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Effects of Process Parameters on Friction Stir Welding of 6063 Aluminum Alloy

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ABSTRACT

Friction Stir Welding is a solid state welding method that is largely used in aerospace, marine, automotive and other industries for welding similar and dissimilar metals. As compared to other welding methods friction stir welding provides superior results. It is a reliable technique because it permits aluminum alloy welding. Products of FSW that is welded aluminum alloys have a great importance in various industries because of good quality welding joint. This paper depict about the friction stir welding carried on aluminum 6063. We observe various welding parameters like transverse speed, rotational speed, tilt angle etc. Our main objective is to find mechanical properties of the friction stir welded aluminum joints on different or optimized input parameters. The Mechanical properties of welded aluminum joints that we investigate by mechanical methods are Tensile strength (UTS, Elongation), hardness, micro-structure. Their structure, physical and mechanical properties of the composite are related to connection with the size effects and other particulars in detail to make high end materials.

Keywords: Friction Stir Welding (FSW), AA6063, Aluminum Alloy.

INTRODUCTION

The Friction Stir Welding (FSW) is the method of welding in which two solid states surfaces are joined with the help of non -consumable tool. This method was invented and later patented by The Welding Institute (TWI) in 1991. In FSW, a cylindrical tool with a special designed pin is rotated and inserted into the joint area between two pieces of plate material. The parts have to be tightly or rigidly clamped to forbid joint faces from being forced apart. Frictional heat develop between the wear resistant welding tool and the work pieces lead to the latter to soften without getting up to melting point, permitting the tool to move along the weld line. A plastic flow in the material is induced by the heat input, the stirring action and the forging action of the tool , forming a solid state weld [1].The plasticized material, transmitted to the trailing edge of tool pin, is forged by intimate contact with the tool shoulder and pin profile. There four different micro structural zones noticed in a FSW weld such as: (i)Base Metal(BM) (ii)Heat Affected Zone(HAZ) (iii) Thermo-mechanically affected Zone (TMAZ) & (iv) Nugget Zone (NZ) [2]. Usually high welding speed lead to ultimate tensile strength increases as compare to low welding rate in as welded condition but it is reversed after post weld heat treatment and the welding process softens the material which lead to decrease the hardness, tensile strength and increases the ductility of material[3] In FSW, it is understood that increase in the weld speed and decrease in the TRS, lead to reduce in the heat input necessary for joining leading to decrease in the thickness of TMAZ and HAZ which, lead to increases in the tensile properties [4]. On cooling, a solid phase bond is obtained between the work pieces .While using FSW in high temperature materials, FSW is turned out very successful on number of alloys and materials, including stainless steel, titanium and high-strength steels. This welding technique provides many benefits such as it produces no fumes, no arc and need no filler metal. Thus we can say that it is an eco- friendly method. Application of FSW give tremendous result in joining ferrous and non-ferrous alloys that were joined by using conventional welding techniques with huge difficulties. The main objective of any manufacturer for choosing a welding method is to get a best quality of welded joint by right selection of most appropriate welding parameters .Robust design given by Taguchi is one of the best method for reaching at a conclusion while choosing most appropriate welding parameters within very short time and at less materials cost and labor effort. Taguchi techniques are being used for large number of products and processes to find out the performance measures and various parameters with minimum variations. To ensure a successful and effective welding cycle the tool speed and tool geometry must be opted with care, as both of these parameters are very important. [6].Various studies have been carried to find out the amount of heat generated and transferred to the joint area. A simplified model is stated in the following equation.**Q = □ □FK.**The schematic process is shown in Figure 1.

