Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 44 No. 2 (2023)

Optimization Of Friction Stir Welding of Commercial Dissimilar Aluminium Grades HE30 & HE9 Using Taguchi Approach

Mr. Prasad S. Kamble*, Dr. Sanjeev Reddy K Hudgikar, Dr. Chandrakant Y. Seemikeri*****

*Research Scholar, Department of Mechanical Engineering, VTU Belagavi, Karnataka, India- 590018
**Mechanical Engineering Department, Sharnbasva University, Kalaburagi Karnataka, India-585105
***Mechanical Engineering Department, Govt. Polytechnic Karad, Maharashtra, India-415124
*email: prasadskamble@gmail.com

Abstract
Aluminium alloy commercial grades6082 and 6063 are widely used in industrial application. For the joining of these grade material TIG welding can be preferably used. Friction stir welding (FSW) is the mechanical type joining process produces high welding strength without adding filler material. In this research article, experimental study is carried out on Al6082 and Al6063 to check weld quality and hardness of friction stir welding samples. Taguchi method and L9 orthogonal array is used for design of experiments. Comparative results revealed that friction stir welding gives tensile strength of weld upto123.23 N/mm² and maximum hardness upto 54Hv at welding nugget zone.

Introduction

Aluminium alloys are widely used in low weight and high strength applications. Where manufacturing processes and joining process of aluminium grades need necessary precautions for better accuracy and quality.

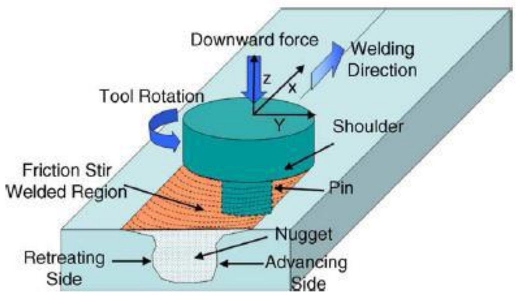

Fig 1. FSW process [7]

Especially for Aluminium alloyjoining, TIG (Tungsten Inert Gas) welding is widely used. Various commercial aluminium grade are used in aerospace application where light weight of material is major criterion. Friction stir welding is process of joining of similar or dissimilar metal by heat caused due to friction between rotating tool and work piece. The FSW tool has different pin profile which significantly causes the generation of heat. This rotating tool pin plunge into the two work piece interface and also advances the interfacing path produces the heat and creates the joint between the different work piece which is schematically shown in fig 1.

In Aircraft building, aluminum bodies are need to be joined with quality strength. Hence, to sustain under such dynamic loading application, joining strength of weld must be important factor. This research article covers the experimental study of friction stir welding of HE30 (Al6082) and HE9 (Al6063), which are commercially used in various applications. L9 orthogonal array and ANOVA is used to get optimum process parameters to know the optimum welding strength and hardness.

LITERATURE REVIEW

1. Anton Naumov et al. performed an experimental study of FSW on aluminium alloy 6082-T6. Primary focus of this study was to check the effect of low and high welding speed on mechanical characteristics and micro structural changes of welding specimen. Work piece sample is taken for this study has thickness of 2mm. There is no specific DOE highlighted, but for low welding speed (200 mm / min) tool rotation is set at 710rpm. And for high welding speed (2500 mm/min), 2100 rpm is set at tool rotation. Combined effect of Tool rotation and high welding speed has significant effect on tensile strength is highlighted in this study.

2. Dr. V.P.Raju et al carried out micro structural study on the work piece of lightweightaluminium alloy 6351 (HE 30). To determine significant improvement in microstructure, heat treatment is also recommended after welding process. For the experimentation tool rotation (800 rpm, 1000rpm & 1200 rpm) , welding speed (14 mm/min, 12 mm/min, 10mm/min) are varied. Tool pin dimensions were set with pin length of 4.7mm and pin diameter of 6mm. Study revealed that tapered cylindrical tool pin gives good mechanical strength.

3. A.K.Revelly et.al investigated the effects of process parameters on FSW strength. For the experimental study four specimens were prepared of material HE 30. Tool is made by H13 (tool steel) with heat treated. Experiments were performed using tool rotation at 1000 rpm, 1200rpm, 1400rpm and 1600rpm. Welding speed is kept constant as 30 mm/min. It is found that at 1600rpm, weld joint gives maximum strength of 92MPa.

4. Radhikachanda has conducted experimental work on aluminium alloy AA6061 of dimension 150x50x6mm. L9 orthogonal array is used for the experimentation. Two major input process parameters are varied. Tool rotation is set at1800rpm, 1400 rpm and 900rpm. Welding speed was set at 135, 100 & 65 in mm/min. It is found that at 1800-rpm tool rotation and 100mm/min welding speed gives 133MPa tensile strength.

