Effects of Process Parameters on FSW of Aluminium Alloy (AA6063)

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Abstract

In this study, an attempt was made to study the impact of process parameters of friction-stir welding (FSW) on the mechanical properties of the FS welded AA6063. Properties like tensile strength, and hardness of the FSW joints were studied. Aluminium 6063 alloy is widely used in visible architectural applications such as door frames, window frames, shop fittings, irrigation tubing, sign frames and roofs. Aluminium 6063 alloy generally is hard to weld using conventional fusion welding processes. With development of Friction Stir Welding process (FSW) producing weld joint in aluminium, 6063 alloys become very easy compared to conventional fusion welding processes. In FSW, the rotating welding tool motion instigate frictional heating and severe plastic deformation and metal joining process is done in solid state. The weld obtained from FSW of AA6063 shows good mechanical properties and is defect free. Friction-stir welds don't show defects like porosity, alloy segregation and hot cracking, which were present in conventional fusion welds. Welds with good surface finish are produced during FSW process. In this study, the changes in mechanical properties of weld zone are compared with that of the parental metal. Process parameters such as welding speed, tool rotational speed and tool tilt angle plays major roles in the joint characteristics. The focus of this study is on the optimization of all these parameters. From investigation it is found that the joint made from the FSW yielded superior tensile properties and impact strength when tool rotational speed is 1100rpm and feed rate is 0.9mm/sec.

Keywords: Friction-stir welding, process parameters, AA6063, tensile strength, hardness

1. INTRODUCTION

Friction stir welding (FSW) process used for joining of metals parts was developed at "The Welding Institute (TWI)", United Kingdom in 1991 (1). FSW is used in a number of fields like aerospace, automotive, railway, and architectural applications. It is considered as an alternative to conventional fusion welding processes. In FSW, the joint is created using a cylindrical rotating tool, traversed mechanically through the materials to be welded. Frictional heat generated between the wear-resistant welding tool shoulder and pin, and the material of the work-pieces causes the weld to take place. The frictional heat and surrounding temperature causes the stirring action and the material get softened and mixed to each other (2).

FSW is a remarkable development in metal joining as compared to the conventional fusion welding methods. FSW requires considerably less energy. No gas or other flux is used, making the process environment friendly. Also this process does not involve use of any filler metal and therefore any aluminium alloy can be joined without the concern for the compatibility of composition, which is a major issue in fusion welding. When desirable, dissimilar aluminium alloys and composites can be joined (3).

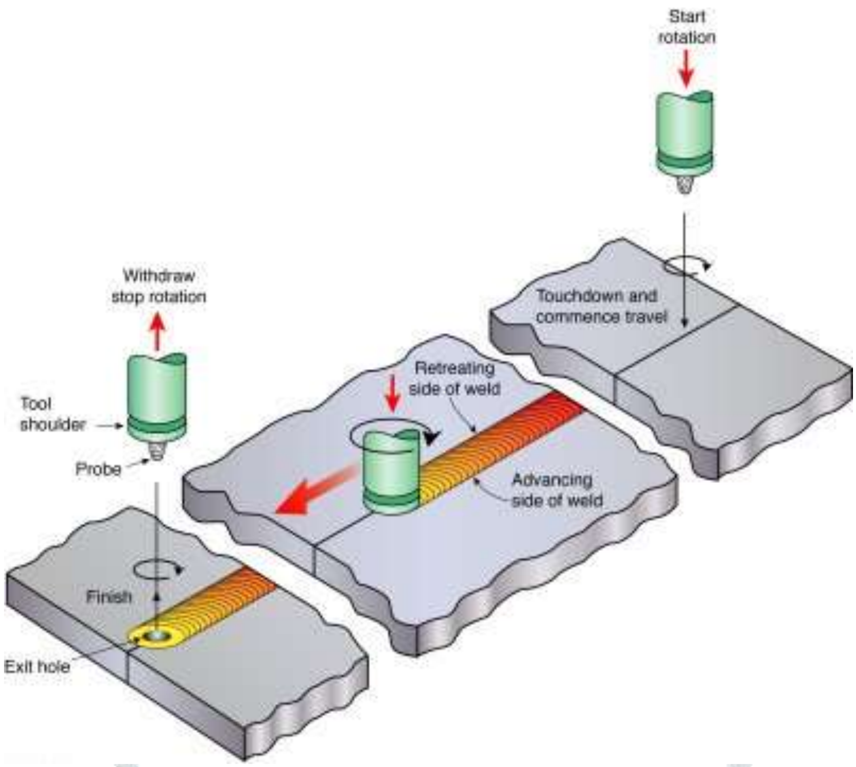

Fig. 1 Friction Stir Welding

FSW involves rotating tool consisting of a shoulder and probe. The tool applies pressure on workpiece continuously through the shoulder of the tool due to which surface which plasticizes material around the probe as shown in figure 1. Due to generation of the heat through the friction and causes the plastic deformation in a relatively thin layer under the bottom surface of shoulder. Rotating motion of the tool is in clockwise and translation is along the weld line are the important parameters (4).

