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Experimental Analysis on Effect of Tool Transverse Feed, Tool Rotational Speed And Tool Pin Profile Type on Weld Tensile Strength of Friction Stir Welded Joint of AA 6061.

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Abstract

Friction stir welding is an emerging solid state joining process which is used to join metals and alloys having low weldability. In this research work experimental analysis has been performed on FSW for AA 6061. Effect of FSW parameters like tool rpm, tool transverse speed and tool pin profile are investigated. A vertical milling head is used to produce FSW joints. Hot work tool steel (H13) is used as a tool material and total 3 number of tools are manufactured namely as cylindrical pin, tapered pin and square pin. Tool transverse feed of 10, 15 and 20 mm/min and tool rotational speed of 2250, 2500 and 2750 rpm are taken for the study. A full factorial method is used for three numbers of parameters and their three levels and total 27 numbers of experiments are conducted keeping all other parameters constant. As a response weld tensile strength of joint is tested according to ASME-IX. Response surface method (RSM) and Analysis of variance (ANOVA) is adopted for the statistical analysis. As a conclusion it has been derived that feed of 15 mm/min, tool rotational speed of 2750 rpm and tapered pin profile gives better weld strength for the given experimental conditions.

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Keywords: Friction Stir Welding, AA 6061, H13, Tool transeverse feed, Tool rpm, ASME-IX, RSM, ANOVA.

1. Introduction

Friction Stir Welding (FSW) is based on the principle of obtaining adequate high temperatures to forge two metal components, using a rotating tool which moves along a joint line. The metal is not melted as in the majority of welding

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operations. Instead in FSW, the metal is heated to forging temperature, making it soft. This has many advantages, the biggest ones being low residual stress from the heat and the ability to weld different materials having low weldability. Furthermore, FSW has been proven to produce high strength joints without inclusions or impurities.

Nomenclature

FSW	Friction Stir Welding
AA 6061	Aluminium Alloy 6061
H13	Hot Work Tool Steel
RSM	Response Surface Method
ANOVA	Analysis of Variance
ASME-IX	American Society of Mechanical Engineers- Section-IX
ASTM	American Society for Testing and Materials
DOE	Design of Experiment

2. Literature Survey

W.Y. Li *et al.*[1], (2014) studied about The effects of rotational and welding speeds on the microstructure and mechanical properties of bobbin tool Friction stir welded (BT-FSW) Mg AZ31 were investigated. **S.Yu.Tarasov *et al.* [2], (2014)** Studied of diffusion wear mechanism in 1.2344 X40CrMoV5-1 steel FSW tool has been carried out from the standpoint of tribological layer generation and interaction with the tool's metal. **Juan Chen *et al.* [3], (2015)** performed double-sided friction stirs welding (DFSW) with the combined use of convex and concave tools (concave-DFSW) were studied for the joining of a magnesium alloy. The sound joints made by the concave-DFSW were possible under the appropriate conditions. **F.F. Wang *et al.* [4] (2015)** investigated the typical microstructure and mechanical properties of joints and the effects of rotational speed on the microstructure and tensile properties are investigated where also investigated. As a result they found that the rotational speed increases, the grain size of the stirred zone increases. **Binxi Chen *et al.* [5] (2012)** in their study small-dimension Al3003 pipe and pure copper pipe of thin wall (Al: 1.5 mm; Cu: 1 mm) and small diameter (19 mm) were successfully joined by a developed welding method with a specially-designed friction stir welding (FSW) system**K. Kumaria *et al.*[6] (2015)** A twin-tool setup has been designed and fabricated to make a comparative study between twin tool and single tool using double pass in a friction stir welding process. **J. Mohammadi *et al.*[7] (2011)** performed lap joint friction stir welding (FSW) between dissimilar AZ31B and Al 6061 alloys sheets was conducted using various welding parameters including tool geometry, rotation and travel speeds. **Z. Shen *et al*.[8] (2014)** In this study Lap welds between Al5754 to DP600 steel (aluminium plate top, and steel plate bottom) were manufactured by friction stir welding (FSW).The effects of welding parameters (i.e. travel speeds and penetration depth into lower steel sheet) on the interfacial bonding, tensile strength, and failure mechanism were investigated. **D. M. Rodrigues *et al*. [9] (2010)** Studies the differences in friction stir weld ability, assessed by weld defect analysis and weld strength characterisation, will be related to the markedly different plastic behaviours of both base materials. Found that high traverse speeds can be achieved in FSW of both base materials with carefully chosen process and tool parameters. **Hasan *et al.*[10] (2007)** developed an artificial neural network (ANN) model for the analysis and simulation of the correlation between the friction stir welding (FSW) parameters of aluminium (Al) plates and mechanical properties. From adequate literature survey parameters like tool rpm, tool transverse feed, and tool profile type were selected for the study and responses like tensile strength of joint was investigated.

