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Parametric Optimization for Friction Stir Welding of Al6061 Alloy using Taguchi Technique

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Abstract: ***Nine welded joints of 6061 aluminium alloy were made on friction stir welding set up with the L9 orthogonal array of Taguchi s methodology of three input parameters with three different levels. The processing parameters such as tool rotational speed, transverse feed and tilt angle are taken into account. Experiments or tests such as tensile test, hardness test and surface roughness tests were conducted to evaluate the mechanical properties such as tensile strength, hardness value and surface roughness values. At last, optimum values of corresponding tests are determined. The results were confirmed by further experiments.***

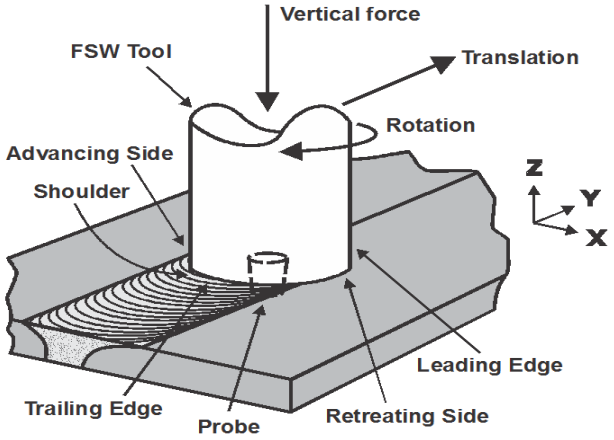
Keywords: Friction Stir Welding (FSW), Al 6061, Tensile Strength, Hardness, Surface Roughness, and Taguchi Technique

1. Introduction.

Traditional fusion welding is not suitable for the welding of soft materials. Friction stir welding is the best technique to full fill the requirements of welding of soft materials like Al, Ti, and Steel etc.Friction Stir Welding is a Solid State Welding process in which source of welding is Friction. Friction will be generated by the non consumable tool on the work piece material. Initially the material will be melted below the melting point temperature and then it converts into plastic state at the welding location by applying amount of axial force. There is no usage of additional filler material here. This technique can be used for the welding of similar or dissimilar materials. Friction Stir welding is a Green welding technology and Non Toxic.Friction Stir Welding is invented by The Welding Institute (TWI) of the United Kingdom in 1991. This fabrication technique plays a vital role in the NASA and other Aircraft Industries.

1.1 Principle of Friction stir Welding Process

The Non consumable tool consists of shoulder and a pin which will be fixed in a tool holder and rotated with certain rpm. The Aluminium square mating edges are fixed with the special clamping fixture to avoid the moment of the work piece during in operation or made to be at rest. Now the rotating tool is plunged into the work piece until the length of the pin. So here shoulder is making contact with the top surface of the work piece. When the tool is rotating about its longitudinal axis,(with or without inclination)stirring action will be made so the material will undergo softened plastic deformation and tool is transverse in the desired direction so the material is intermixed along the desired direction and weld will be formed under the below the melting point temperature. There is no addition of filler material in this process.



Schematic diagram of Friction stir welding Technique

1.2 Need

Since the invention of friction stir welding, it plays a vital role in the industries and has wide range of applications in variety of industries. It is selected as a most appropriate one on behalf of its nature of higher efficiency at higher mass production. This welding gives very characteristic values, uniformity of weld properties. Some of the advantages are no need of external source of energy, welding will be takes place at much below melting point of the work piece material, the wear and tear of the tool is less or tool life will be good. These are some additional advantages of friction stir welding made it as a unique welding process. The welding is possible with very low cost.

2. Methodology and Experimental Set Up

Methodology

The nine welded joints were made on friction stir welding setup with three different levels of processing parameters like Spindle Speed (rpm), Translational feed (mm/min) and Tilt Angle (in degrees). The testing will be followed to determine the optimum characteristic values of tensile strength, hardness and surface roughness.

