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Experimental Investigation of Tensile Strength in Single Sided Friction Stir Welding on Aluminium Alloy 6061

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***Abstract* – In the present work, staight cylindrical tool of three different shoulder diameters all made of High speed steel for the friction stir welding (FSW) aluminium alloy 6061 and tensile test of the welded joint are tested by universal testing machine. The detailed mathematical representation is simulated by Minitab 15. In this investigation, an effective approach based on Taguchi way has been developed to determine the optimum conditions leading to higher tensile strength. Experiments are conducted by using L9 orthogonal array in Taguchi method. The present work aims at optimizing process parameters to achieve high tensile strength. In Tensile strength the rotational speed play a key role in FSW. The shoulder dia. and feed rate does not contribute the main effect in FSW.**

***Keywords* – Friction stir welding (FSW) tool, Milling machine, Aluminium alloy AA6061, Minitab 15, straight cylindrical tool, tensile test.**

I. INTRODUCTION

In FSW process the coupled material is plasticize by heat generated due to the friction between the face of the plates to be welded and the contact face of tool. It was invented, developed & patented at the welding institute (TWI), UK possible of combination high strength to weight ratio materials fruitfully made the process to be applied to an increasing number of combination. The tool rotation bring plastic deformation due to an elevated temperature. The maximum temperature reached is lesser than the melting temperature of base metal. FSW creates weld by the combined action of frictional heating and mechanical deformation. It is being considered as a thermo-mechanical process, which transforms heterogeneous microstructure of metal to more homogeneous microstructure. The process is most appropriate for vital applications like combination of structural components made of aluminium and its alloys.

II. SYSTEM MODEL

First select the material for the work piece and shoulder dia. secondly cut off the material into the desired pieces according to our dimension. Thirdly select the parameters by which the process should be done then fabricate the pieces. And at last Analyze the pieces and result is out.

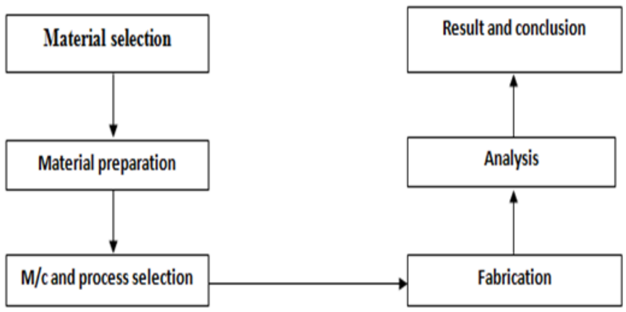

Fig. 2.1 Prcess Flowchart

III. PREVIOUS WORK

Friction stir welding (FSW) is a new solid-state joining technology invented by The Welding Institute of UK in 1991 [10]. Compared to many other conventional fusion welding processes, it has been considered to be an outstanding and eco-friendly equipment due to its fine microstructure, dearth of common metallurgical defects, free of shielding gas and filler metal, low residual stresses, and superior dimensional stability [5,11]. A rotating cylindrical tool usually consisting of shoulder and pin is inserted into and stirred along the butt joint of the joining material partners. Since heating and plastic flow of the welded material produced by the rotating FSW tool attain bonding of the joining partners well below the melting point [4]. Hassan et al. [3] studied the nugget zone (NZ) produced with various welding process parameters in Al alloy 7010 and pointed out that there was an optimum rotational rate for a given travel speed to achieve the highest strength and ductility for the NZ. Rajamanickam et al. [7] concluded that the peak temperature in the weld zone was primarily influenced by the rotation rate, and the weld speed was the main input parameter that had the highest statistical influence on tensile properties of the FSW joints of AA2014 alloy. Sharma et al. [8] reported that the mechanical properties of FSW AA7039 joints improved with the increasing rotation rate and the decreasing welding speed. Hao et al. however, found that increasing the tool rotation rate reduced the ultimate tensile strength (UTS) of the Al–Mg–Er FSW joints, while increasing the welding speed increased the UTS [2]. Optimization of process parameter is the key role in the

