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INFLUENCE OF WELDING PARAMETERS ON THE MECHANICAL PROPERTIES OF SIMILAR AA6063 FRICTION STIR WELDS

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Abstract: Friction stir welding which is an innovatory method in solid joining procedure. FSW is energy effectual and most significant improvement in metal joining from decagon. Here, we are going to study mechanical properties about total nine friction stir welds of AA6063 are produced by following with three input independent processing parameters like spindle speed or tool rotational speed ,transverse feed and Tilt angle. The motto of this study is to find the optimum parametric values with FSW of AA6063 by using Taguchi technique.

Different experimental tests are done on specimens of total nine AA6063 welded joints. We evaluate the mechanical properties values like Hardness, tensile strength, surface roughness by using hardness, tensile and surface roughness tests simultaneously. Finally we need to find the optimum values out of all tests. A High Speed Steel (HSS) was used for welding process. That tool having 6mm in diameter, 5.5mm as pin length and 18mm as shoulder diameter. Transverse feeds are 25, 35 and 45 mm/min; Spindle speeds are 950, 1250, 1450rpm; and the tilt angles are 0°, 0.5°and 1° are taken as the input parameters. We welded two metallic workpieces by using FSW. Each Aluminium workpiece is rectangle in shape having dimensions of 125X60mm and 6mm in thickness.

I INTRODUCTION

Friction stir welding is one of the welding process for joining of Solid materials. It can be used joining of either similar or dissimilar alloys. FSW is a low cost welding technique and is used where we need high strengthened joints are required. This welding process is used in railways, aerospace, shipbuilding and nuclear industries. FSW having many benefits while comparing with other conventional methods. The welds produced by the FSW process always have good mechanical properties such as surface finish, hardness and tensile strength etc. It can be possible only by elimination of flux or filler material. Unlike using of filler material in other welding processes a high speed revolving tool is feed on to the area moves in the transverse motion where we need welding leads to melt the material within its melting point. Friction stir welding never release any toxic emissions into the atmosphere. That's why many industries are adopting this eco-friendly welding technique. Other than this it can be used for increasing the production rate by working in high speed rates. So, it can be used for mass productions. But, this process is not suitable to join soft materials and also for non linear welds.

II.LITERATURE REVIEW:

The main reason here is to selecting the aluminum as material for welding always have great importance. Because aluminium is always light in weight and also have high strength while compare to other materials. Aluminium is widely used in industrial applications. The properties of Friction stir weld depends only on tool pin profile and input parameters like tool Spindle speed or rotational speed, transverse feed, axial force and Tilt angle.

K. Lakshmi narayanan and V. Balasubramanian (2008) Taguchi was applies to establish the most substantial control factors for Fs-welded RDE-40 aluminium alloy to get welded joints with more suitable tensile strength. To assess the process parameters effects that are axial force, transverse speed and tool rotational speed on tensile strength of Fs-welded aluminum alloy RED-40 the parametric design approach of taguchi was used determine the optimum levels of process perameters.In FSW the welding speed, axial force, and rotational speed these parameters decides the tensile strength of the joint[1]. C. Devanathan et al. (2013) discussed that FSW has became most popular significant process for joining of lightweight materials like aluminium, magnesium and its alloys. Taguchi experimental design technique was used in this paper to get maximizing tensile strength of friction stir welded Al 6063 alloy. The effect of process parameters on tensile strength of welded joints were evaluated using ANOVA and signal to noise ratio of robust design. It was observed that the welding speed exhibited more influence on tensile strength of the welded joints followed by spindle speed and axial force [2]. M. Jayaraman et al. (2009) studied to improve weld joint strength in the fusion welding of aluminium alloys. The technique of Fs-welding is employed to exterminate hot cracking, porosity and micro-fissuring etc. In this paper discussion is made for maximizing tensile strength of casted aluminium A139 alloy by using taguchi experimental design technique and ANOVA . The optimum welding condition for maximizing tensile strength was determined

III. EXPERIMENTAL PROCESS AND SETUP :

The Aluminium Alloys are available in variant grades of series. They are 2xxx, 3xxx, 4xxx ,5xxx, 6xxx,7xxx and 8xxx. Each Aluminium Alloy having mixed composite materials. That means in each Aluminium Alloy there are different composite materials like Cu, Ti, Mn, Cr, Fe, Si, Mg etc. In this study Aluminium 6063 was taken as the workpiece material for the FSW.

