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To Study the Mechanical Behaviour of Friction Stir Welded Joints of Aluminium Alloy of Aa6061 with Aa5086

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Abstract: *In the present work, the joining of dissimilar AA5086 and H32-AA6061 aluminium plates of 5mm thickness was carried out by friction stir welding technique. The present work shows that dissimilar alloy materials have highest effect on mechanical properties of the welded specimen taken from welded zone. They were tested for mechanical properties such as tensile strength. Effect of tool pin profile, feed rate and spindle speed on tensile strength of welded joints were investigated. The experimental results were analysed with analysis of variance (ANOVA), which is used to investigate the influence of parameters consider for the study.*

Keywords: *Friction stir welding, tensile strength, ANOVA technique.*

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I. Introduction

Friction Stir Welding (FSW) is a recently developed friction welding process which was developed at The Welding Institute (TWI), Cambridge, UK. This method uses a rotating non-consumable welding tool. This method utilizes a non-consumable rotating tool to make frictional heat and distortion at the welding position, accordingly upsetting the advancement of a joint, while the material is in the strong state. The principle advantages of FSW are that we can join even those alloys that do not join by conventional welding process (e.g., 5xxx and 6xxx series aluminium alloys). Moreover FSW welded joints are viewed as the absence of filler material or since it requires no filler. Likewise the hydrogen damage that happens during welding of steel and other iron combinations must be kept away from by diminishing the hydrogen substance of the FSW welded joints.

Generally, friction welding is done by moving one part with respect to the next along a typical interface, while applying a compressive force over the joint. The contact warming produced at the interface softens the two parts, and when they progress toward becoming plasticised the interface material is expelled out of the edges of the joint with the goal that spotless material from every segment is left along the first interface. The relative movement is then stopped, and a final compressive force might be connected before the joint is permitted to cool. In friction welding no molten material is created and the required weld being shaped in the solid state.

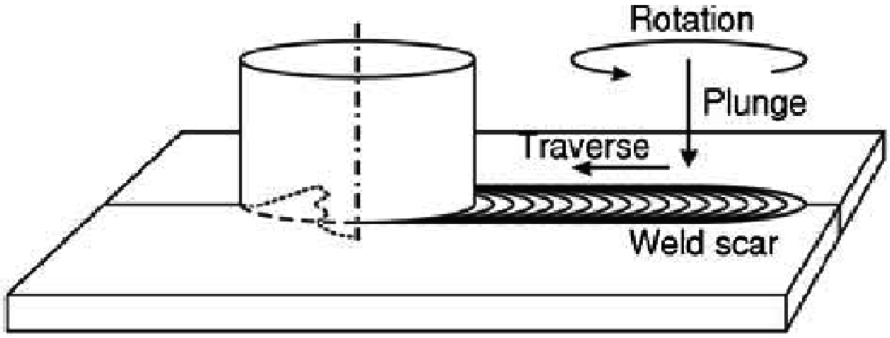

Fig. 1 Schematic diagram of Friction stir welding

II. Review work

Bhate et al. (2016**)** reviewed of research papers related to friction welding is performed. Friction welding is a best till date recognized approach to weld similar as well as dissimilar metals. It is an ordinarily used welding process in industries like vehicle industries, submarine engineering industries aeronautical industries, and heavy responsibility industries.[]

Verma et al. (2016) studied solid state joining process used to merge non- similar or similar metals. It is an extensively used welding process in industries like aeronautical industries, car industries, submarine engineering industries and heavy obligation industries. On this research work friction welded joints of non-similar and similar metals i.e. mild metal-slight.[] Dubey et al. (2017) have executed friction stir welding of marine grade aluminium alloy 5083 and high strength aluminium alloy 2024 T3 must be anticipated. The existing work suggests that different varieties of alloy substances have maximum effect on mechanical properties of the specimens taken from welded zone. They had been examined for mechanical properties together with tensile strength and Rockwell hardness respectively and are optimize with TOPSIS technique to predict the parameter of welding joints.[]

III. Objectives Of Work

- Prepare weld sample of aluminium alloy AA5086 H32-AA6061 T6 grade (300mmx30mmx 5mm).
- To study the effect of different tool pin profiles on the quality of the welded joint.
- To study the effect of spindle speed and feed rate on the welded joint

IV. Methodology and experimentation

1.1 Material Used

1.2 Workpiece material:-

The current experimental research is a try to discover the feasibility of using FSW method in joining dissimilar AA5086 H32-AA6061 T6 grade aluminium alloy sheets of 5 mm thickness. Two workpieces of size 300 mm x 30mm x 5mm are joined collectively to make butt joint. The composition of aluminium alloys are given in table 4.1.