5. T.A.Osman et al performed the experimental study to check the mechanical strength of friction stir welded component. for this study dissimilar grades of aluminium alloy were used. AA 5454 and AA 7075 are joined using FSW. For the experiments, tool rotations were set to 1000rpm and 1225rpm. And welding speed is kept at 17mm/min and 21mm/min. Workpiece plate thickness was taken of 3.5mm. RSM is used to optimize the process parameter. Tensile strength is significantly enhanced to 217MPa.

6. Vanita S Thete et al. carried out an experimental work of friction stir welding on HE 30. In this experiments tool rotations ,axial force and welding speed are the process parameters. Tool pin profile is modified with cylindrical pin with three flutes. It is found that tensile strength is achieved upto 73MPa from this experimentation.

7. Prasad Kamble et al performed experimental study on AA 6061 alloy of 200x75x12 mm workpiece. Failure analysis of FSW tool in discussed using fishbone diagram. Welding quality of specimen is improved using threaded conical pin.

Methodology:

a) Machine used:

The experiment set is made using conventional milling machine with fixture to support the work pieces during friction stir welding experiments shown in fig 2.

- Conventional Milling Machine. Vertical Stroke - 450mm
- Top speed- 1600 rpm Machine bed length-700mm Width- 250 mm

Fig.1. Conventional milling machine (PriyankaUdyog, Pune)

b) Material selection:

For the experimental study two dissimilar commercial aluminium grades are selected namely Al6063 and Al6082. Composition of these alloys are mentiond in table 1 & 2.

For the experimentation nine workpieces of size 100x30x5mm are prepared.

Table 1 : Composition of HE9 (Al6063)

Grade	Al	Si	Fe	Mg	Ti	Cu	Mn	Cr	Zn
Al6063	98.2%	0.4%	0.35%	0.45%	0.10%	0.10%	0.10%	0.10%	0.10%

Table 2 : Composition of HE30 (Al6082)

Grade	Al	Si	Fe	Cu	Mg	Zinc	Cr
Al6082	0.95	0.7	0.5	0.1	0.6	0.2	0.25

c) FSW Tool:

Friction stir welding tool is made of tool steel material. Three different pin profiles are selected for the study like cylindrical threaded, conical threaded and conical threaded with two side faces shown in fig 3. The role of pin is to produce heat due to friction at two specimen interface. Hence the heat will cause to weld the specimen. Tool is made up of material D2 steel which is high carbon- chromium air hardening tool steel.

(a) (b) (c)

Fig.3(a) Cylidrical threaded, (b) Conical threaded, (c) Conical threaded with 2 face

d) Process parameters & DOE:

To perform the experiments L9 taguchi orthogonal array is used with three input process parameters and three levels like Tool rotation, tool feed rate and tool pin profile. Table 3 specifies the parameters and their levels. Table 4 is specifying the L9 orthogonal array for the experimentation.

Table 3. Process parameters & their levels

Levels / **Parameters**	**1**	**2**	**3**
Tool Pin profile	Cylidrical threaded	Conical threaded	Conical threaded 2 faces
Tool Speed (RPM)	1000	1250	1600
Feed (mm / min)	10	16	25

Table 4. L9 orthogonal array (DOE)

Sr. No.	**TOOL PIN PROFILE**	**RPM**	**FEED mm/min**
1	CYLIDRICAL THREADED	1000	10
2	CONICAL THREADED	1000	16
3	CONICAL THREADED 2	1000	25
4	CONICAL THREADED	1250	10
5	CONICAL THREADED 2	1250	16
6	CYLINDRICAL THREADED	1250	25
7	CONICAL THREADED 2	1600	10
8	CYLIDRICAL THREADED	1600	16
9	CONICAL THREADED	1600	25

Experimental set up:

Al 6063(HE9) and 6082(HE30) plates were held together by bolts & table fixture shown in fig.4 to absorb the shocks, vibrations, occuring while applying the axial load on plates.The tool being advance in vertically downward direction to plunged into the work peice. During the welding process the lubricant was not used. Different speed were maintained during the trials to facilitate the welding operation.

