International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 05 | May - 2023 SJIF 2023: 8.176 ISSN: 2582-3930

EFFECT OF PROCESS PARAMETERS ON HARDNESS &TENSILE STRENGTH IN FSW OF AL7050 ALLOY

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ABSTRACT: Friction stir welding technique is a solid state joining method, It is non-conventionally used for welding the aluminium and aluminium alloys. These type of material are very light in weight but having very high strength. In the present study, tensile strength &brinell hardness of the FSW weld on various parameters have been investigated. Two plates of AL7050 were joined by using vertical milling machine. The main aim of experiment is to get the optimum tensile strength and hardness. Here Taguchi L9 orthogonal array methodology was used, in which we consider 3 levels and 3factors. MINITAB-17 was used for graphical presentation and mathematical solution. ANOVA approach was used for feasibility of experimental model. Rotational speed, traverse speed and tilt angle were used design approach parameters in this experiment.

INTRODUCTION: FSW is a solid phase welding process, first used in 1991 by Thomson at TWI (The Welding Institute) in London. A cylindrical tool which is non-consumable and rotating is plunged in the workpiece. It travels along the joint line. Because of stirring action of this tool heat is generating at the junction of two work piece by which temp at joint line goes under the melting point. The friction results in atomic diffusion between the two sheets. This diffusion leads to bonding of materials. Design of tool can affect the weld quality. Shoulder provides extra heat and also protect the plasticized soften material from exiting the weld zone. This technique reduce many problems like shrinkage splatter & porosity. In this experiment Taguchi L9 orthogonal array approach is used. After observations concluded that main parameter is tool rotational speed which affect the mechanical properties. But the speed of travel and the angle of inclination of the tool also have a significant effect on the properties of the joint.

It reduce the problem related to solidification because filler material is not required. The fsw is mainly used for making lap and butt joints. In FSW mainly two types of machines are uses pressure controlled and machine controlled. This process is also employ for welding of light and difficult to weld material for example magnesium and copper so it is applicable in automobile and aerospace sectors. It is environment friendly green manufacturing process.FSW is reasoned to be important development in the metal welding in a decade because of its energy effectiveness, atmosphere friendliness and flexibility. On comparing to the traditional welding methods, it requires relatively very less energy.

EXPERIMENTAL DESIGN AND PROCEDURE: For experimental design, here Taguchi L9 orthogonal array is used. It is developed by scientist named as Dr. Genichi Taguchi. It suggested a better way to ensure quality. This technique determine which factor is most influencing the product quality by use of minimum experimentation which saves time and resource.

For welding of aluminium AA7050 alloy H13 die-steel tool is used. A carbide single point cutting tool is used to prepare the profiles of tool on Lathe machine. The tool pin profile has been used in present work is cylindrical.

Al 7050	Composition %	H13 (Tool)	Composition %
Al	90.5	C	0.32-0.45
Zn	5.1	Cr	4.75-5.5
Mg	2.31	Mn	0.2-0.5
Fe	0.15	Mo	1.1-1.75
Si	0.12	P	0.03
Mn	0.23	Si	0.8-0.12
Cr	0.21	S	0.03
Others	2.5	V	0.8-1.2

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Vertical milling center machine used as friction stir welding machine setup.

Three factors for FSW are studied (i.e. rotating speed, welding speed and tool pin profile) in which three levels of each factor are considered. Hense an L9 (3^3) orthogonal array is select for the experiment because in L9 (3^3) in 9 combination of experiments 3 factor with 3 level can be analysed.

In the present investigation, the base material Al7050thickness of 5mm is employed. Rotational speed (1000, 1400 & 2000), traverse speed (40, 50 & 60) and tilt angle (0, 1 &2) were process parameters.

Orthogonal Array Taguchi Design L9 actual values

S. No.	Rotation Speed(rpm)	Traverse speed (mm/min.)	Tilt angle (degree)
1	1000	40	0
2	1000	50	1
3	1000	60	2
4	1400	40	1
5	1400	50	2
6	1400	60	0

7	2000	40	2
8	2000	50	0
9	2000	60	1

The statistical analysis of quality characteristics which include tensile strength and hardness for all the trials was carried out by ANOVA (analysis of means). The most optimum combinations of technique parameters were predicted and analyse.MINITAB-17 a software package is used for making the model, graphical representation and analysing the results.