3. Experimental work

Experimental work was carried out on a vertical milling head which is situated at SHREE GAJANAND ENGINEERING 366/5/1 GIDC, Makarpura, near hanuman temple, Krishna Steel Street, Vadodara, Gujarat. As a base material aluminium alloy 6061 (AA 6061) was used and the dimensions of the plates were 180*150*6 mm. Hot work tool steel (H13) was selected as a tool material and total 3 types of tools were manufactured as shown in fig. 1. Tool rpm of 2250, 2500 and 2750 rpm and tool transverse speed of 10, 15 and 20 mm/min was selected for the study.

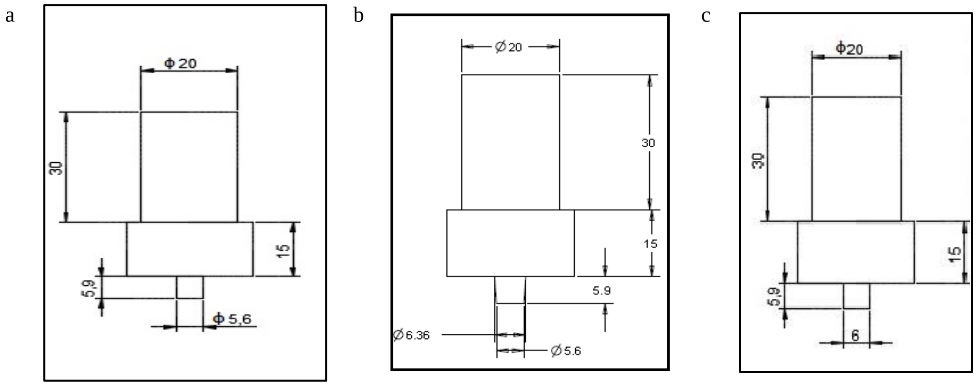

Fig. 1. Different tool configuration and dimensions of tool (all the dimensions are in mm). (a) Cylindrical pin tool; (b) Tapered pin tool; (c) Square pin tool.

Full factorial method is adopted for the statistical analysis and as per that three levels of each parameters are selected and experimentation work is carried out all different configuration of tools and all other parameters were kept constant. Fig. 2 shows the experimental work and interaction between tool and base plate. After the successful welding of all 27 plates tensile testing was carried out using ASME-IX. All the test were carried out at MET-HEAT ENGINEERS PVT. LTD. 857/2, G.I.D.C. Industrial Estate Makarpura, Vadodara - 390 010 Gujarat.

Fig. 2. Interaction between tool and base plate and experimentation on vertical milling head

4. Design of Experiment (DOE)

A full factorial method was adopted for three parameters and three levels and according to that total 27 experimentation were carried out. For the analysis purpose Design Expert 7.0.1 was used and ANOVA was carried out to find out the most significant parameter.

5. Results and Discussion

Table 1 shows the tensile test results for Cylindrical, Tapered and Square pin profile tool. From the table it can be seen that maximum tensile strength is achieved for tapered pin profile tool and 10 mm/min feed with 2750 rpm of tool. Fig. 3 shows the effect of tool rpm on tensile strength of joint. From the figure it is clear that as the rpm of tool increases and the reason behind that as the tool rpm increases the friction between tool pin profile and the base plate increases and due to which heat input increases and that takes base material in to plastic stage and proper bonding between two plates which are to be joined. This proper bonding leads to increase the strength of joint.

