ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 5, Issue 3, March 2020

Investigation of Friction Stir welding on AA6061 using Taguchi method

[1] Philip K Cherian, [2]Jiss Thomas, [3]Akhil A.M, [4]Murali Krishnan K S, [5] Sabu K.T.
[1][2][3][4] Mechanical engineering, Rajiv Gandhi Institute of Technology, Kottayam

***Abstract:*-- AA6061 Aluminium alloy is widely used in aircraft wing manufacturing, automobile and rail industries owing to its light weight structure with high strength to weight ratio. In Friction Stir Welding (FSW) process the material while welding is not melt as compared to traditional methods viz. fusion welding, so it doesn't damage the structure. The weld created is seamless and aesthetically good. This process is fully automated and weld created does not have any porosity. The experimental architecture was planned as per Taguchi's L9 orthogonal array so as to extract maximum information with minimum experimental runs. The data were taken from the machine itself. The tool used for the Friction Stir Welding was spiral shaped pin type to get the best welding properties. The tensile test was carried out to get the ultimate tensile stress for each weld. Thus, this process has a wide application in the field of manufacturing. In view of this, the present work proposes an experimental investigation, to analyse the effect of welding parameters such as welding speed, tool rotation speed and force applied on welding strength and study the property of the best weld.**

Index Terms:-Aluminium, Coconut Shell Ash, Graphite, MMC

1. INTRODUCTION

Aluminium alloy material is very important in field of manufacturing. It is widely used for fabrication of light weight structures, wings of aircraft etc. It has many advantages like low density, high strength, good corrosion resistance,high formability and good machinability. But welding of aluminium alloy using conventional method cause decreasing strength, porosity, and have a wide heat-affected zone and discontinuities.
Friction Stir Welding (FSW) is an emerging field in the joining of materials. .It is a rapidly maturing solid state welding technique invented in the early 1990's. It has a large development and potential in the joining of metals. The weld produced is seamless and have less porosity. This process can locally eliminate casting defects. The weld produced have refined microstructure therefore improving strength and ductility.

In this study we have used a commonly used aluminium alloy AA6061 and studied the behaviour of the ultimate tensile strength of the weld formed using FSW while changing its different parameters and finding the optimum values.

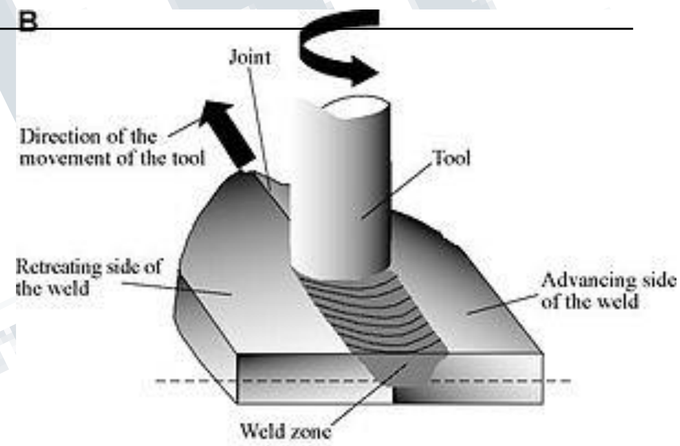

Figure 1Schematic representation of fsw process

1.1. Literature review

The main process parameters of FSW are the rotational speed of the tool, tool transverse speed and axial force on the plates during welding. The FSW tool geometry which involves the geometry of the tool pin probe and shoulder surface is also having huge importance. Mohanty et al. [3] haveinvestigated the effects of tool shoulder and probe geometries on friction stirred aluminium welds with respect to weld strength, weld cross section area, grain size of weld and grain size of thermo-mechanically affected zone using response surface methodology. Z. Zhang [4] have done a research on the variation of axial pressure on the weld formed. It was concluded that axial force was an essential parameter and insufficient and excessive axialforce leads to failure

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 5, Issue 3, March 2020

The study reveals that the tool rotational speed plays an important role to the overall welding parameter's. Koilraj et al. [5] have used a Taguchi's L16 orthogonal array to carry out the experiments by taking parameters like rotationalspeed, welding speed, tool geometry and ratio of tool shoulder to pin diameter with reference to the tensile strength.
In this work, Taguchi's L9 orthogonal array has been adopted to analyse the effect of tool rotational speed, tool travel speed and force applied on the tensile strength of the welding. Finally, the optimal parametric setting obtained through the study has been validated by conducting confirmative test predicting results within the scope of the experiment.