2. LITERATURE REVIEW

Cavaliere et all (5) investigated the changes in microstructure formation of the welded joint by FSW. He displayed the study FSW of different aluminium alloys plates AA2024 and AA7075. Whereas, the comparison between FSW and TIG welding of Al-Mg-Si that mechanical and microstructural changes with the change in welding techniques was shown by Munoz et al. (6). Muhsin et al (7) studied the temperature variances occurring during the FSW process and resultant is that temperature is a function of tool rotational speed and heating rate is a function of transverse motion of tool in the welded line.

Several more parameters were investigated like micro-hardness, behaviour in material flow, microstructure formation and different mechanical properties like welded depth, heat affected zone etc. Most effective parameters that can improve the quality of welded joint with strength and resistivity are the favourite topics for researchers (8-10).

FSW has a vast literature that describe the connection between mechanical properties and parameters of research. This research paper focuses on the optimisation of process parameters such as ultimate tensile strength, % of elongation and tilt angle.

3. EXPERIMENTAL PROCEDURES

3.1 Material

Chemical composition and mechanical properties of AA 6063 are shown in following table 1 and 2 respectively.

table: 1 chemical composition of Al 6063

Element	Si	Fe	Cu	Mn	Mg	Zn	Ti	Al
wt%	0.45	0.19	0.02	0.04	0.45	0.03	0.02	Bal.

table: 2 mechanical properties of Al 6063

Name of Al alloy	Yield strength in MPa	Ultimate strength in MPa	Elongation %	Hardness in Hv
AA6063	214	245	2.5	80

3.2 Friction Stir Welding Tool

Apart from welding speed and tool rotational speed, the FSW process also depends on tool profile. A proper tool produces a good welding finish. Tool profile involves the geometry of the tool selected and the material used to make the tool. A non-consumable, cylindrical tool pin made of high carbon steel is used in the experimentation.

3.3 Welding Process

Following parameters are considered for this study:

1. Transverse Speed (TS)
2. Rotational Speed (RS)
3. Tilt Angle (TA)

In this research a simple butt joint of rectangular plates of aluminium alloy is prepared through FSW process producing a plate of dimensions 100x100mm. In this research various speeds like 900rpm 1100rpm and 1250rpm are used. The transverse speed taken are 25mm/min 35mm/min and 45mm/min respectively. The tilt angle taken are 1° 2° 3° respectively. The length of the tool pin was 4.5 mm. The mechanical clamps are used to fix the plate. The plates of AA6063 aluminium alloy are machined to prepare the butt joint. Axial force is kept constant in this research work (11-13).

4. RESULTS AND OBSERVATIONS

Several different FSW butt welds are obtained by varying the process parameters within the range and the optimum values are drawn based on those values. The tensile strength and hardness the weld joints are tested.

3.1 Tensile Test

After the welding, the samples were cut into standard shapes for the further experimentations. For the tensile test, UYS, level of prolongation tests samples were cut into I-shapes. Information acquired from the experimentation was considered further to see the effects of the different process parameters on the weld joint. Results are shown in the following table 3 for different tests.

table 3: mean uts and mean % elongation

SAMPLE NO.1	MEAN UTS	MEAN % ELONGATION

1	68.59	4.210
2	71.25	6.021
3	80.45	5.231
4	67.66	4.590
5	81.50	6.132
6	78.95	5.032
7	65.58	3.981
8	73.20	5.989
9	58.36	5.980

3.2 Hardness Test

The results of Hardness of Weld Zone (WZ), Parent Metal (PM) & Heat Affected Zone (HAZ) on different sets of combination of parameters were calculated according to the Brinell hardness (HB). The nine experiments were executed based on the L9 orthogonal array. The effect of various parameters on the weld zone such as tool rotational speed, translational feed and tilt angle was observed. The observational values of hardness is shown in table 4.9

table 4.9: hardness of aa6063

SAMPLE NO.	HARDNESS BM(HB)	HARDNESS TMAZ(HB)	HARDNESS HAZ(HB)
1	71.1	48.3	63.3
2	71.2	48.9	63.9
3	72.2	50.5	64.0
4	72.3	47.1	63.1
5	71.5	48.3	64.1

6	70.9	48.8	64.7
7	71.3	47.4	62.5
8	72.1	47.5	63.0
9	72.1	48.2	63.2

CONCLUSION

The joining of Aluminium alloy AA6063 was successfully done using FSW process. Characterization of samples was on the basis of their mechanical properties. Following conclusions were made from the present research work.

• The optimum values of FSW have been obtained for two plates of aluminium alloy AA6063 welded in butt joint.

• Maximum mean ultimate tensile stress was exhibited by tool with optimal process parameters of tool rotational speed, 1100 rpm and transverse speed of 0.9mm/sec.

• Rotational speed affects the weld joint greatly followed by transverse feed rate.

• It is seen that percentage of elongation was less for all the specimens, which shows that the amount of heat generated in the process was less.

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