Table 3.1 : Chemical composition of AA6063

Element	Ti	Zi	Cu	Mg	Si	Cr	Fe	Mn	Aluminium
Weight (%)	0.1	0.1	0.1	0.90	0.6	0.1	0.35	0.1	Balance

Fig. 3.1 : AA6063 work pieces

3.1 Dimensions of Work piece:

Table 3.2. Work piece with dimension

Item	Size
AA6063	125X60X6 mm^3

Through this experiment, we are going to produce nine welded joints with variation in their processing parameters on the basis of Taguchi Technique (L9 orthogonal array).The figure 3.1 shows the work pieces whose welding is done on friction stir welding.

For this experimentation total nine different welds are produced by alternating the variant process parameters based upon the Taguchi analysis (L#9 orthogonal array).

3.2 Experimental Procedure:

During the experimentation, use emery paper to remove surfaces of total 9 work pieces. As per Taguchi technique L9 orthogonal arraying is started. The following table 3.3, 3.4 gives the chosen parameters for the friction stir welding.

Table 3.3: Input Processing Parameters

			Level		
S.No.	**Input Process Parameters**	**Units**	**1**	**2**	**3**
1	Speed of Spindle	RPM	950	1250	1450
2	Feed	Mm/min	25	35	45
3	Tilt Angle	Degrees	0	0.5	1

As per Taguchi method the processing parameters spindle speed, Transverse feed and tilt angle are taken in three different levels based on the L9 orthogonal array.

Table 3.4: L9 orthogonal array of processing parameters

S.No	**Process Parameters**		
Specimen No	**Speed of Spindle**	**Translation feed (mm/min)**	**Tilt Angle (degree)**
1	950	25	0
2	950	35	0.5
3	950	45	1
4	1250	25	0.5
5	1250	35	1
6	1250	45	0
7	1450	25	1
8	1450	35	0
9	1450	45	0.5

3.4. Experimental Setup and tool selection:

Friction stir welding equipment is used for Friction stir welding. Take two AA6063 plates each having dimension of125×60×6 (in mm) and fix rigidly side by side using fixtures set to give zero degrees of freedom to get best weld . Set the welding processing parameters Spindle speed (rpm), Translational Tilt angle (degrees) and speed (mm/min) are as per the serial number '1' in 3.4 table. Applying the manual mode option and set the values of rotational speed and translational feed once the friction stir welding starts. After that tool angle is unique for performing each individual work piece. The axial force is taken as per the suitable force. During welding we need to do temperature measurement by suitable device. In 3.2 figure operation during friction stair welding is shown.

Tool have Shoulder and small Pin. The tool having 6mm in diameter, 5.5mm as pin length and 18mm as shoulder diameter. As per the thickness of work piece material the tool size is selected. Here we are welded 6 mm thick plates

The shape of the shoulder the pin concave and pin with threading. By Manual mode settings the input parameters are loaded and which was shown on the figure 3.3

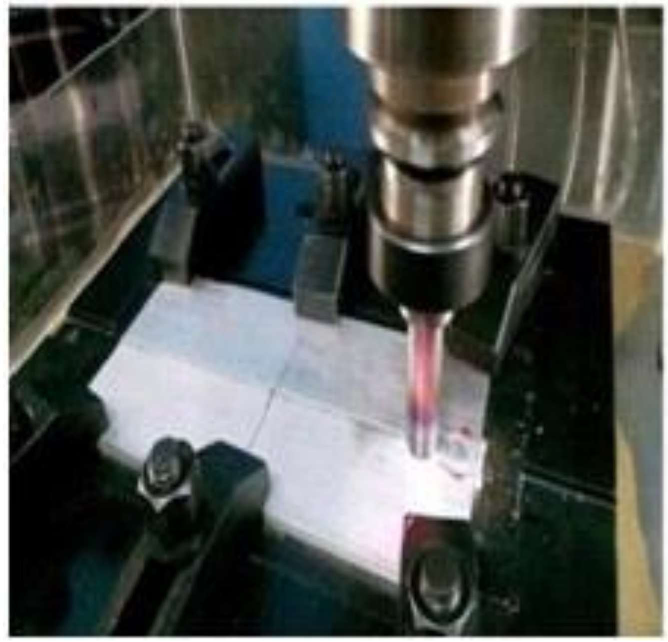


Figure 3.2: Set up of FSW during the operation

Figure 3.3: Manual mode settings of FSW during operation

3.5 Processing Parameters:

The axial load in kN, Translation feed in mm/min, tilt angle in degrees and Spindle speed in rpm are the main process parameters of Friction stir welding.