Taguchi way to achieving high value without increasing cost. Optimization of process parameters can improve value and the best process parameters obtained from the Taguchi way and other noise factors. These study results showed that the effect of the FSW parameters on the joint properties is varies for different aluminum alloys. As an important class of structural material of light metals, Al–Zn–Mg–Cu alloys are widely used in aerospace, railway, automotive, and shipbuilding industries because of their balanced properties [1,6,9].

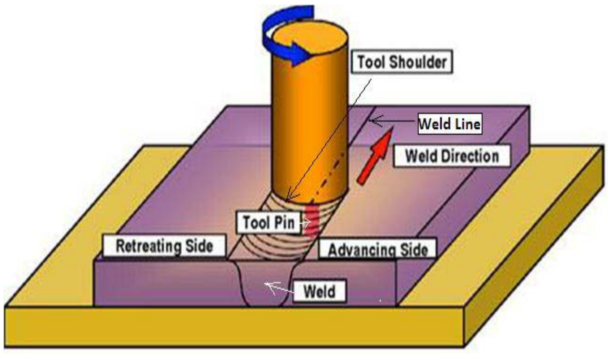

Fig. 3.1 FSW Process

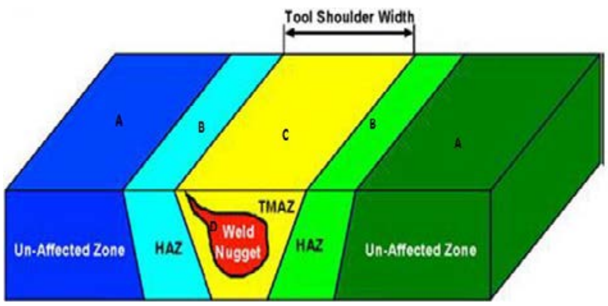

Fig. 3.2 Different types of Zone's made during welding

IV. FSW WITH VERTICAL MILLING MACHINE

The simple vertical milling machine is used to machining the process by using rotating tool for stirring the material

Table.1 Specifications and Standards

Manufacturer	*Simple milling machine*
Spindle position	Vertical
RPM range	1930 rpm
Dia. of Tool holder	24
Motor	5 hp, 1450 rpm
Transverse speed range	10-900 in.

V. FSW PROCESS PARAMETERS

Process parameters take part in important role in deciding the weld value. The process parameters selected are shown in table.

Table 1. Process Parameters with equivalent levels

Sr No.	Process Parameters	Range	Level 1	Level 2	Level 3
1	RPM	1570-1930 rpm	1570	1700	1930
2	Transverse speed	20-30 mm/min	20	25	30
3	Shoulder dia.	17-21	17	19	21

VI. MATERIAL SPECIFICATION

1) Aluminium Alloy AA6061

The base material selected for this survey are AA6061 aluminium alloys sheets of 6 mm thickness having chemical composition and shown in the Table 2. In the present study, sheets of size 305mm x 153mm (1ft. x 0.5ft.) AA6061 of 9 pieces were cut for welding as shown.

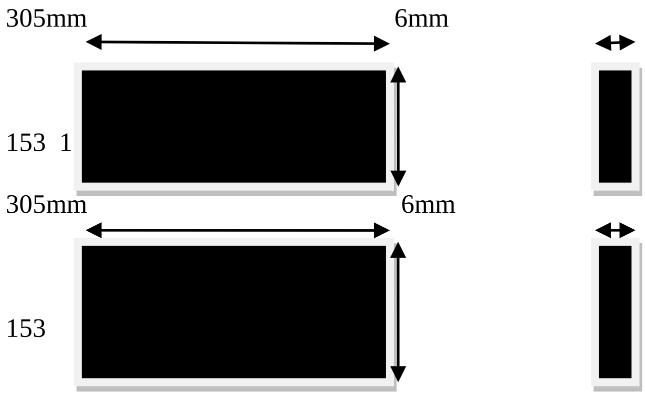

Fig. 3.3 Cutting View of AA 6061 pieces

Table 2. chemical composition of AA 6061

Material	Cu	Mg	Mn	Si	Fe	Al
AA6061	0.15-0.40	0.8-1.2	Max 0.15	0.4-0.8	Max 0.7	Balance