2.EXPERIMENTAL DETAILS

The experiments were conducted on a friction stir welding machine where a tool is mounted in an arbor with a suitable collate. The vertical tool head can be moved along the vertical guide way (Z axis), the horizontal bed can be moved along X and Y axis. The aluminium alloy (AA6061) chosen for the experimental study was 6mm thick plate of commercially available aluminium alloy (composition as given in Table 1). The weld faces of the test plates clamped in horizontal bed. The tool can be moved and positioned according to the purpose required.

At the beginning the tool must be positioned above the path of weld to be made. Then we have to feed the initial position of the tool and final position of the tool to the machine. The speed of weld, rotation speed and force to be applied are to be fed. On giving the start command the weld be made according to the input details.

2.1 Tool Design

There are many types of tools available for the FSW. The tool which was chosen for this experiment was cylindrical tool with spiral pin. There are three parts for the tool- shank, shoulder and pin. Shank is the part that is fitted into the machine holder. Shoulder is the part that creates weld by friction between the shoulder part and plate during rotation. To minimize the HAZ in this experiment, shoulder diameter was taken as 20mm. The pin size used was 5.7mm long and 6mm diameter.
The material used was H-13. The composition of the alloy is given below.

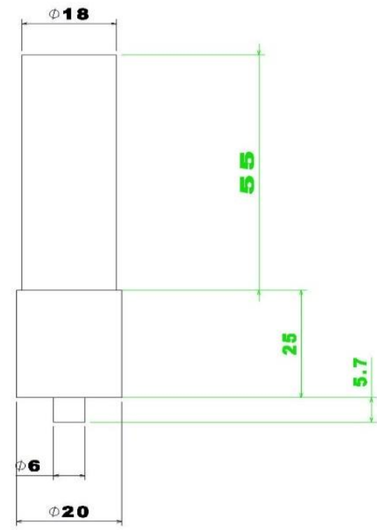

Figure 2 Tool Design

Table 1 Composition of FSW tool by percentage

C	Cr	Mo	Mn	Si	V	Fe
0.32-.40%	5.15-5.25%	1.33-1.4%	0.35-0.40%	1.0%	1.0%	90.9%

The spiral shaped pin helps in producing an increase in the heat produced due to friction and proper movement of material in weld pool. It is necessary that the melting point of the tool must be higher than that of the aluminium plate to reduce the chance of wearing of the tool. The H-13 tool steel was made to undergo series of heat treatment process to increase the machineability and hardness is used for this investigation.
Since the tool rotates at high speed it generates high temperature because of higher friction heating and result in more intense stirring and mixing of material. Thus increase in heat are directly proportional with the tool rotation rate thus the coefficient of friction between the interfaces will change.
The stirring and mixing of materials around the rotating pin is done by the rotation of tools thus stirs material from the front to the back of the pin and finishes the welding process.
Since the tool rotates at high speed it generates high temperature because of higher friction heating and result in more intense stirring and mixing of material. Thus increases in heat are directly proportional with the tool rotation rate is not expected as the coefficient of friction at interface will change with increasing tool rotation rate.

IFERP
connecting engineers... developing research

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 5, Issue 3, March 2020

2.2 AA6061 Plate

Table 2 Composition of AA6061

Cu	Cr	Mg	Mn	Si	Ti	Zn	Fe	other	Al
0.15-.040%	0.04-0.35%	0.8-1.2%	0.15%	0.4-0.8%	0.15%	0.25%	0.7%	0.05%	90%

2.3. Taguchi Method

Taguchi methods are statistical methods developed by Genichi Taguchi.It is one of the most powerful Design of Experiment (DOF) methods for analysing of experiments. It can be used to improve the quality of manufactured goods, and more recently also applied to engineering biotechnology, marketing and advertising. Taguchi first applied his methods was Toyota. Since the late 1970s.