RESULT AND DISCUSSIONS: FSW is used for joining of Al7050 alloys and investigated by using different process parameters like Tool tilt angle , rotational speed and traverse speed. Taguchi methodology is used to optimize the hardness and tensile strength. The analysis of variance technique is used to determine the importance of parameters for validation. The Percentage contribution of Traverse Speed, tool tilt angle and Tool Rotation Speed to hardness and tensile strength were studied and analysed by means of the use of analysis of variance technique.

HARDNESS TEST

Below table shows the hardness result with process variable and its design levels. These values are taken into account to perform present work, like Tilt angle, Traverse Speed, Tool Rotational Speed.

Hardness test result

Trial no.	Rotation Speed(rpm)	Traverse Speed (mm/min.)	Tilt angle(°)	Hardness test (HB)	S/N RATIO	MEAN
1	1000	40	0	63.1	36.0000	63.1
2	1000	50	1	71.1	37.0374	71.1
3	1000	60	2	75	37.5013	75
4	1400	40	1	76	37.6123	76

5	1400	50	2	80.2	38.0802	80.2
6	1400	60	0	77.6	37.8003	77.6
7	2000	40	2	71	37.0278	71
8	2000	50	0	72.5	37.2013	72.5
9	2000	60	1	76.7	37.6959	76.7

The signal to noise ratio SNj for Hardness, is defined as:

$$\mathbf{SN_I = -10*log\,(\Sigma^n i_{=1}(1/Y_{ijk}{}^2)/n)}$$

ANOVA for hardness test

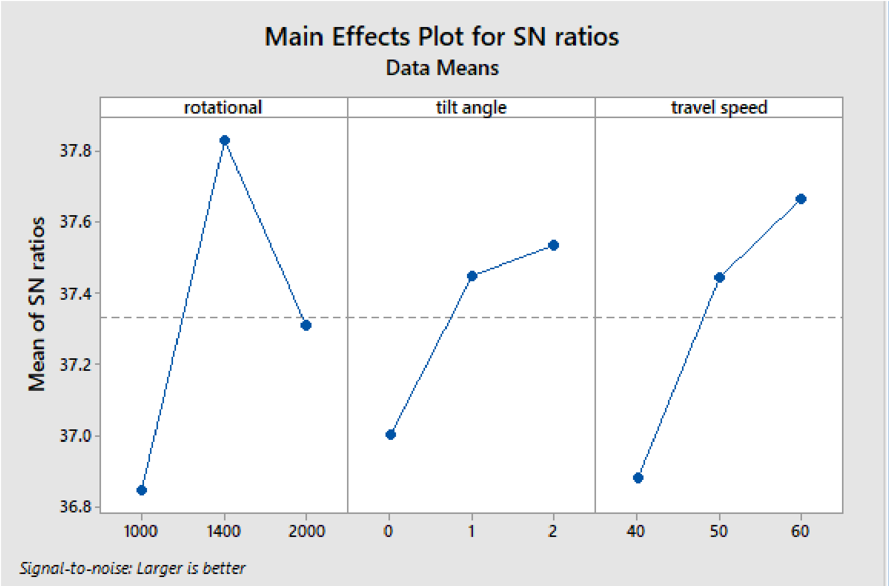
The present study shows that the rotation speed having maximum percentage of contribution