Fig. 3.2 AA 6061 Material

2) Selection of Tool:

The tool consists of a pin and a shoulder, Contact of the pin with the workpiece generate frictional heating and soften the workpiece, contact of the shoulder to the workpiece increase the workpiece heating and expands the zone of softened material. Tool was made in two different parts, one is having same pin length, and other one is three different shoulder dia. with suitable collets for holding purpose.

Table 3. Specifications of welding tool

Length of Tool	60 mm
Tool shoulder dia.	17 mm
Pin dia.	6 mm
Pin length for single pass	5.7 mm

VII. DESIGN OF EXPERIMENT FOR FRICTION STIR WELDING PROCESS

Three experiments in each set of process parameters have been performed on AA-6061 plates by L9 orthogonal array. The three factors used in this experiment are the rotating speed, travel speed and shoulder dia. The factors and the levels of the process parameters are presented in Table. The experiments are performed on a vertical milling machine.

Table 4. experimental layout of L9 orthogonal array

Experiment	Rotational speed (rpm)	Travel speed (mm/min)	Shoulder dia. (mm).
1	1570	20	17
2	1570	25	19
3	1570	30	21
4	1700	20	19
5	1700	25	21
6	1700	30	17
7	1930	20	21
8	1930	25	17
9	1930	30	19

Fig. 3.4 Shows tool on vertical milling machine

VIII. TESTING PROCEDURE

Later than friction stir welding tensile test performed on universal testing machine of capacity 100 KN as shown in fig.6. Testing performed in room temperature of 25°C and relative humidity 40-60%, if A is the cross sectional area and F is the maximum force and tensile strength calculated by:

Tensile strength=F/A (Force/Area)

Fig. 3.5 UTM setup for Tensile Test

As prescribed by the design matrix nine joints were fabricated. The welded joints were sliced using a power hacksaw and then machined to the required dimensions by using horizontal milling machine. Tensile specimen can be made according to ASTM (American Society for Testing of Material's) standards to evaluate the tensile strength of the joints Tensile strength of the FSW joints were evaluated by conducting test in Universal Testing Machine (UTM).

Fig. 3.6 Horizontal milling machine

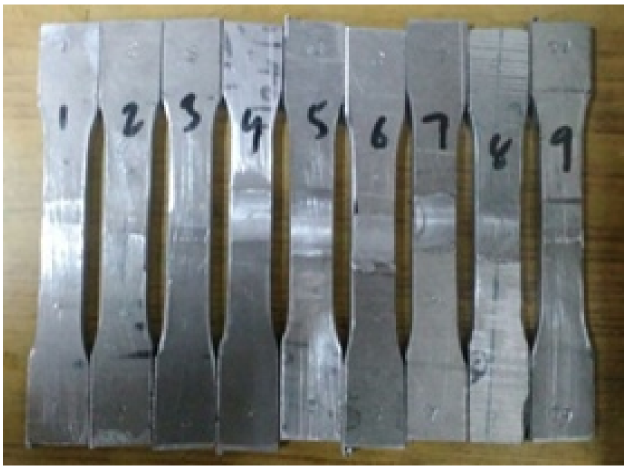

Fig. 3.7 Tensile test specimen before failure

Fig. 3.8 Tensile test specimen after failure

IX. RESULT AND DISCUSSION

Table 5 Result input/output parameter of orthogonal array

Speed (rpm)	Feed rate (mm/min)	Shoulder Dia. (mm)	Area (mm^2)	Load (km)	Tensile Strength
1700	25	21	90	24	0.266

