mm
Big diameter of the tool = 20mm
Height of the tool = 80.9mm

Figure 3 : FSW Tool

WORKPIECE DETAILS :
In this experiment Aluminium alloy has been used as workpiece material which belongs to wrought Aluminium of 100mm * 70 mm * 3mm in the form of plates.

3. EXPERIMENTAL PROCEDURE

FSW uses a non consumable rotating welding tool with a specially designed pin shoulder. The base plates to be joined are clamped tightly in the proper joint configuration. The tool is rotated at a constant speed and slowly plunged into the adjacent edges of the plates to be joined until the shoulder of the tool makes sufficient contact with the surface of the plates for welding. The shoulder rubs against the surface of the workpiece and heats the material by breaking the surface oxide layer. Frictional heat is induced locally due to the friction of the tool shoulder with the workpiece.

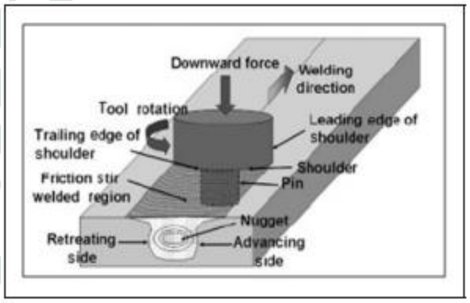

Figure 4 : The schematic of friction stir welding

However the temperature of the welding zone is significantly lower than the melting point of the alloys being welded. The tool shoulder also serves to constrain material within the weld. After preheating, the tool is forced towards the weld joint. The pin surface provides frictional heat to the joint but somewhat less than the shoulder surface. Local heating softens the material around the pin and the combined effect of translation and rotation of the tool leads to movement of the material from the front to the back of the pin, thus filling the hole left by the tool as it moves forward. So, Friction Stir Welding is a solid state joining process where the two plates are mechanically joined by frictional heating and severe mechanical deformation. [11-12]

4. EXPERIMENTAL METHODOLOGY

Taguchi method has been used for this experiment.

SELECTION OF PROCESS PARAMETERS:

Table 1 : Input Parameters

Sl No.	Parameters	Level 1	Level 2	Level 3
1	Spindle Speed	600	750	900
2	Travel Distance	11	24	37
3	Tool Angle	1	1.5	2

Table 2 : Design of Experiment (DOE)

Spindle Speed	Travel Distance	Tool Angle
600	11	1
600	24	1.5
600	30	2
750	11	1.5
750	24	2
750	30	1
900	11	2
900	24	1
900	30	1.5

5. EXPERIMENTAL INVESTIGATION

MECHANICAL PROPERTIES EVALUATION :

TENSILE TEST : Tensile tests were carried out on the weld joints using the Friction Stir Welding method to determine the mechanical properties of the welded joint.

Figure 5 : Sample for Tensile Test

Tensile testing, in which a specimen is subjected to controlled tension before fracture which is commonly used to determine the mechanical properties of welds. Tensile test is used to evaluate the mechanical properties of the welded joints, such as yield strength, ultimate tensile strength and ductility.

Table 3 : Input Data for Tensile Test

Gauge Length (mm)	Final Gauge Length (mm)	Width (mm)	Final Width (mm)	Thickness (mm)	Final Thickness (mm)
190	-	-	-	3	-
190	197	12	11	3	2.5
190	210	12	11	3	1.5
190	195	13	12.5	3	2.5
190	200	13	10.5	3	1.5
190	207	12.5	10.5	3	2
190	197	13.5	11.5	3	1.5
190	204	13.5	13	3	2
190	204	13	11	3	2

HARDNESS TEST :

The Rockwell test is generally easier to perform and is more accurate than other types of hardness testing methods.

The Rockwell method measures the permanent depth of indentation which is produced by a force/load on an indenter. Ball indenter and red scale are used in this test.

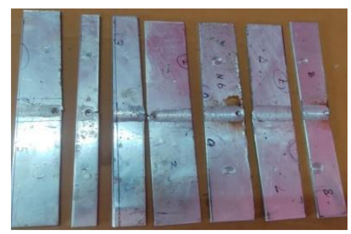

Figure 6 : Sample for Hardness Test

Table 4 : Input Data for Hardness Test

Sample ID	Scale	Indenter	Load (Kg)	Dial
S1 - S9	G	160 ball	60	Red Scale

METALLURGICAL EXAMINATION :

Scanning Electron Microscopy (SEM) : FSW joints FSW results in a significant change in the microstructure of the materials in and around the weld zone. This results in significant changes in the post-weld mechanical properties of Friction Stir welds. This section attempts to explore the microstructure involvement and the micro-mechanism around the joint line during FSW.

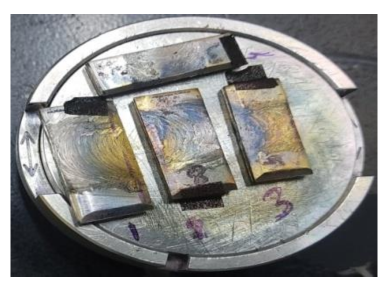

Figure 7 : Sample For Microstructure Test

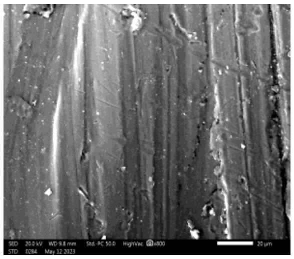 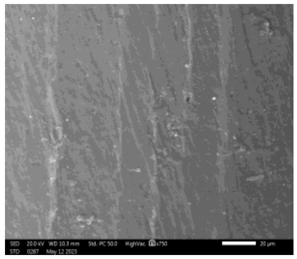

Figure 8 : Scanning Electron Microscopy

6. RESULTS

Table 5 : Final Result Table of Exp.

Spindle Speed	Travel Distance	Tool Angle	Tensile Strength	Hardness Weld Zone	Hardness HAZ Zone
600	11	1	0.144	32.5	34
600	24	1.5	0.143	48	35
600	30	2	0.149	55	35
750	11	1.5	0.145	40.5	35
750	24	2	0.149	41	35.5
750	30	1	0.383	45.5	35
900	11	2	0.133	37.5	36.5
900	24	1	0.094	36	27.5
900	30	1.5	0.151	48.5	36.5

7. CONCLUSION

Friction Stir Welding of Aluminum alloy was successfully performed using specific spindle speed, travel distance and tool angle by simple and threaded pin tool.

i) The welding of smooth surfaces in the joints depended on sufficient heat input applied during the FSW process, which was related to the transverse and rotational speed.

ii) Pin rotation during the stirring process causes onion rings and wavy deformations in the nugget zone for similar friction welding. The microstructure on the advancing side was more abrupt than that on the retreating side due to the movement of pin and materials on the advancing side.

iii) Micro-hardness indentation exhibits different hardness profiles, with lower hardness obtained at the welding centre.

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