Table 4.1 Chemical Composition by wt%

Material	Mg	Mn	Si	Fe	Cu	Zn	Cr	Ti	Ni	Al
AA5086 H32	4.2	0.59	0.07	0.16	0.05	0.15	0.08	0.06	0.01	Balance
AA6061 T6	0.91	0.09	0.52	0.32	0.21	0.095	0.11	0.04	-	Balance

4.3 Welding Tool Material

The tool geometry plays an important role in FSW process. Localized heating and material flow are the two basic functions of FSW tool. Tool is used in this study is made of high-speed tool steel. This is the most commonly used material due to easy availability, thermal fatigue resistance, wear resistance, especially for aluminium and copper.

The selected tool geometries and the fabricated tool for FSW of 5mmthick aluminium alloy is manufactured using lathe.

In the current study, the four types of tool profiles were designed and applied; namely,

• Plain Circular or round tool profile
• Circular with Threaded tool profile
• Square tool profile.

4.4 Process Variables and Their Limits

The working ranges of the parameters for subsequent design of experiment, based on Taguchi's L9 Orthogonal Array (OA) design have been selected. In the present experimental study spindle speed, feed rate and tool profile have been considered as process variables. The process variables with their units and notations are listed in Table 3.3

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Table 3.3: Process variables and their limits

Parameters/Factors		Level		
		1	2	3
A	Spindle speed (rpm)	900	1200	1500
B	Feed rate (mm/min)	20	30	40
C	Tool Profile	Round	Round with threaded	Square

4.5 Friction Stir Welding Procedure

Nine weldments had been prepared by joining AA5086 and H32-AA6061 T6 grade aluminium alloy plates. The welding of aluminium alloys is completed on a vertical milling machine. The three factors used in this experiment are the rotating speed, feed and tool pin profile. The elements and the levels of the process parameters are presented in table 3.3. A rotating device is plunge as much as the shoulder within the abutting edges of aluminium plates having dimensions are 300 mm x 30mm x 5mm (L x b x t) respectively. Those plates have been placed on fixture in a manner that the displacement of plates in the course of welding and fasten them along the travel line of welding tool. The velocity difference among the rotating tool and the stationary work piece, heat is produced through frictional work and deformation of aluminium. This deformed material fused as a single piece creates a joint. To perform the welding, the rotating tool is traversed alongside the line, at the same time as the shoulder of the tool is maintained in intimate contact with the plate surface. Shoulder confirms the underlying material so void formation and porosity behind the probe are averted. As the heat dissipated into the surrounding material, the temperature rises and material softens without reaching the melting point (for this reason known as solid state process). as the pin is moved within the path of the welding leading face of pin, assisted with the aid of a precise pin profile, forces plasticized material to the again of the pin while making use of a large forging pressure to consolidate the weld steel. While the weld distance is protected, the tool is pulled out of the workpiece leaving in the back of ahole as a foot print of the device. The following figure 3.4 contains the sample prepared by friction stir welding.

V. Tensile Strength Test

After friction stir welding, tensile test is performed on universal testing machine. If A is the cross sectional area and F is the maximum force and tensile strength calculated by:
Tensile strength=F/A.

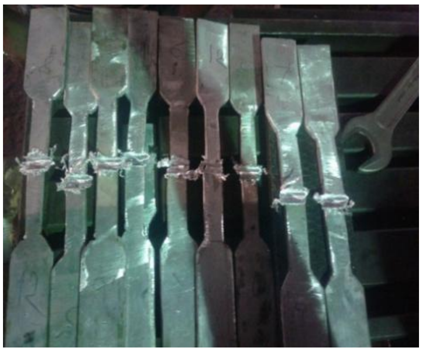

Fig 2 Tensile test specimen

Fig 3 Process setup for tensile test

Fig 4 After performing tensile test

Table 5.1: Tensile test for Aluminium alloys weld material

Experiment no.	Spindle speed (rpm), N	Feed rate (mm/min), f	Tool Profile	Tensile strength (MPa)
1	900	20	Square	25.32
2	900	30	Round with Threaded	27.05
3	900	40	Round	28.42
4	1200	20	Round with Threaded	26.42
5	1200	30	Square	27.20
6	1200	40	Round	28.15
7	1500	20	Square	27.67
8	1500	30	Round	26.25
9	1500	40	Round with Threaded	25.12

5.1 CALCULATIONS OF S/N RATIOS FOR TENSILE TEST

S/N ratio is obtained by using Taguchi's methodology. Here the term 'signal' represents the desirable value (mean) and 'noise' represents the undesirable value (standard deviation).