Table 1: Shows Processing Parameters and their levels

S.No	Parameter	Unit	Level		
			1	2	3
1	Spindle speed	Rpm	900	1000	1100
2	Transverse feed	Mm/min	42	55	68
3	Tilt angle	Degree	0	1	2

Table 2: Shows Taguchi L9 orthogonal array

S.NO	Processing Parameters		
	Spindle speed	Transverse feed	Tilt angle
1	900	42	0
2	900	55	1
3	900	68	2
4	1000	42	1
5	1000	55	2
6	1000	68	0
7	1100	42	2
8	1100	55	0
9	1100	68	1

The working ranges are finalised by the previous research work and conducting trail run.L9 orthogonal array of Taguchi is applied in the present study.

Work piece Material and TOOL

The material under the investigation found that Al 6061 has excellent joining characteristics and wide range of applications. So Al 6061 is taken with dimensions 125×60×6 (in mm).

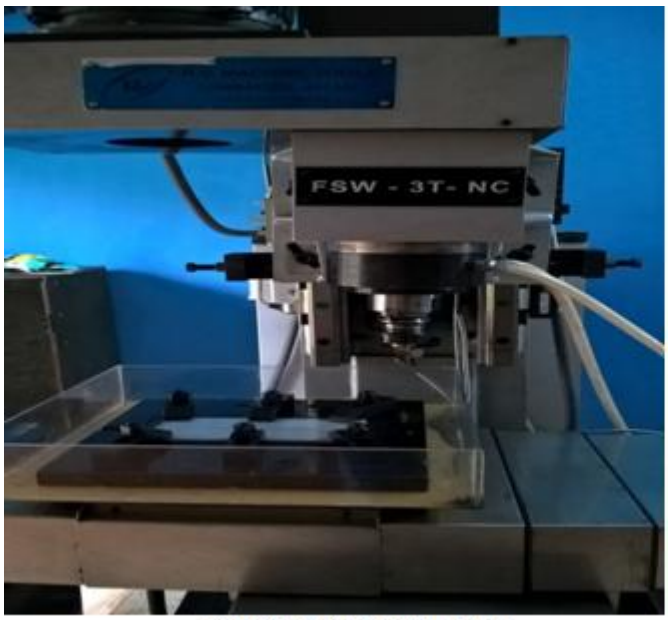
Nominal chemical composition of 6061

Element	Si	Fe	Cu	Mn	Mg	Cr	Zi	Ti	Al
Wt (%)	0.59	0.38	0.26	0.03	0.96	0.25	0.02	0.04	Balance

Al specimens to be welded

3. Experimental Setup

Nine Square butt joints were made on Friction Stir welding equipment setup. The Friction stir welding setup is manufactured by R.V. MACHINE TOOLS, Coimbatore.



Friction stirs welding setup

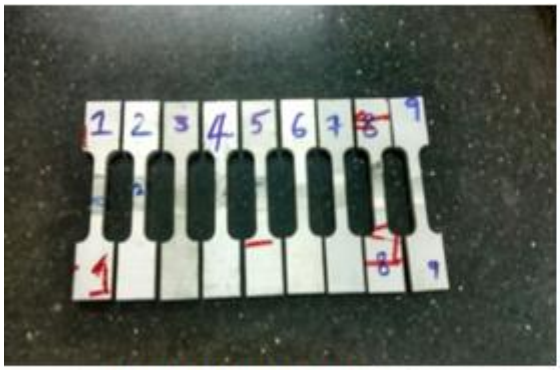
Al6061 welded specimens

4. Results and Discussions

The Tensile Test, Surface Roughness Test and Hardness tests are conducted to evaluate the mechanical properties of the welded joints and corresponding S/N Ratios, Mean values, Main effects plots for means and S/N ratios are calculated with the help of Minitab17. These values will give a clear idea to determine the best quality of weld.