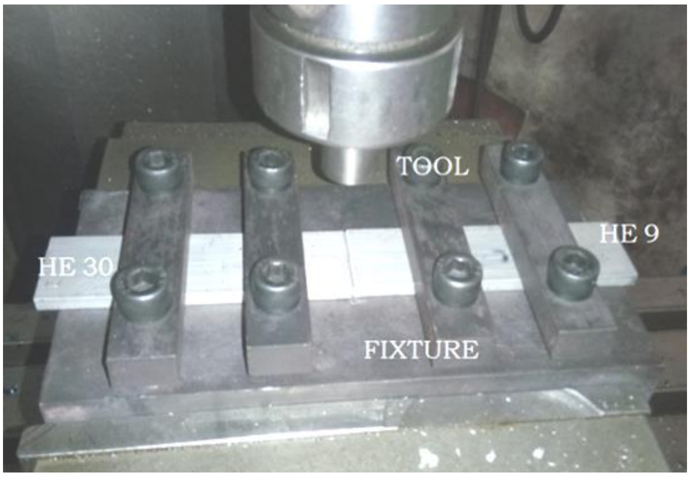

Fig.4 Experimental Set Up

Fig.5 Welded specimen for before & after Tensile test

Table 5. L9 array (DOE) & Observations

Expt. No.	RPM	FEED	Pin Profile	UTS (N/mm²)	Hardness (Hv)	S/N -(UTS)	S/N- (Hv)
1	1000	10	1	99.87	51	40.0	34.2
2	1000	16	2	54.57	53	34.7	34.5
3	1000	25	3	123.23	50	41.8	34.0
4	1250	10	2	105.42	53	40.5	34.5
5	1250	16	3	105.34	54	40.5	34.6
6	1250	25	1	103.3	46	40.3	33.3
7	1600	10	3	87.7	46	38.9	33.3
8	1600	16	1	96.02	49	39.6	33.8
9	1600	25	2	112.99	52	41.1	34.3

Table 6. Response Table for S/N Ratios (Larger is better)

Level	RPM	FEED	PIN PROFILE
1	38.85	39.77	39.97
2	40.4	38.28	38.75
3	39.86	41.05	40.38
Delta	1.55	2.77	1.62
Rank	3	1	2

The ANOVA results and optimum conditions for the better tensile strength are shown in table 7 & table 10.

Table 7. Analysis of Variance for S/N ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
RPM	2	3.713	3.713	1.857	0.27	0.786
FEED	2	11.555	11.555	5.778	0.85	0.542
Pin Profile	2	4.283	4.283	2.142	0.31	0.761
Residual Error	2	13.652	13.652	6.826		
Total	8	33.204				

Table 8. Response Table for Hardness (S/N Ratios Larger is better)

Level	RPM	FEED	PIN PROFILE
1	34.21	33.96	33.74
2	34.13	34.31	34.43
3	33.79	33.85	33.96
Delta	0.41	0.46	0.69
Rank	3	2	1

The ANOVA results and opimum conditions for the better hardness are shown in table 9 & table 11.

Table 9. ANOVA for Hardness (Hv)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
RPM	2	0.289	0.289	0.1445	0.38	0.725
FEED	2	0.3465	0.3465	0.17325	0.46	0.687
Pin Profile	2	0.7516	0.7516	0.3758	0.99	0.503
Residual Error	2	0.7615	0.7615	0.38075		
Total	8	2.1486				

Result and Discussion:

Effect of Speed, Feed & Pin profile on Welding strength (UTS):

from the experimental study of FSW, it is found that RPM of the tool increases gives better tensile strength. Higher feed rate also affect significantly on tensile strength and conical threaded with two faces gives good tensile strength shown in figure 6.

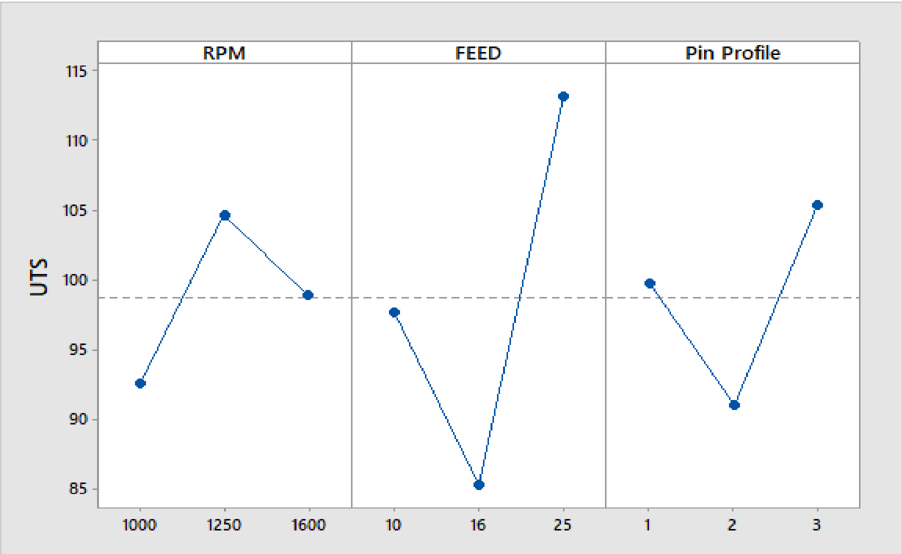

Fig6. Effect of Speed, Feed & Pin profile on UTS

Table 10. Optimum combination for better tensile strength

	RPM	Feed	Pin Profile
Optimum Parameters for Better UTS	1250rpm	25mm/rev	Conical threaded 2 face

Effect of Speed, Feed & Pin profile on Hardness (Hv):

From the experimental study of FSW, it is found that Hardness of welded region of the improves at lower tool rotation, average feed rate and conical threaded tool pin shown in figure 7.