Table 1 Tensile strength (MPa) result for all the welded plates

Sr.no	Tool Rotational Speed (rpm)	Tool Traveling Speed(mm/min)	Tool Shape	Tensile Strength(MPa)	
1	2250	10	Cylindrical	73.3	112.8
2	2250	15	Cylindrical	63.1	71.5
3	2250	20	Cylindrical	78.9	82.1
4	2500	10	Cylindrical	63.5	82.3
5	2500	15	Cylindrical	97.2	110.3
6	2500	20	Cylindrical	40.5	57.5
7	2750	10	Cylindrical	109.1	117.4
8	2750	15	Cylindrical	119.5	121.5
9	2750	20	Cylindrical	123.5	126.5
10	2250	10	Tapered	78.8	82.6
11	2250	15	Tapered	90.1	92.6
12	2250	20	Tapered	52.7	104.6
13	2500	10	Tapered	59.9	106.9
14	2500	15	Tapered	94.3	111.1
15	2500	20	Tapered	83.5	90.4
16	2750	10	Tapered	103.8	131.8
17	2750	15	Tapered	127.7	130.4
18	2750	20	Tapered	68	86.4
19	2250	10	Square	58.8	61.7
20	2250	15	Square	79.5	81.1
21	2250	20	Square	83.1	93.2
22	2500	10	Square	55.1	62.7
23	2500	15	Square	39.2	54.4
24	2500	20	Square	34.6	38.9
25	2750	10	Square	71.9	97.4
26	2750	15	Square	43.2	47.8
27	2750	20	Square	110.2	120.2

Fig. 4 indicates the effect of tool transverse speed on tensile strength of welded joint. It can be seen that as the feed of tool increases the joint tensile strength increases but on further more rise in feed leads to decrease the strength of joint. The reason behind that as the tool transverse feed is low the rate of heat input is very high and that leads to melt the metal to be joined. If the value of tool transverse feed is so high than the rate of heat input is very low and due to which it is not possible to achieve the temperature which will take material to plastic stage and if the material is not in plastic stage than proper flow of material from retracting side to advancing side is not possible which leads to improper bonding of metals to be joined. From ANOVA tool shape is having a "p" value of less than 0.0001 which means that it is the most significant parameter which affects the tensile strength of welded joint.

6. Conclusions

From the present experimental investigation following conclusions are derived:

- As the tool feed increased, UTS of FSW joint increases up to certain level as feed is furthered increased, UTS decreases.
- As the tool rpm increases UTS of FSW joint increases as more heat is generated due to more friction.
- For this experiment condition, tapered tool geometry gives the good UTS for joints the reason behind that is the increased contact area between tool and base plate.
- For the adopted experimental condition feed of 15 mm/min, geometry of tapered pin and tool rotational speed of 2750 rpm gives the good results of UTS of FSW joint.
- According to ANOVA it is found that tool shape is the most significant parameter which affects the UTS of FSW joint.

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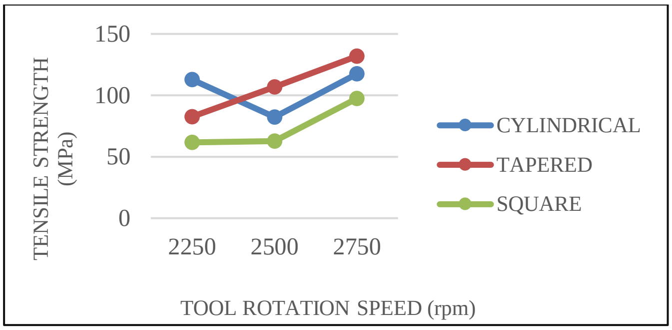