The weld quality is depends upon only these parameters. This experimenting is to find how formation of the weld occurs with change in processing parameters. The involving of processing parameters during testing were mentioned by the fig. 3.4 resultant during welding actions.

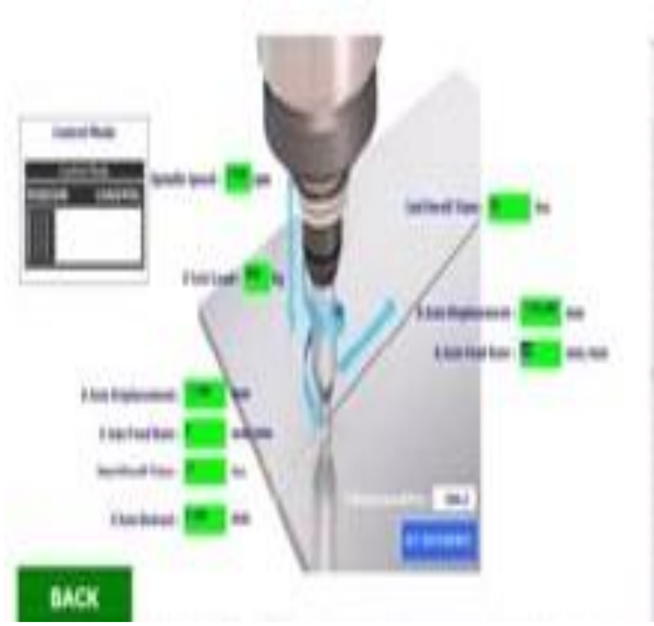


Figure 3.4 : The process setup during welding

Figure 3.5 : AA6063 welded joints

IV RESULTS AND DISCUSSION :

In this study; surface roughness test, hardness test and tensile tests are done on welding joint area. These are done in metallurgical laboratory. In order to accomplish the tension test the opposite ends of a specimen is fixed in the test machine's load frame. Now with the application of tensile force results gradual elongation after that slow deformation starts and finally specimen may broke into two pieces. Total nine specimens are cut by Wire Cut EDM into required shape and size for conducting tensile testing.

Figure 4.1: Universal Tensile Testing Machine

Figure 4.2 : Workpieces Before and After Tensile testing

The main aim in Tensile testing is to find the Max. Tensile Strength of each specimen individually on all nine test specimens. The percentage of elongation and maximum tensile strength of each specimen are recorded in the table 4.1. After that the maximum load at where specimen withstand corresponds to its process parameters is found.

4.1. Tensile strength analysis :

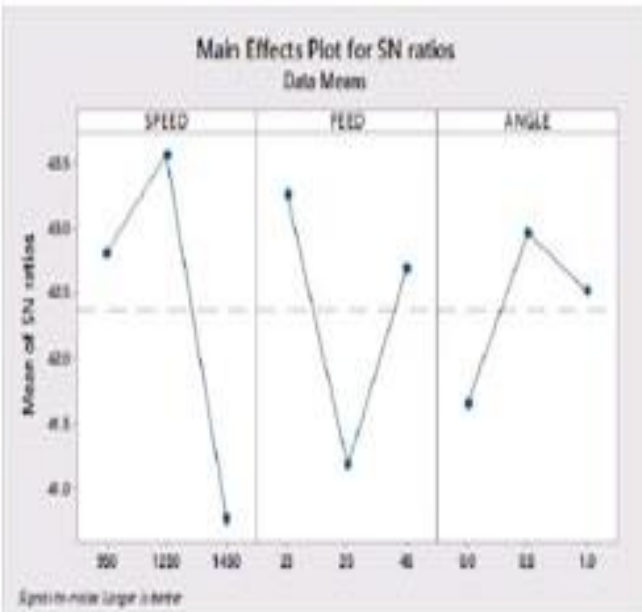
After Tensile testing the experimental values are recorded in the below table: 4.1