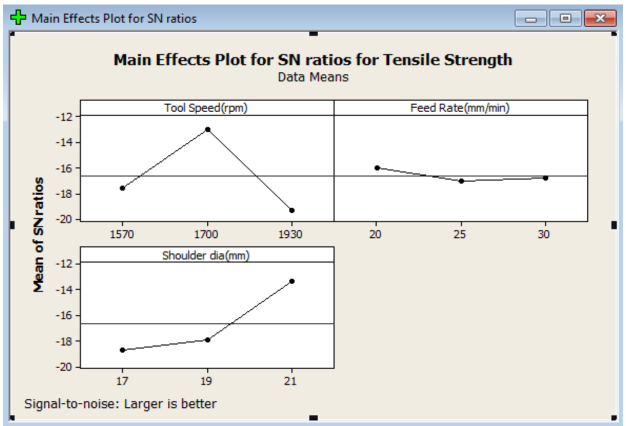

Fig. 3.9 Main effects plot for SN ratio for Tensile Strength

1) *Effect of Tool Speed in Tensile Strength*

The effect of tool speed on the tensile strength value is shown in fig. 3.9 for S/N ratio. At Lower TRS, the heat generation is not sufficent to soften the material & therefore results in insuffícent amalgamation of materials hence tensile strength of joints are found to be low. When the Tensile strength increases with the increase in TRS right from 1570 to 1700 rpm this is fundamentally due to the increased heat generation obtained with increase in TRS resulting in superior material flow & mixing of materials.

Furthur increase in TRS beyond 1700 rpm casuses reduction in tensile strength which can be attributed to increase in grain size due to grain growth at higher peak temprature.

2) *Effect of Feed Rate on Tensile Strength*

The effect of feed rate on the tensile strength value is shown in fig. 3.9 for S/N ratio. The joint made-up at a welding speed of 25 mm/min. gives good tensile strength. When the welding speed increases from 20–25 mm/min. gives fine tensile strength because due to enough heat generation that is exactly sufficient to cause the material to flow plastically under appropriate condition. When the tool traveled at higher speed, with the increase in welding speed above 25 mm/min, the UTS of the joint decrease.

3) *Effect of Shoulder Dia. on Tensile Strength*

The effect of shoulder dia. on the tensile strength value is shown in fig. 3.9 for S/N ratio. With the increase in diameter from 17-21 the UTS also increased as shown. This might be because of the increased contact area with the increase of shoulder diameter and might be the reason for the increase of higher temperature region. The temperature distribution under the shoulder becomes more uniform. With the increase of shoulder size (21 mm) the higher temperature region might be increased. Although the material flows at retracting side & the advancing side were different, it might be estimated that the temperature distribution is nearly symmetric to the welding line.

DISCUSSION

Optimization of process parameter is the key role in the Taguchi way to achieving high value without increasing cost. Optimization of process parameters can improve value and the best process parameters obtained from the Taguchi way and other noise factors.

The S/N ratio for the larger-the-better is:

$$S/N = -10\log_{10}\{1/n\sum 1/y^2\}$$

X. CONCLUSION

Taguchi method is used in this work. The following conclusions have been drawn according to the Taguchi Graph's:

1. In a Tensile strength, the rotational speed plays a key role in FSW. The shoulder dia. and feed rate contribute a little effect in FSW.
2. According to the results the output values at1700 rpm, 25mm/min feed rate, 21mm shoulder diameter are the best results for AA 6061 in FSW.

XI. FUTURE SCOPE

1. Effect of different kinds of Microstructure of Tool and Plate can be studied.
2. The variation in temprature can be analyzed by using temprature sensors.
3. Better monitoring and control of FSW needs a substantial attention.

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