Tensile test

Tensile test is used to determine the tensile strength of the welded portion of the friction stir weld specimen. Wire cutting EDM machine is used to cut tensile specimens from the Nine FSW welded joints individually. The below figures will show the tensile specimens before the test and after the test.



Before the Tensile Test

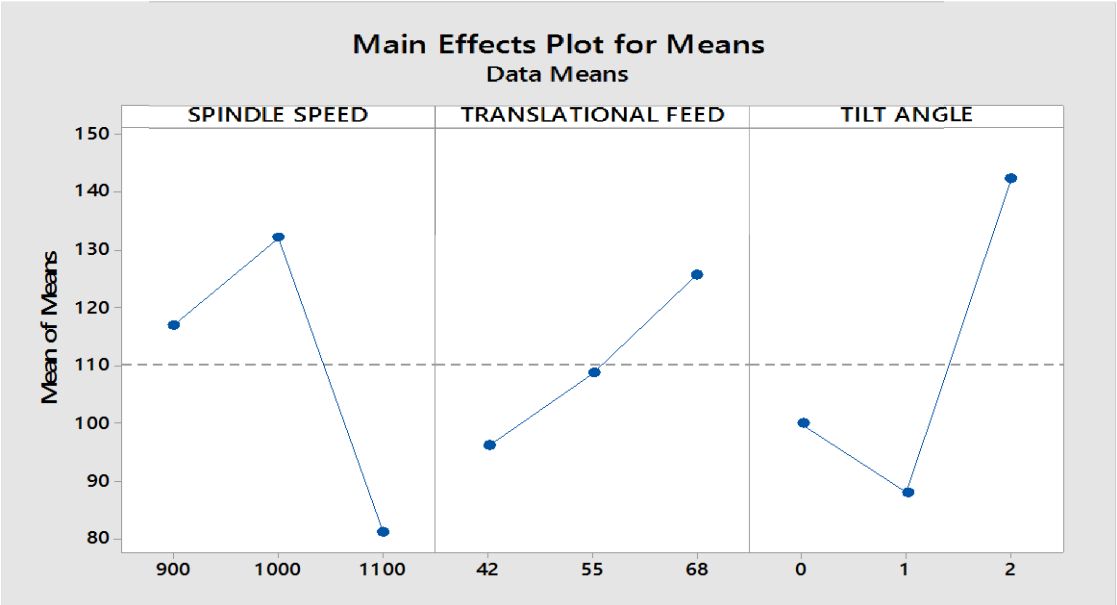
After the tensile Test

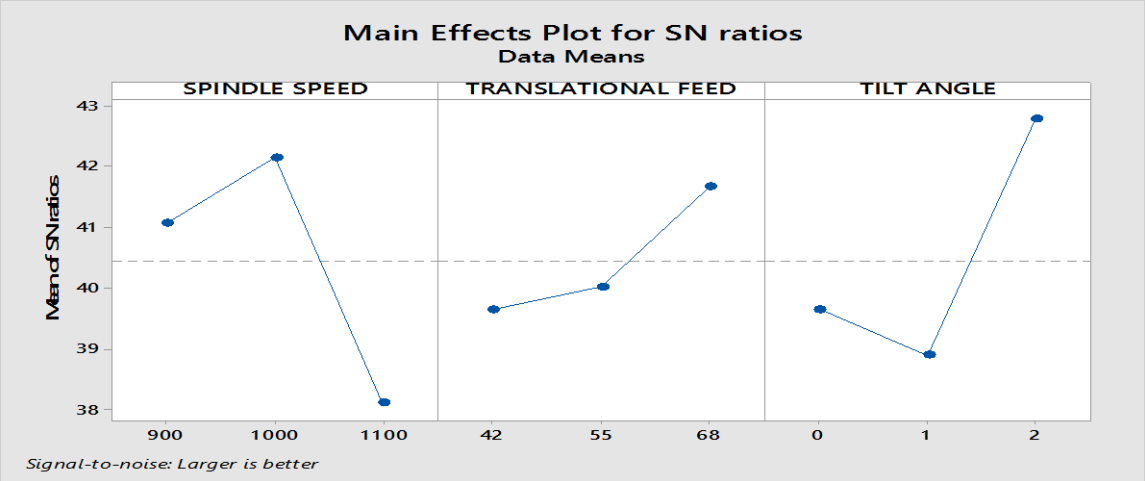
Tensile Strength Analysis

Table: Process parameters and experimental results

S no	Process Parameters			Experimental Results			
Specimen number	Spindle Speed (rpm)	Translational feed(mm/min)	Tilt Angle (Degrees)	Temperature (in centi grade)	Tensile strength	Percentage elongation	S/N Ratios
1	900	42	0	116	100.750	8.44	40.0649
2	900	55	1	105	89.166	9.80	39.0040
3	900	68	2	147	134.536	22.80	44.1403
4	1000	42	1	127	92.405	6.80	39.3139
5	1000	55	2	195	170.633	16.36	44.6413
6	1000	68	0	143	133.129	14.36	42.4855
7	1100	42	2	135	95.041	9.12	39.5582
8	1100	55	0	120	66.071	4.72	36.4002