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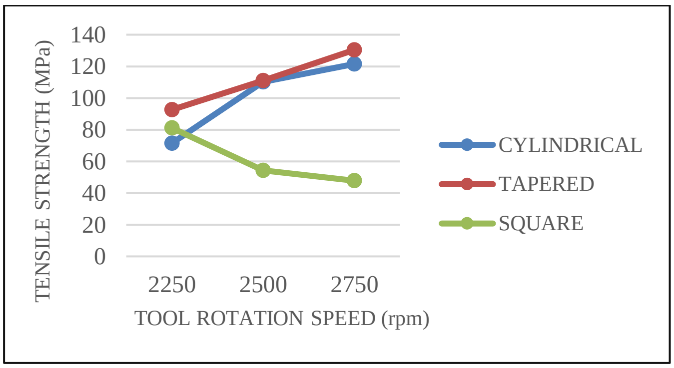

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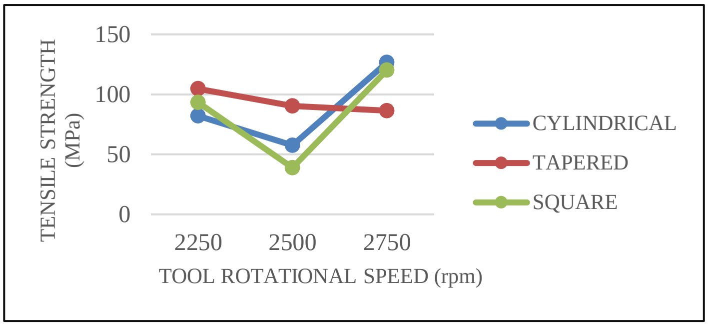

Fig. 3. Effect of tool rpm on weld tensile strength for different feed and tools; ,(a) 10 mm ;(b) 20 mm; (c) 30 mm.

a

b

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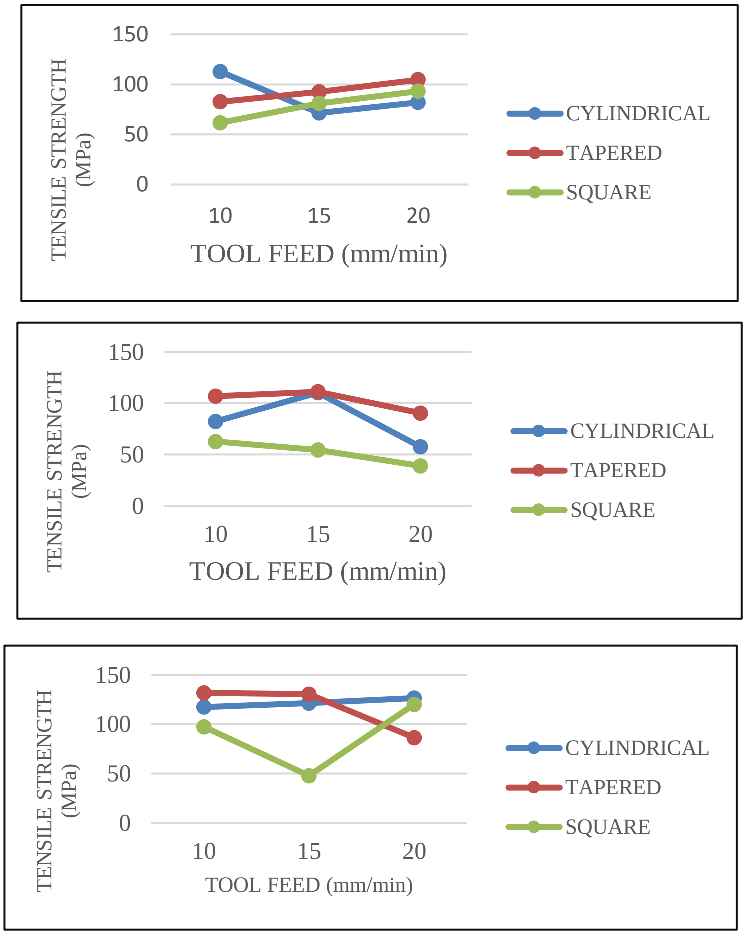

Fig. 4. Effect of tool rpm on weld tensile strength for different feed and tools,(a) 2250 rpm;(b) 2500 rpm; (c) 2750 rpm.

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