ANOVA Table for hardness

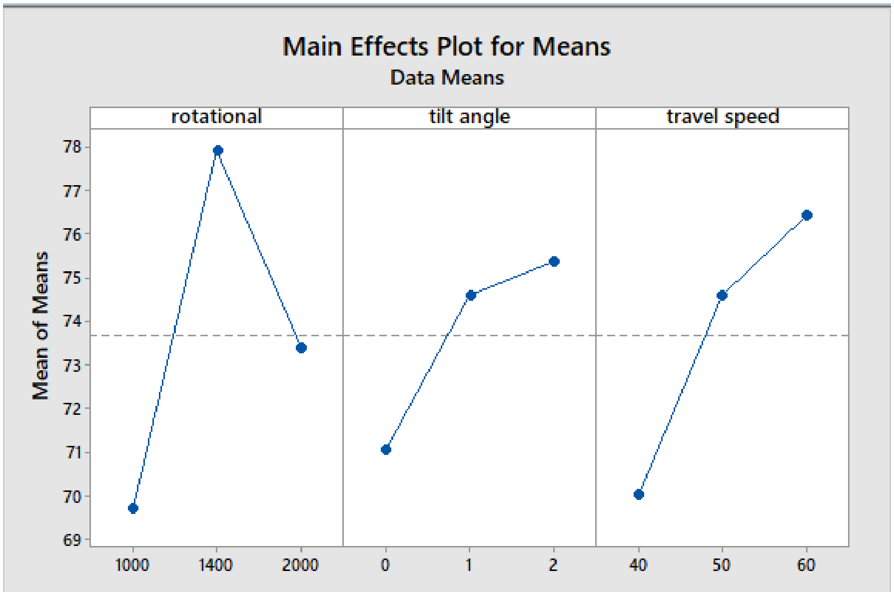
Source	DOF	Adj. SS	Adj. MS	F-value	% Contribution
Rotation speed	2	101.224	50.61	35.39	50.24
Traverse Speed	2	65.193	32.59	22.79	32.387
Tilt Angle	2	32.007	16	11.18	15.901
Error	2	2.86	1.443		
Total	8	201.289			

Graphical presentation is done with the help of MINITAB 17

This graph shows the variation of SN ratios with process parameters



This graph shows that variation of means of mean with respect of process parameters



The above graphs show the main effect plotted against mean values for various outputs and using percentage contribution. Here it shows that the tool rotation speed is the main factor to be effectively decided with the contribution ratios as mentioned in the above ANOVA table. From the above graphs maximum hardness is observed at travel speed of 60 mm/min ,the Tool Rotation speed of 1400 rpm, and tilt angle of 2.

TENSILE STRENGTH TEST

Below table shows the Tensile Strength result with process variable and its design levels. These values are taken into account to perform present work, like Traverse Speed, Tool Rotational Speed, Tilt angle

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Trial no.	Rotation Speed(rpm)	Traverse Speed (mm/min.)	Tilt angle(°)	Tensile Stress(N/mm^2)	S/N Ratio	MEAN
1	1000	40	0	105	40.4237	105
2	1000	50	1	135	42.6066	135
3	1000	60	2	128.5	42.1780	128.5
4	1400	40	1	109.67	42.8017	109.67
5	1400	50	2	151.3	43.5967	151.3
6	1400	60	0	130.45	42.3088	130.45
7	2000	40	2	87.33	38.8232	87.33
8	2000	50	0	97.7	39.7979	97.7
9	2000	60	1	95.34	39.5855	95.34

The signal to noise ratio SNj for Tensile strength is defined as:

$$\mathbf{SN_I = -10*log\ (\Sigma^n i_{=1}(1/Y_{ijk}{}^2)/n)}$$

ANOVA for tensile strength test

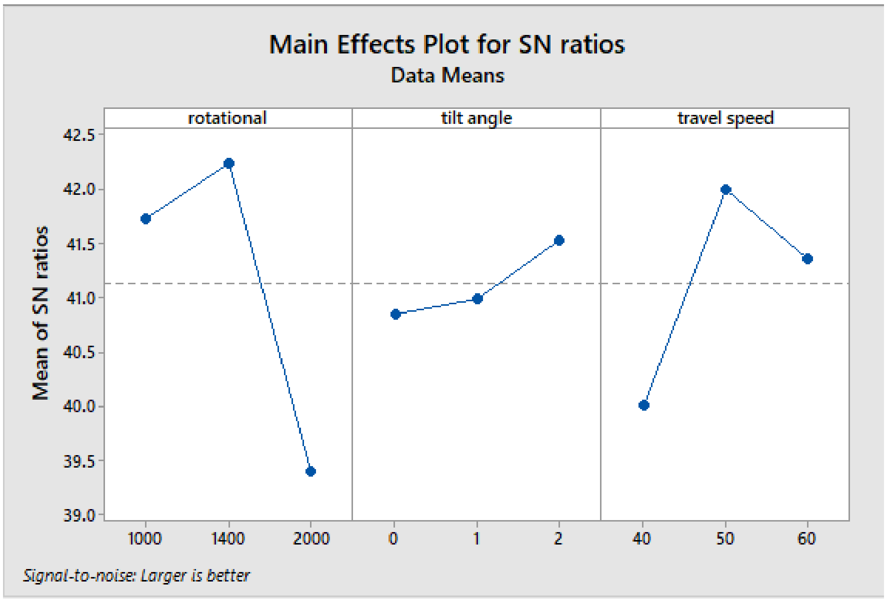
The present study shows that the rotation speed having maximum percentage of contribution