$$\frac{S}{N_{(Bigger\ )}} = -10\ \log\left(\frac{\sum\left(\frac{1}{y_i^2}\right)}{n}\right)$$

Table 5.2 S/N ratio for tensile test result

Experiment no.	Spindle speed (rpm)	Feed rate (mm/min), f	Tool Profile	Ultimate Tensile Load, N	Tensile strength (MPa)	S/N ratio
1	900	20	Square	1862	25.32	28.07
2	900	30	Round with threaded	1990	27.05	28.64
3	900	40	Round	2070	28.42	28.99
4	1200	20	Round with threaded	1921	26.42	28.34
5	1200	30	Square	2001	27.2	28.69
6	1200	40	Round	2078	28.15	29.02
7	1500	20	Square	2035	27.67	28.84
8	1500	30	Round	1931	26.25	28.38
9	1500	40	Round with Threaded	1848	25.12	28.00

5.2 ANOVA for Tensile Strength

Results obtained for the tensile strength are shown in the Table 5.1. The results for tensile strength were obtained from the nine samples of each weldjoints those are performed by Taguchi. The experimental results analysed with ANOVA are shown in the Table 5.2. The F value calculated through MINITAB 18 software is shown in the second last column of ANOVA table which suggests the significance of the factors on the desired characteristics. Larger is the F value higher is the significance (considering confidence level of 95%). The results show that only tool pin profile is the most significant factor. In the Table 5.3 ranks have been given to the various factors.

Table 5.2: Analysis of Variance for Means of tensile strength

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Percentage Contribution
Spindle speed (rpm), N	2	1.0771	1.0771	0.5385	0.23	0.815	10.22 %
Feed rate (mm/rev), f	2	0.9756	0.9756	0.4878	0.21	0.829	8.62%
Tool profile	2	3.8838	3.8838	1.9419	0.82	0.82	76.45 %
Error	2	4.7450	4.7450	2.3725			
Total	8	10.681					
S = 1.54031 R-Sq = 55.58 % R-Sq (adj) = 0.31 %							

Table 5.3: Response table for means for tensile strength

Level	Spindle speed (rpm), N	Feed rate (mm/min), f	Tool profile
1	26.84	26.37	26.61
2	27.19	26.83	26.1
3	26.35	27.17	27.67
Delta	0.84	0.8	1.58
Rank	2	3	1

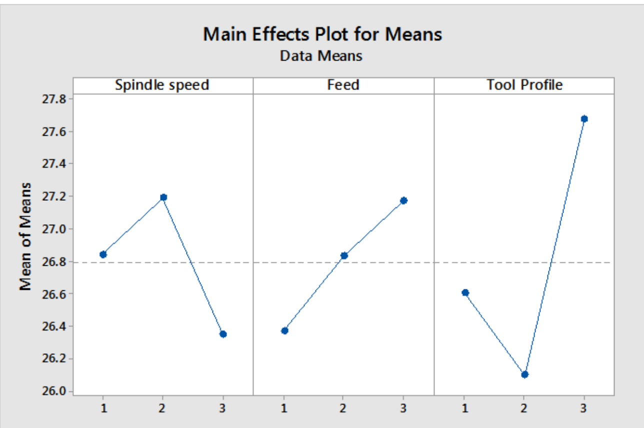

Fig 5 Main effects plot for means for tensile strength.

5.3 ANALYSIS OF S/N RATIO FOR TENSILE STRENGTH

The signal to noise ratios tells us about the deviations present in the process. The values of all the results according to Taguchi array parameter design layout are presented in this section. The S/N ratios have been calculated to identify the major contributing factors for variation of values. In this design situation, bigger-the-better is used.

Table 5.3 shows the ANOVA calculations for the S/N ratio. The analysis was carried out at a significance of α=0.05. The main effect is shown in the figure 6. Table 5.4 shows the response table for S/N for tensile strength. Ranks have been given to the various factors. Higher is the rank higher is the significance so spindle speed is the most significant factor. It was found that only spindle speed is a significant factor with F value of 11.01.