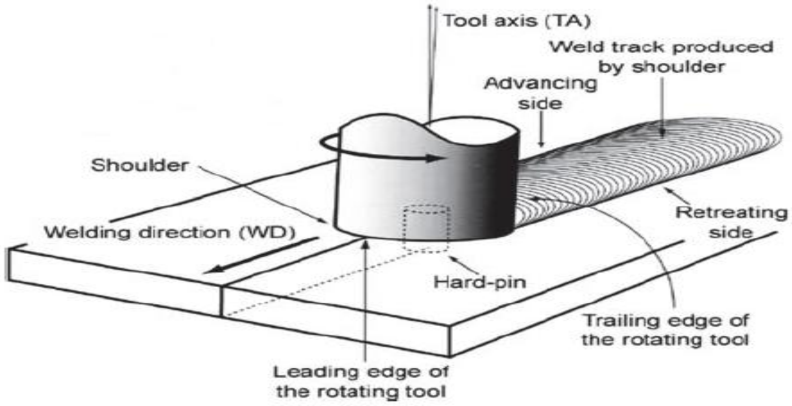


Figure 1: Friction stir welding process

EXPERIMENTAL PROCEDURE

Material

AA6063 material is used for this investigation in the form of plates of size 100 x 50mm x 5 mm. AA6063's Chemical composition is listed in Table1.

Table.1: AA6063's Chemical composition

Element	Si	Fe	Cu	Mn	Mg	Zn	Ci	Tr	Al
%	0.2-0.6	0.35	0.1	0.1	0.45-0.9	0.1	0.1	0.1	Bal

Tool Design

The tool should be made of a material that can withstand the whole process and offer adequate frictional heat generation. When choosing a material to manufacture the FSW tool the material is to be welded must be considered. The tool material should be stronger and have a good wear resistance than the material to be welded and should have high melting temperature [7]. A basic and schematic design for a FSW tool is given in Figure 2.
1. This cylindrical design is compared to other complex and still emerging tool variants.

FSW tools follows some basic pattern in termsof shapes and geometries. They are generally made up of three basic features:

1) A shoulder section;
2) A probe and
3) Any external features on the probe.

The shoulder is designed relatively large, as compared to the probe, profiled surface. Although the probe makes the initial contact with pre-welded material but the shoulder has a larger contact area and produces more friction.

Fig. 2 Weld tool

Welding Parameters

For this study following parameters are considered. They are
1. Tilt Angle (TA)
2. Transverse Speed (TS)
3. Rotational Speed (RS)
The different parameters considered for welding is given in the table.

FSW Process

The plates are placed in butt configuration of 100 mm length; 50 mm width and the FSW process is performed in direction normal to the plates. The tool rotation is in the direction of translation of the tool. The two plates that have to weld are kept in the bed and they are fixed very tightly using the clamps in the bed. These clamps hold the plates tightly even larger pressure or force is acted on it. With the help of the hydraulic devices the movement of the bed, rotation of the motor and movement of tool holder are done and they are operated by using the Control buttons which are present in control panel in FSW machine. The machine and assembly are shown in fig.

Table. 2: Process Parameters

SAMPLE NO.	ROTATIONAL SPEED(RPM)	TRANSVERSE SPEED(MM/MIN)	TILT ANGLE
1	1200	79	0
2	1200	95	1
3	1200	124	2
4	1350	79	1
5	1350	95	2
6	1350	124	0
7	1500	79	2
8	1500	95	0
9	1500	124	1

A set of 27 samples are prepared to find out the mechanical properties are shown in Figure 6.