9	1100	68	1	117	82.761	5.64	38.3565

The above table represents the results of the tensile tests conducted on Friction stir weld tensile specimens of Al 6061. Through the usage of Minitab-17, the S/N ratio values are also evaluated. The S/N ratio values are used to determine the quality of weld. That means the weld which is having high S/N ratio value means it is good quality of a weld. The Minitab-17 is also used to plot the graphs like Main Effects of plot for SN ratios. The ultimate tensile test is 170.633, determined at specimen weld no.5, and its parameters are 1000 rpm, 55 mm/min and 1 degree.





Response Table for Means

Level	Spindle speed	Translational Feed	Tilt angle
1	117.00	96.07	99.98
2	132.06	108.62	88.11
3	81.29	125.65	142.25
Delta	50.76	29.59	54.14
Rank	1	3	2

Table for Signal to Noise Ratios

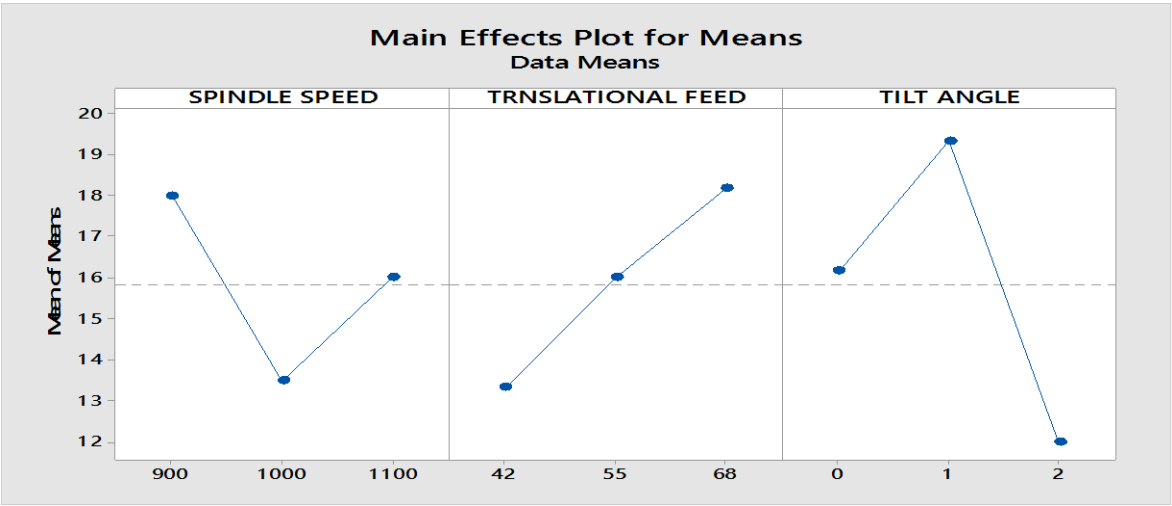
Level	Spindle speed	Translational Feed	Tilt angle
1	41.05	39.65	39.65
2	42.15	40.02	38.89
3	38.10	41.66	42.78
Delta	4.04	2.02	3.89
Rank	1	3	2