The present study aims to get the effect of parameters like Force applied, Rotation speed and welding speed (Transverse motion) on the Tensile strength of weld formed on AA6061 using FSW. There different values for each parameter is selected. The combination of these parameter values sum up to Twenty-seven combination. But for reducing the complicity and the cost of welding we use Taguchi method to reduce the number of weld. Taguchi's L9 orthogonal array has been selected for the experimentation as shown in the table.

Table 3 Parameter Value and their level

Level	**A**	**B**	**C**
	Force Applied	**Rotation Speed**	**Weld Speed**
Level 1	1KN	1200 RPM	10mm/Sec
Level 2	2KN	1500 RPM	20mm/Sec
Level 3	3KN	1800 RPM	30mm/Sec

Other parameters like clamping of the plates, rigidity condition and back lash of the travelling machine bed are some of the variables are some of the variables that might affect the weld reinforcement and strength. The machine which was used for this experiment was semi-automated thus the error caused was reduced to a great extent. The numerical modelling for the determination of the FSW weld quality like weld tensile strength might be difficultconsidering the aforementioned varying input process and other variables. Since in the present study the Taguchi's experimental design was selected for each type of tool by taking three levels of force applied and tool rotational speed and welding speed, a comparison study of the main effect on the weld strength could be made.

Table 4 The Taguchi (L9) orthogonal array

Run	Force Applied(KN)	Rotational speed(RPM)	Weld speed(mm/Sec)
1	1	1200	10
2	1	1500	20
3	1	1800	30
4	2	1200	20
5	2	1500	30
6	2	1800	10
7	3	1200	30
8	3	1500	10
9	3	1800	20

3. RESULTS AND DISCUSSION

3.1Tensile Test

This test was conducted to determine the ultimate tensile strength of each weld created. As we are trying to find the optimum parameters w.r.t ultimate tensile strength.From the tensile test conducted on different specimen, tensile strength, yield strength and percentage elongation were obtained for each weld joint. All the values obtained is recorded and shown in table 5.

3.2 Signal to Noise Ratio

Since the objective of the study is to obtain the maximum tensile strength of the weld formed using optimum process parameters. The formula used for calculating the SN ratio is given below.

$$\text{S/N ratio} = -10\log_{10}\frac{1}{N}\sum_{i=1}^{n}\frac{1}{{y_i}^2}$$

Wherey_i is the value of tensile strength for the i^thtest ,n is the number of test conducted and N is the total number of data points.

Table 5 Table showing Tensile Strength value for different input parameters

Ex. No.	Force Applied (KN)	Tool rotation speed (rpm)	Welding speed (mm/min)	Tensile strength (MPa)	S/N Ratio
1	1	1200	10	97.61	39.7899
2	1	1500	20	110.68	40.8814
3	1	1800	30	129.12	42.2199
4	2	1200	20	157.11	43.9241
5	2	1500	30	147.91	43.4000
6	2	1800	10	110.87	40.8963

7	3	1200	30	161.11	44.1424
8	3	1500	10	119.81	41.5699
9	3	1800	20	128.12	42.1523

Experimental data are converted into S/N ratio. The calculated S/N ratio values are tabulated in Table 5. The analyses are made using the popular software known as MINITAB 16.

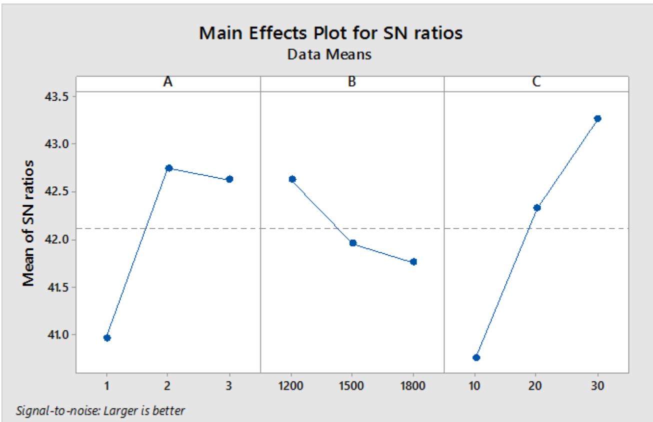

Figure 3Main effects plot for SN ratios

From the main effect plots the optimum levels of the process parameters were chosen as, 2 KN axial force, 1200 rpm rotational speed, 30 mm/min welding speed.