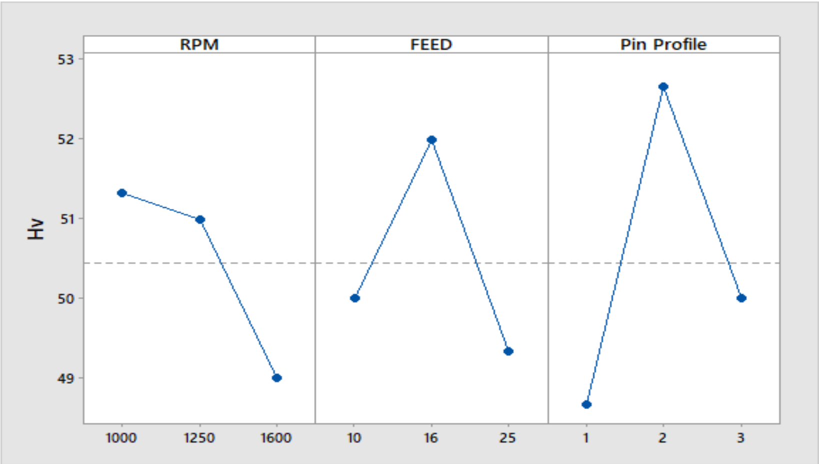

Fig7. Effect of Speed, Feed & Pin profile on Hardness (Hv)

Table 11. Optimum combination for better hardness

	RPM	Feed	Pin Profile
Optimum Parameters for Better Hv	1000rpm	16mm/rev	Conical threaded

Conclusion

1. Friction stir welding process can be effectively performed with conventional milling machine.
2. Optimum combinations of RPM, Feed & tool pin profile can significantly gives the ultimate tensile strength upto 123.23N/mm² and Hardness upto 54Hv.

ACKNOWLEDGEMENT

The authors acknowledge the gratitude towards industrial support by Mr. PrashantSalunkhe, Priyankaudyog, Pune and HariomSai Enterprises, Narhe Pune.

REFERENCES

[1] Anton Naumov; IuliiaMorozova 2;Evgenii Rylkov; AlekseiObrosov; FedorIsupov;VesselinMichailov;AndreyRudskoy, Metallurgical and Mechanical Characterization of High-Speed Friction StirWelded AA 6082-T6 Aluminum Alloy, *MDPI Materials* 2019, 12, 4211

[2] Dr. V. P. Raju; E.Srikanth, Determination of Microstructure of Friction Stir Welded Joint for Aluminium Alloy 6351 (He-30), *Journal of The Gujarat Research society*, Volume 21 Issue 7, November 2019

[3] A.K. Revelly; B. Rajkumar; V. Swapna, Evaluation of Microstructure and Mechanical Properties for Friction Stir Welding of Aluminium HE-30 Plates, *Trans Tech Publications Ltd,* Switzerland ,Vol. 969, pp 720-726, Aug 2019.

[4] Radhika Chanda, Evaluation of Tensile Toughness and Also Turnout Toughness of Abrasion Uproar Soldered Dissimilar Aluminium Lightweight Metal ,*International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, Volume-8 Issue-10, August 2019

[5] Mohamed Mohamed Abd Elnabi; T. A. Osman; A. E. El Mokadem; A. B. Elshalakany, Modeling and Optimization of Friction Stir Welding Parameters for Joining Dissimilar Aluminum Alloys, *Advanced Journal of Graduate Research*, Volume 4, Issue 1, pp. 1-14, July 2018

[6] Vanita S Thete; Vijay L. Kadlag, Effect of Process Parameters of Friction Stir Welded Joint for Similar Aluminium Alloys H30, *Int. Journal of Engineering Research and Applications*, Vol. 5, Issue 5, (Part - 6) May 2015, pp.10-17

[7] Dr. Sanjeev Reddy K Hudgikar; Dr. Chandrakant Y. Seemikeri; Prof. Prasad S. Kamble, Experimental Investigations of Friction Stir Welding (FSW) on Al 6061 : A Case study, *International Research Journal of Engineering and Technology* (IRJET), Volume: 04 Issue: 08, Aug -2017