Figure.3: Friction Welding Machine

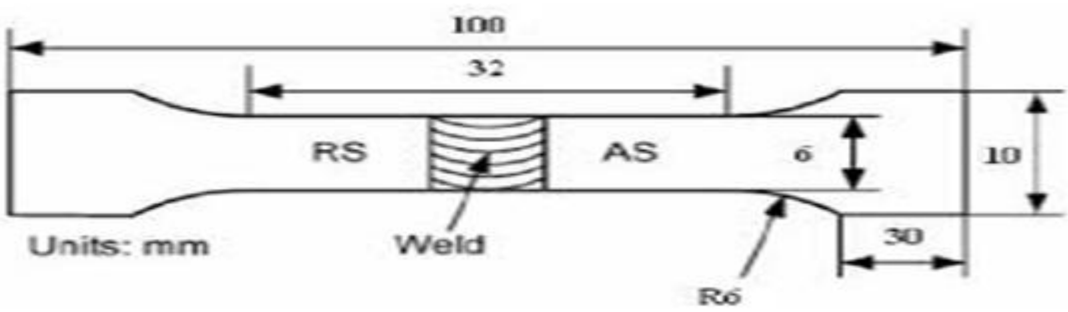


Fig.4: TEST SAMPLES FOR TENSILE TESTING

Fig.5: Friction stir welded joints

Fig.6: SAMPLES BEFORE TESTING

Fig.7: TESTED SAMPLES

TENSILE TESTING

The samples for tensile test were prepared agreeing to the guidelines of American Society for Testing of Materials (ASTM) as shown in Fig5. Tests were carried out at Universal Testing Machine at a room temperature. The sample finally failed after necking and the load versus displacement was recorded UTM for Table 3 defines the sample specifications used on the testing and table-4 is mean values of 27 sample. The tensile tested pieces are shown Fig.7.

Table. 3: Tensile Test Results of various process parameters

SAMPLE NO.	TENSILE STRENGTH(KN/MM=2^)	% ELONGATION
1.1	.053	3.030
1.2	0.094	6.061
2.1	0.107	9.091
2.2	0.069	12.121
2.3	0.053	3.030
3.1	0.078	9.091
3.2	0.088	6.061
3.3	0.085	6.061
4.1	0.037	6.061
4.2	0.078	6.061
4.3	0.072	6.061

5.1	0.071	6.061
5.2	0.075	6.061
5.3	0.095	9.091
6.1	0.081	6.061
6.2	0.083	6.061
6.3	0.096	9.091
7.1	0.076	3.030
7.2	0.105	3.030
7.3	0.084	6.061
8.1	0.092	1.515
8.2	0.093	3.030
8.3	0.140	21.212
9.1	0.036	1.515
9.2	0.080	6.061
9.3	0.053	3.030

Table.4: Mean Values for Tensile Test Results

SAMPLE NO.1	MEAN UTS	MEAN % ELONGATION
1	73.55	4.540
2	76.33	8.080
3	83.66	7.071
4	62.33	6.061
5	80.33	7.071
6	86.66	7.071
7	88.33	4.040
8	108.33	8.580
9	56.33	3.535

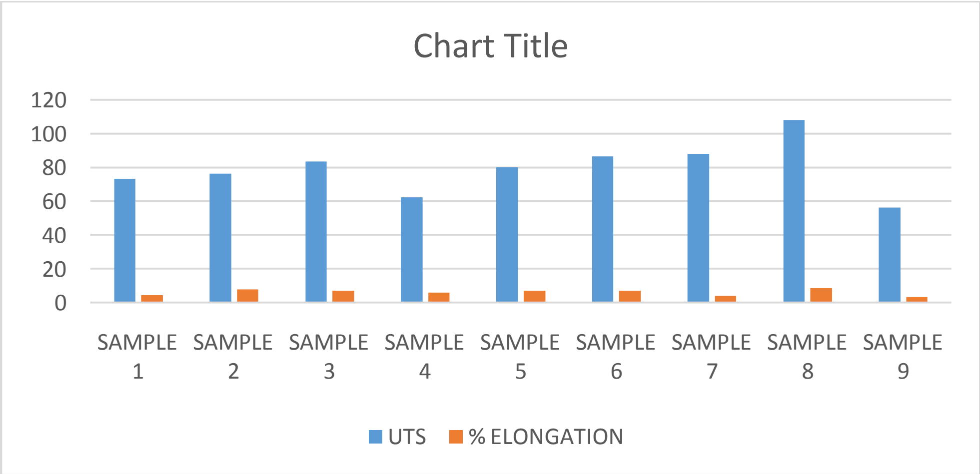


Fig.8: chart of UTS&% elongation

Hardness Test

Each mound sample is placed on the vicker's Micro hardness machine and hardness survey is seen on 3 portions that is named as Parent metal, HAZ and nuggetz one. Each value is plotted in the table 5. In fig.9 hardness of various zones is plotted for different samples.