Table 5.3: Analysis of Variance for S/N ratio for tensile strength

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Percentage Contribution
Spindle speed (rpm), N	2	0.11576	0.8560	0.4280	1.24	0.446	10.22 %
Feed rate (mm/rev), f	2	0.09769	0.8348	0.4174	1.21	0.452	8.62 %
Tool profile	2	0.41269	0.3665	0.1832	0.53	0.653	76.45 %
Error	2	0.50602	0.6886	0.3443			
Total	8	1.13216					
S = 0.5867 R-Sq = 74.92 % R-Sq (adj) = 0.25 %							

Table 5.4: Response table for S/N ratio for tensile strength

Level	Spindle speed (rpm), N	Feed rate (mm/min), f	Tool profile
1	28.57	28.42	28.49
2	28.68	28.57	28.33
3	28.41	28.67	28.84
Delta	0.28	0.25	0.51
Rank	2	3	1

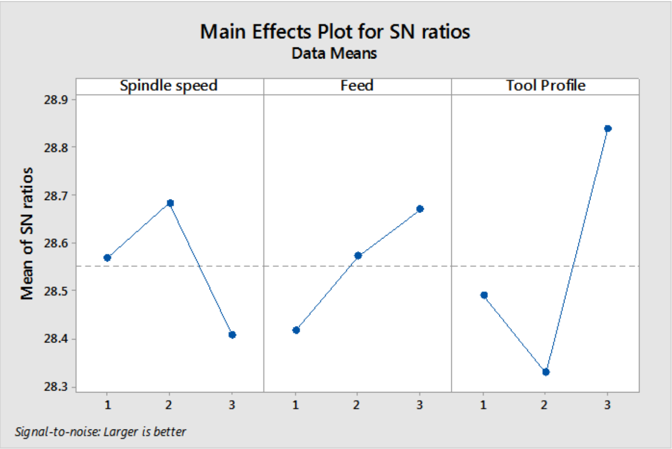

Fig 6 Main effects plot for S/N ratio for tensile strength

5.4 Pie Chart Representation of Percentage Contribution of Process Parameters For Tensile Strength

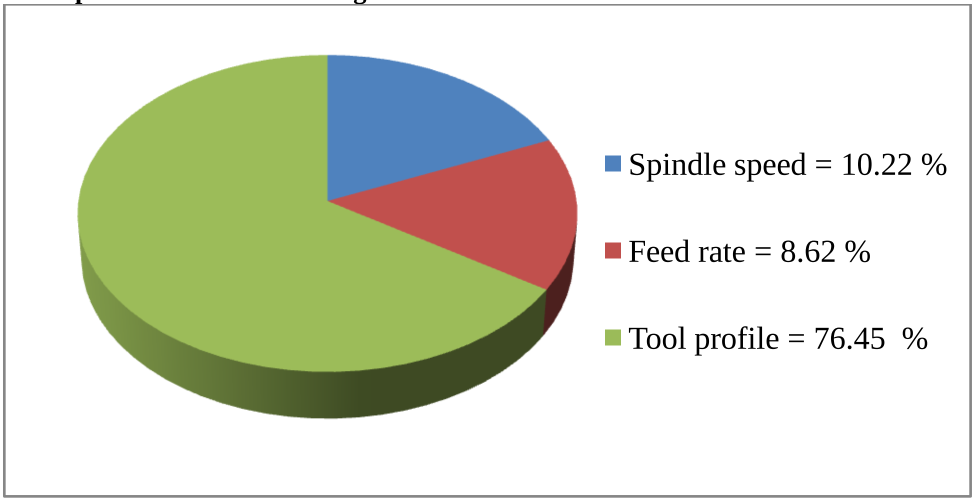

Fig 7: Percentage contribution of process parameters on tensile strength

Pie-chart: Pie- chart is used to describe the percentage contribution in a graphical manner to clearly distinguish the contribution of parameters- spindle speed, feed rate, tool profile including error. This is described below.

1. Spindle speed- It is denoted by dark blue colour, it contributes only 10.22 % which is the minimum.

2. Feed rate- It is denoted by red colour, it contributes 8.62 % which is the maximum contribution.

3. Tool profile- It is denoted by green colour, it contributes only 76.45 % which is the maximum contribution. It is mainly responsible to affect the tensile strength of work piece.

VI. Conclusions

It can hence be concluded that use of round tool profiles yield better results than that of the square tool and round with thread tool profiles. The tensile strength increases with increase in the tool feed rate. The maximum tensile strength achieved was 28.42MPa while welding at 900rpm with 40 mm/min feed using the round tool. The analysis of variance for the tensile result concludes that the tool profile is the most significant parameter with a percentage of 76.45 %, followed by the feed of 8.62 % and spindle speed 10.22 %.

VII. Future scope

By considering the aspects of present study more work can also be done in the same work area. More work can also be done by changing some parameters, working conditions and data analysis method. In the present work, welding is done on aluminium alloys so we can also change the workpiece material such as copper, mild steel etc. In the present study, Taguchi’s technique and ANOVA analysis used for optimazation and for results analysis of various parameters so we can use other methods like Regression analysis, RSM, Fuzzy logic etc.

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