Table: 4.1 Process parameters and experimental results of Tensile test

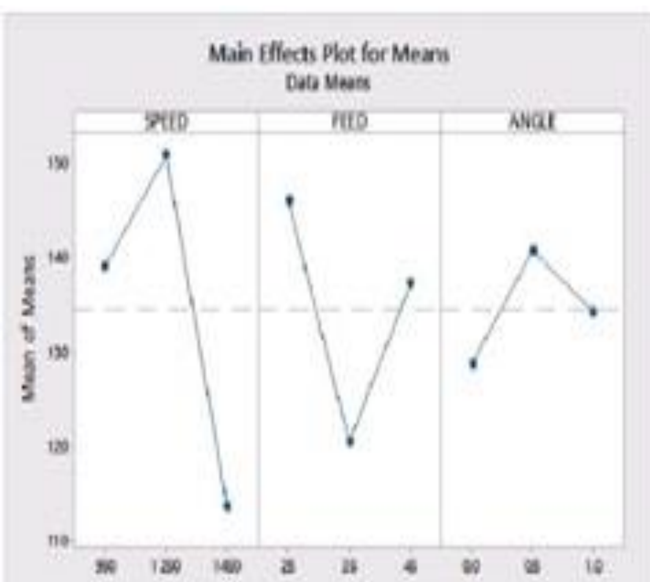
S.No	Process Parameters			Experimental Results			
Speci-men No	Speed of Spindle	Translation feed (mm/min)	Tilt Angle (degree)	Temperature (in °C)	Tensile Strength N/mm^2	Percentage of Elongation	S/N Ratio
1	950	25	0	395	159.42	13.44	44.0509
2	950	35	0.5	345	138.56	9.92	42.8328
3	950	45	1	350	119.21	11.76	41.5263
4	1250	25	0.5	385	146.29	14.44	43.3043
5	1250	35	1	350	151.25	15.08	43.5939
6	1250	45	0	499	154.99	13.32	43.8061
7	1450	25	1	380	132.07	11.28	42.4161
8	1450	35	0	450	71.53	3.84	37.898
9	1450	45	0.5	503	137.31	13.64	42.7540

From the above table the values of S/N ratio of each test specimen have been find out through Minitab-17 which are used to find weld quality. It means which weld have high S/N ratio value is called as good weld. The below graphs #1 and #2 represents plots of means and S/N ratios respectively. The maximum ultimate tensile strength is 159.42 N/mm^2; where weld number 1 and 950 rpm, 25 mm/min and 0° are the processing parameters.

The most influencing process parameter can be revealed by the Responsible table. It could be done by averaging of the actual values and S/N ratios at corresponding intervals.



Graph #1 : Main effects plot for means for tensile test Graph



Graph #2 : Main effects of S/N ratios tensile test

Table 4.2: Response Table for Means

Levels	Spindle Speed (rpm)	Translation Feed (mm/min)	Tilt Angle (In Degrees)
1	139.1	145.9	128.6
2	150.8	120.4	140.7
3	113.6	137.2	134.2
Delta	37.2	25.5	12.1
Star	1	2	3

Table 4.3: Responsible Table for Signal to noise ratio

Levels	Spindle Speed (rpm)	Translation Feed (mm/min)	Tilt Angle (In Degrees)
1	42.80	43.260	41.65
2	43.57	41.17	42.96
3	40.75	43.70	42.51
Delta	02.81	02.08	01.31
Star	1	2	3

4.2 .Hardness test :

Hardness testing is done on Rockwell Hardness testing machine it consist of 4 individual scales. Those were A, B, C and D scales. Those scales used to find the hardness values on surfaces of 9 test pieces at the welded area. In this study we are using Scale-B to find values of hardness. A 1/16" in diameter Conically shaped Diamond having round tip is used to indented on the welded zone with applying of 100kN force.

The present experiment is carried out on Rockwell hardness testing machine with B Scale. In this experiment, Conically shaped Diamond having round tip with diameter of 1/16" is used to measure the hardness on the welded specimen when 100 KN load applied on it. That hardness of the weld area values recorded randomly by indenter at different zones on weld joint, and finally the average of those means will give the Rockwell Hardness Number (HRB) of single weld joint. This process is applied to each weld specimen individually and tabulated as in Table 4.4

4.3 Hardness test analysis :

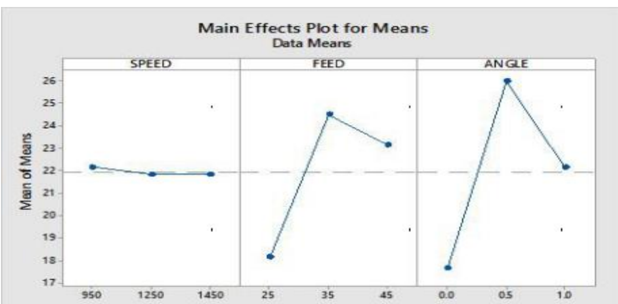
Table 4.4: Hardness processing parameters with experimental results