Table no. 5: hardness values for tested samples

SAMPLE NO.	HARDNESS BM(HB)	HARDNESS TMAZ(HB)	HARDNESS HAZ(HB)
1	71.4	48.5	63.3
2	71.5	49.2	64.1
3	72.4	50.9	64.2

4	72.5	47.3	63.1
5	71.9	48.3	64.3
6	71.2	49.2	64.9
7	71.5	47.3	62.8
8	72.4	47.5	63.3
9	72.3	48.2	63.5

Table no.6: mean value of hardness

SAMPLE NO.	MEAN HARDNESS
1	61.0667
2	61.6000
3	62..5000
4	60.9667
5	61.5000
6	61.7667
7	60.5333
8	61.0667
9	61.3333

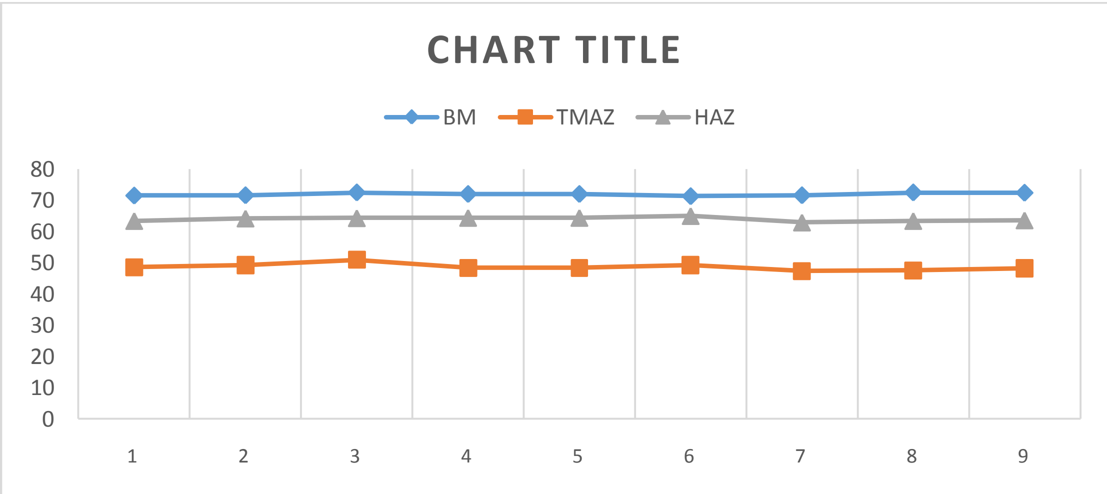
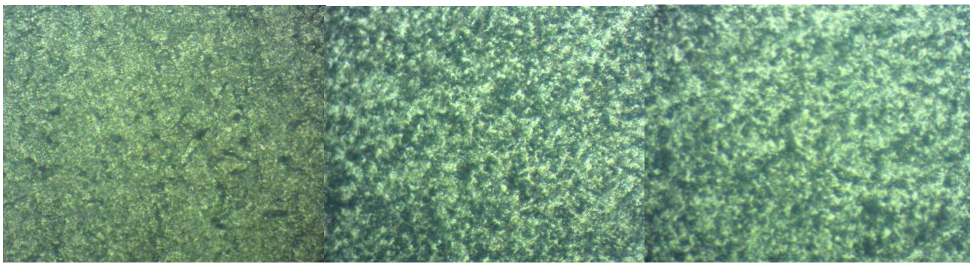