ANOVA table for tensile strength

Source	DOF	Adj SS	Adj MS	F-value	% contribution
Rotation Speed	2	2292.03	1146.01	38.39	61.69
Traverse Speed	2	1148.59	574.29	19.24	30.91
Tilt Angle	2	215.06	107.53	3.6	5.78
Error	2	59.69	29.84		
Total	8	3715.37			

Graphical presentation is done with the help of MINITAB 17

This graph shows the variation of SN ratios with process parameters



This graph shows that variation of means of mean with respect of process parameters

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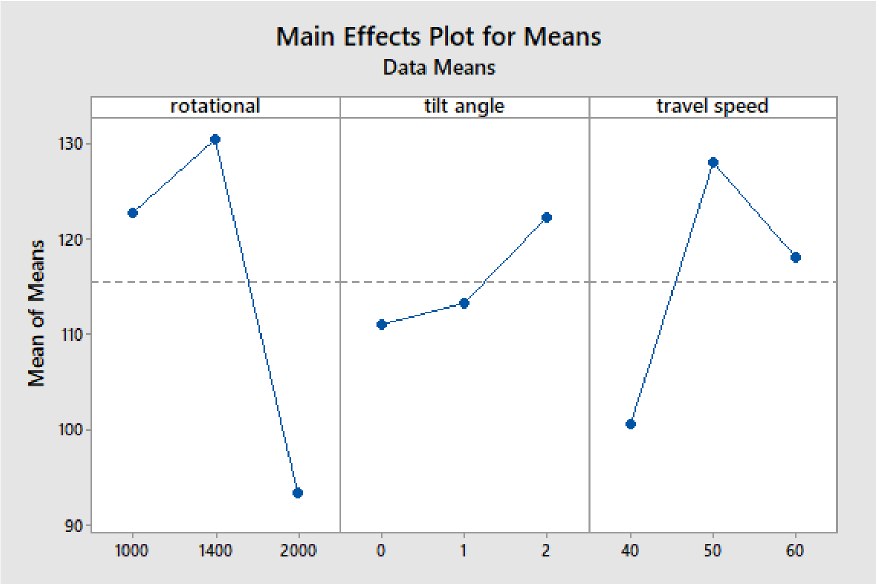

The above graphs show the main effect plotted against mean values for various outputs and using percentage contribution. Here it shows that the tool rotation speed is the main factor to be effectively decided with the contribution ratios as mentioned in the above ANOVA table. From the above graphs maximum hardness is observed at travel speed of 50 mm/min ,the Tool Rotation speed of 1400 rpm, and tilt angle of 2.

CONFIRMATION TEST

As per experimental result the level of optimized process parameters are tool rotational speed 1400rpm, traverse speed 60mm/min and tilt angle 2° for hardness and optimized process parameters are tool rotational speed 1400rpm, traverse speed 50mm/min and tilt angle 2° for tensile specimen. The result of hardness and tensile strength is given in table, which justify that welding at optimized

Table: Confirmation Table for hardness

Rotation speed (rpm)	Traverse speed (mm/min)	Tilt angle (degree)	Hardness (HB)
1400	60	2	80.20

Table: Confirmation Table for tensile strength

Rotation speed (rpm)	Traverse speed (mm/min)	Tilt angle (degree)	Tensile strength
1400	50	2	147.88

CONCLUSION

The research work examines the process parameters optimization and microstructure characterization of FSW joints of AA7050aluminium alloy. The responses that are considered in research are tensile strength, hardness, percentage elongation and temperature. All the objectives of the research work have been accomplished.

1. Rotational speed has the greatest impact on tensile strength and hardness of all process parameters.
2. As the tilt angle and traverse speed increase, the hardness increases, but as the rotation speed increases, the hardness first increases and then decreases.
3. After performing the confirmation experimental at the optimum setting, the tensile strength and the brinell hardness are 147.88 MPa and 80.20 respectively which are near to the expected values by the model.

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