3.3 Analysis of variance (ANOVA)

ANOVA is a statistical tool which aims at evaluating the significant factors. This gives how much each factor has affected the tensile strength value.The F test is being carried out to study the significance of the process parameter. The high F value indicates that the factor is highly significant in affecting the response of the process. From the value of F it is clear that transverse welding speed has affected the tensile strength of weld the most.

Table 6Analysis of Variance(R-sq=95.24,R-sq(adj)=80.95)

Source	DF	Adj SS	Adj MS	F	P
Force Applied	2	1259.7	629.83	6.76	0.129
Rotational Speed	2	420.5	210.23	2.26	0.307
Transverse Speed	2	2047.0	1023.49	10.98	0.083
Residual Error	2	186.4	93.21		
Total	8	3913.5			

3.4 Confirmation test

As the optimal level of process parameters are identified from the study, it is customary to validate the responses. As the maximum value for tensile test is found for 2 KN axial force, 1200 rpm rotational speed, 30 mm/min welding speed. This values are taken for confirmatory testing. The result of confirmatory test is given in Table 6

Table 7 Confirmatory Result

Force Applied	Rotational speed	Transverse Speed	Tensile Strength
2KN	1200 RPM	30 mm/min	167.8 MPa

4. CONCLUSION

In this work, an extensive experimental investigation is carried to analyse the effect of important process parameters of FSW on the tensile strength of AA6061. It shows the effect of important process parameters on the response with analysis and justifications. The process parameters were optimized with respect to tensile strength of the joint and the optimum level of settings were found out. From the experiment the result obtain shows failure occurs at insufficient and excess axle force. The optimum values for force applied, rotational speed and transverse speed are 2KN, 1200 RPM and 30mm/min respectively. The confirmatory test were conducted. From Analysis of variance (ANOVA) it was clear that the Transverse speed influenced the tensile strength the most.

REFERENCES

1.Vikas Gupta, Rajesh Bansal, Vineet Kumar Goel, Entifing parameters affecting friction stir welding process, International Journal of Technical Research (IJTR) Vol. 2, Issue 2, Jul.-Aug. 2013

2. D.M. Rodrigues, T. Mira-Aguiar, M.I. Costa, C. Leitão, friction stir welding of very thin steel plates, FSWP International Conference, 2015

3.H. K Mohanty, M.M. Mahapatra, P. Kumar, P. Biswas, N.R. Mandal,Modeling the effect of tool shoulder and probe profile geometries onfriction stirred aluminum welds using RSM, J. Marine Sci. Appl. 11 (2012): 493-503.

4. Z. Zhang and H.W. Zhang, Numerical studies on effect of axial pressure in friction stir welding, Science and Technology of Welding and joining, 2007 ,12(3):226-248.

5.M. Koilraj, V. Sundareswaran, S. Vijayan, S.R Koteswara Rao, Friction stir welding of dissimilar Aluminum alloys AA2219 to AA5083 optimization of process parameters using Taguchi technique, Mat. & Designs 42 (2012): 1-7.

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 5, Issue 3, March 2020

6. BahmanMeyghani, MokhtarAwang, SattarEmamian, Mohd Khalid B. Mohd Nor, Thermal Modelling of Friction Stir Welding (FSW) Using Calculated Young's Modulus Values, The Advances in Joining Technology, May 2018.
7. Güvenİpekoğlu, Ö. Akçam, GürelÇam, Effect of plate thickness on weld speed in friction stir welding of AA6061-T6 Al-alloy plates, ISSN 0957-798X the Paton Welding journal, 2018.
8. P Raja, S Bojanampati, R Karthikeyan, RGanithi, Effect of rotation speed and welding speed on Friction Stir Welding of AA1100 Aluminium alloy, IMMT, 2017.
9. PatrykJedrasiak, Hugh R. Shercliff, Small strain finite element modelling of friction stir spot welding of Al and Mg alloys, Journal of Materials Processing Technology, July 2018.
10. Kishan Kumar, C. Kalyan, SatishVasu Kailas, T. S. Srivatsan, An Investigation of Friction During Friction Stir Welding of Metallic Materials, Materials and Manufacturing Processes, April 2009