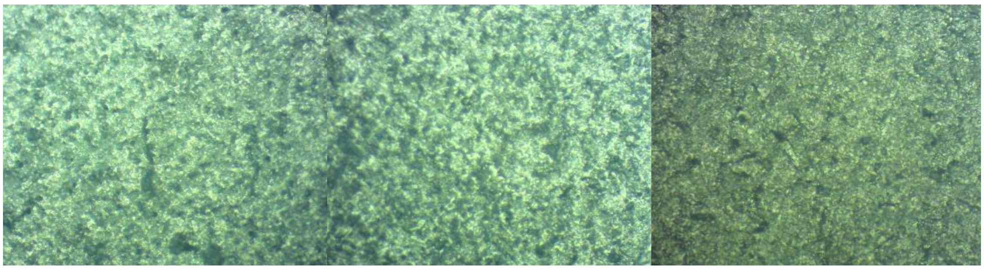
Fig.9: plot of hardness values

MICROSTRUCTURE

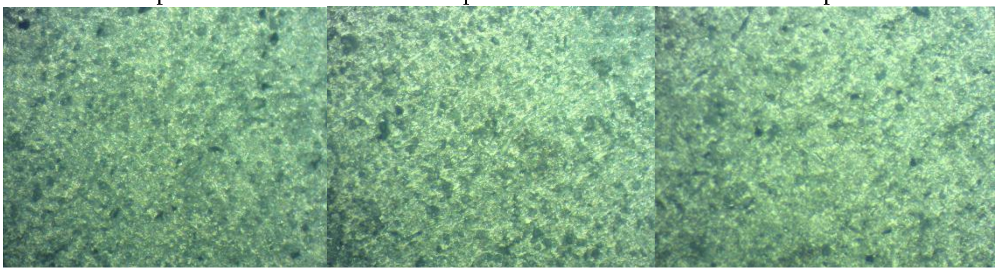
When the FSW joints are tested under the microscopes we get results in various views like weld penetration, cracks or blow holes if present in the weld, heat affected zone, effect of welding on grain structure of the material. The metallurgical testing of the joints has been done in accredited lab to find out desired results. Also the results of microstructure is carried out for each of the joints as shown in the figure no. 10 are tabulated in the table.7



Sample.1 Sample.2 Sample .3



Sample.4 Sample.5 Sample.6



Sample.7 Sample.8 Sample.9

FIG.10 : MICROSTRUCTRE OF SAMPLES

Table no.7: Results of microstructure

Sample no.	Crack	Blow Holes	Heat Affected Zone	Effect on grain structure
1	Observed	Not observed	Observed	Elongated grains observed
2	Not observed	Not observed	Observed	Elongated grains observed
3	Not observed	Not observed	Observed	Elongated grains Observed
4	Observed	Observed	Observed	Elongated grains Observed
5	Not observed	Not observed	Observed	Elongated grains Observed
6	Observed	Not observed	Observed	Elongated grains Observed
7	Observed	Not observed	Observed	Elongated grains Observed
8	Not observed	Not observed	Observed	Elongated grains Observed
9	Observed	Not observed	Observed	Elongated grains observed

CONCLUSION

The butt welding of Aluminum alloy AA6063 was fruitfully carried out using FSW technique. The samples were characterized by mechanical properties. The following conclusions were made from the present investigation.

- The finest operating conditions of FSW have been obtained for two plates of aluminium alloy AA6063 welded in buttjoint.
- From the experimental results the better performance is occurred at 3,6,7,8.
- A maximum mean ultimate stress of (108.33KN/MM^2) exhibited by tool with best process parameters of tool rotational speed, 1500rpmand transverse speed of 95mm/min.
- Axial force and rotational speeds are the main parameter for equivalent stress developed on the tool followed by rotational speed.
- It is observed that percentage of elongation is less for all the samples, which show the quantity of heat produced in the process is less.
- Hardness of sample-3 is relatively high in all zones of among the different sample.

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