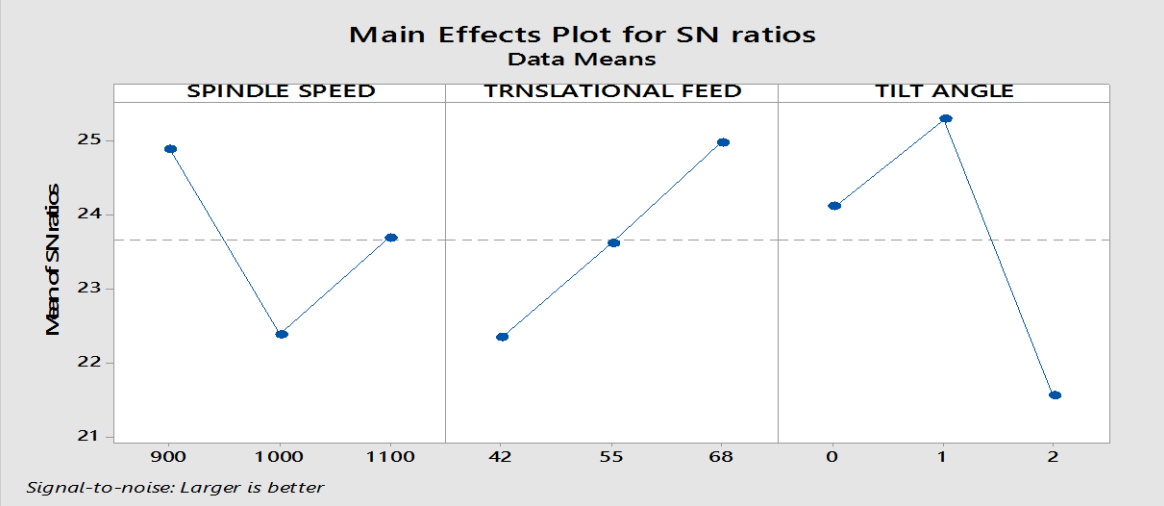
Hardness Analysis

The below table represents the Hardness values of Nine Friction stir welded joints and corresponding S/N Ratios, Mean values. The hardness test was conducted on Rockwell hardness testing machine.

S no	*Process Parameters*			*Experimental Results*		
Specimen number	*Spindle Speed (rpm)*	*Translational feed (mm/min)*	*Tilt Angle*	*Temperature (in centi grade)*	*Hardness Number (HBN)*	*S/N Ratios*
1	900	42	0	116	17	24.6090
2	900	55	1	105	23.5	27.4214
3	900	68	2	147	13.5	22.6067
4	1000	42	1	127	11.5	21.2140
5	1000	55	2	195	11	20.8279
6	1000	68	0	143	18	25.1055
7	1100	42	2	135	11.5	21.2140
8	1100	55	0	120	13.5	22.6067
9	1100	68	1	117	23	27.2346

The Best Hardness value is determined at specimen weld no.2 is 23.5 HBN, and its parameters are 900 rpm,55 mm/min and 1 degree. The S/N ratio values are calculated with the help of MiniTab-17 and also the Main Effects plot for S/N ratios can be dawned.