S no		Process Parameters			Experimental Results	
Specimen number	Spindle Speed (rpm)	Translational feed (mm/min)	Tilt Angle (Degrees)	Temperature (^{0}C)	Hardness Number (HRB)	S/N Ratios
1	950	25	0	395	18.0	25.1055
2	950	35	0.5	345	23.5	27.4214
3	950	45	1	350	25.0	27.9588
4	1250	25	0	385	23.5	27.4214
5	1250	35	0.5	350	28.5	29.0969
6	1250	45	1	499	13.5	22.6067
7	1450	25	0	380	13.0	22.2789
8	1450	35	0.5	450	21.5	26.6488
9	1450	45	1	503	31.0	29.8272

Here, the weld number #9 having highest hardness number that was 31 HBN and where the pps are 1450 rpm, 45 mm/min and 1°. The Signal to Noise Ratios values are calculated and plotted as graph #3 and Graph #4 by using MiniTab – 17.

Table 4.5 Response Table for Means Response

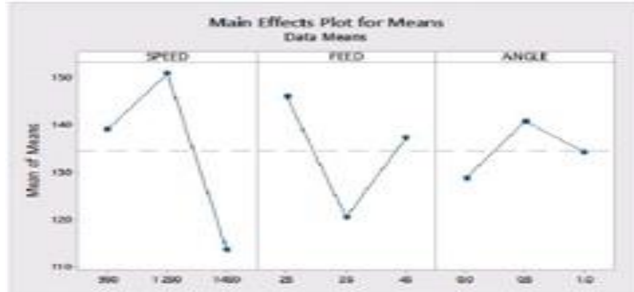
Levels	Speed Of Spindle (rpm)	Translation Feed (mm/min)	Tilt Angle (In Degrees)
1	22.17	18.17	17.67
2	21.83	24.50	26.00
3	21.83	23.17	22.17
Delta	0.33	6.33	8.33
Star	1	2	3



Graph #3: Main effects plot for means for Hardness test Graph

Table 4.6 Responsible Table for S/ N Ratios

Levels	Speed Of Spindle (rpm)	Translation Feed (mm/min)	Tilt Angle (In Degrees)
1	26.83	24.94	24.79
2	26.37	27.72	28.22
3	26.25	26.80	26.44
Delta	0.53	02.79	03.44
Star	1	2	3



Graph #4 : Main effects of S/N values for Hardness Test

4.4 .Surface Roughness Test :

Surface Roughness was measured by using tallysuf equipment. Tallysurf has a moving probe in front of equipment. If we want to measure the roughness first we place the probe on the welding area. We can see the reading in terms of microns in LED screen. Here we need to measure at three positions of a single specimen. After that take average (Ra) of three readings (Rz). Hence that mean value will gives us the surface roughness in terms of "Ra". Now its "Ra" value is only relates to the specimen number-1. We need to follow the same process on all the nine weld joints. The readings are shown in figure 4.5.

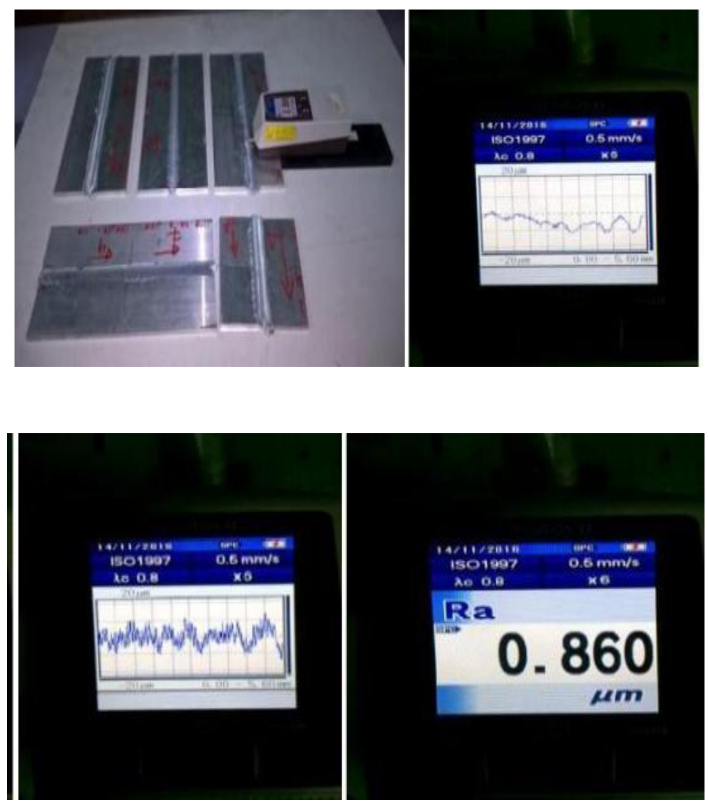


Fig 4.5: Testing of surface roughness

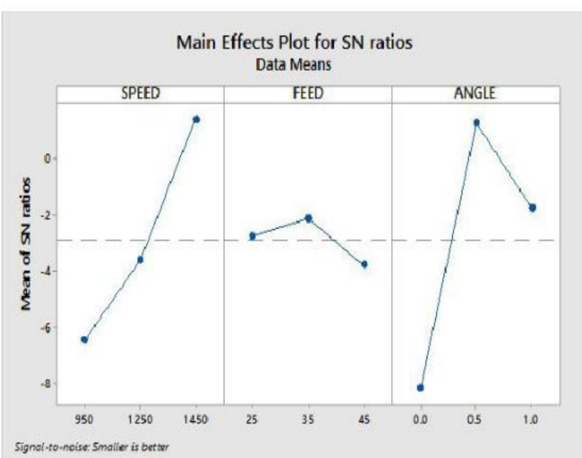
4.5. Surface roughness test Analysis :

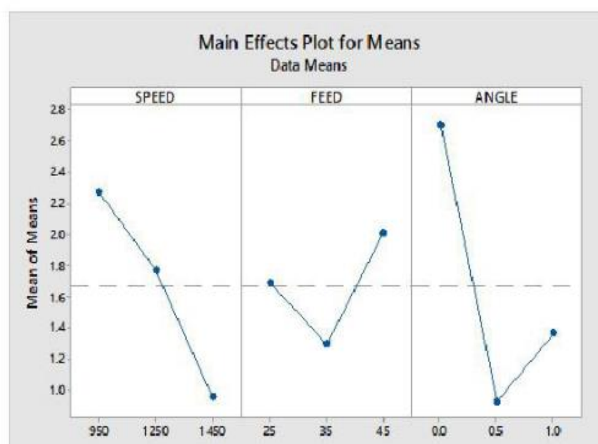
The good surface finish was found at weld number-9 specimen where the surface roughness value is 0.5000; and the pps are 1450 rpm, 45mm/min and 1°. The signal to noise ratios and its graphs (#5 & #6) are plotted by using MiniTab – 17.

Table 4.8 Response Table for Means

Levels	Speed Of Spindle (rpm)	Translation Feed (mm/min)	Tilt Angle (In Degrees)
1	2.2711	1.6930	2.7077
2	1.7762	1.3023	0.9394
3	0.9687	2.0207	1.3689
Delta	1.3024	0.7184	1.7682
Star	2	3	1

Levels	Speed Of Spindle (rpm)	Translation Feed (mm/min)	Tilt Angle (In Degrees)
1	-6.482	-2.782	-8.212
2	-3.645	-2.160	1.088
3	1.225	-3.961	-1.778
Delta	7.707	1.801	9.229
Star	2	3	1





Graph #5: Means of Surface roughness test

Graph #6: S/N Ratios of surface roughness test

V. CONCLUSIONS:

Finally at last by using Friction Stir Welding AA6063 butt joints having high strength are produced at cheaper price with undepletable taper pinned rotating tool. The quality of welds are determined by their three mechanical properties like Surface Roughness, Hardness and Tensile Strength. By L9 orthogonal array of Taguchi method is applied for evaluate the Process Parameters. Below the results are shown.

The maximum tensile strength for weld joint obtained when combinations of process parameters at 950 rpm spindle speed, 25 millimeter/minute translation feed and 0° tilt angle.

The maximum hardness for weld joint obtained when combinations of process parameters at 1450 rpm spindle speed, 45 millimeter/minute translation feed and 1° tilt angle.

The good surface finish where the surface roughness is very less for weld joint obtained when combinations of process parameters at 1450 rpm spindle speed, 45 millimeter/minute translation feed and 1° tilt angle.

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