Response Table for Means

Level	Spindle speed	Translational Feed	Tilt angle
1	18.00	13.33	16.17
2	13.50	16.00	19.23
3	16.00	18.17	12.00
Delta	4.50	4.83	7.33
Rank	3	2	1

Table for Signal to Noise Ratios

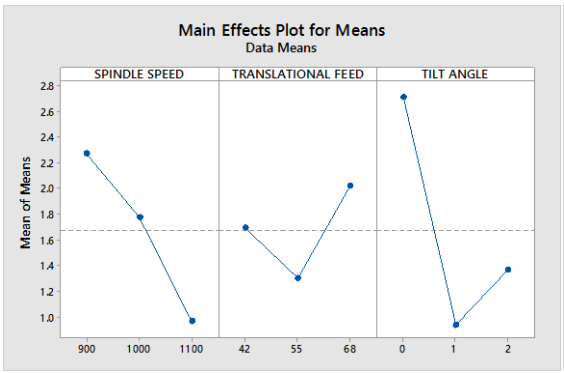
Level	Spindle speed	Translational Feed	Tilt angle
1	24.88	22.35	24.11
2	22.38	23.62	25.29
3	23.69	24.98	21.55
Delta	2.50	2.64	3.74
Rank	3	2	1

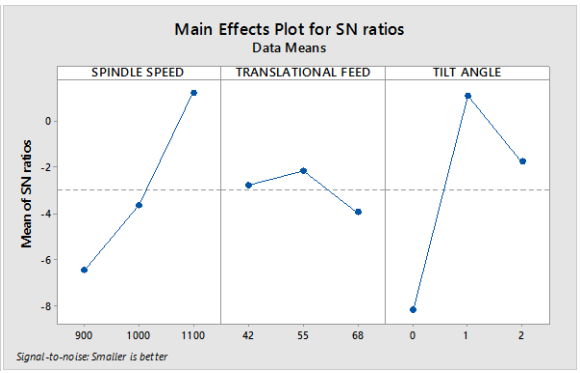
Surface Roughness Test

Surface Roughness test is conducted to find the surface roughness values at the friction stir welded joints. This test reveals the Surface finish or the smoothness of the friction stir weld joints.

Specimen number	*Spindle Speed (rpm)*	*Translational feed (mm/min)*	*Tilt Angle (Degrees)*	*Temperature (in centi grade)*	*Surface roughness*	*SNRA1*
1	900	42	0	116	3.272	-10.2963
2	900	55	1	105	1.2533	-1.9611
3	900	68	2	147	2.288	-7.1891
4	1000	42	1	127	1.036	-0.3072
5	1000	55	2	195	1.0476	-0.4039
6	1000	68	0	143	3.245	-10.2243
7	1100	42	2	135	0.771	2.2589
8	1100	55	0	120	1.606	-4.1149
9	1100	68	1	117	0.529	5.5309

The ultimate surface roughness value is determined at weld specimen no.7 is 0.771, and corresponding processing parameters are 1100 rpm,42 mm/min and 0 degree. The S/N ratio values are calculated with the help of MiniTab-17 and also the Main Effects plot for S/N ratios can be dawned.





Response Table for Means

Level	Spindle speed	Translational Feed	Tilt angle
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
Rank	2	3	1

Table for Signal to Noise Ratios

Level	Spindle speed	Translational Feed	Tilt angle
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
Rank	2	3	1

5. Conclusion

In the present study, the butt joint configuration of 6061aluminium alloy was successfully prepared on Friction stir welding equipment. The weld specimens were tested for tensile strength, hardness and surface roughness at their weld postion.L9 array of Taguchi technique was performed in the study.

The optimum tensile strength is observed at spindle rotational speed 1000 rpm, transverse feed 55 mm/min, and tilt angle 1degree.

The optimum hardness value is observed at spindle speed 900 rpm, transverse feed 55 mm/min, tilt angle 1 degree. The optimum Surface roughness value is observed at spindle rotational speed 1100 rpm, transverse feed 42 mm/min, tilt angle 0 degree.

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