Process Optimization of Friction Stir Welded AA6061 Boron Carbide Composites by Taguchi Method

Neerja Parmar[1] , Mr. Rajkumar Duhan[2]
[1]Student, M.Tech (Mechanical Engineering) Department of Mechanical Engineering, UIET, MDU Rohtak-124001
[2] Professor Department of Mechanical Engineering, UIET, MDU Rohtak-124001

Abstract: Friction stir welding process is a new age edge developing strong state joining process used to join high quality aluminum metal matrix composite. Grating mix welding produce sound welds in metal matrix composite with no harmful response amongst matrix and reinforcement. This present work centered to assess the impact of process parameters, for example, welding speed; tool rotational speed on tensile strength and hardness of friction stir welded B4C composite joints. Process parameters were controlled by the Taguchi parametric plan approach. Result demonstrated that instrument revolution speed, welding pace and device geometry impact on elasticity of joints that were welded.

Keywords: *tensile strength, joint efficiency, metal matrix composite and Taguchi method.*

1.1 INTRODUCTION

So as to deliver more grounded joints, the Friction stir Welding process (FSW) can be utilized. Numerous applications, for example, aviation, car and ship building ventures, [1] friction stir welding is a strong state welding process. The work pieces that are to be combined are clipped on a backing plate. A pivoting non consumable device with a profiled pin and substantial concentric shoulder gradually dove into the joint line between two plates which are braced together. Here blend is made by the joined activity of frictional warming amongst instrument and work pieces and the plastic misshapening of base metal because of the turn of the device. 95% of warmth created in the process is exchanged to the work piece and just 5% streams into the apparatus [2]. Taguchi strategies created by Genichi Taguchi to enhance the nature of assembling products are as of late connected to the field of building, assembling and advertising. The Taguchi technique is an intense device for doing test outline. The principle point of the Taguchi technique is to create an ideal come about by examining the factual information which have been given as an information work. This technique permits predetermined number of exploratory keeps running by using an all around adjusted trial configuration called symmetrical cluster plan and flag to commotion (S/N) proportion. Taguchi strategies have been effectively used by Lakshminarayananet.al. [3]. So as to examine the impact of parameters of Friction stir welding technique, most labourers take after conventional trial strategies, by taking one parameters variable and by taking other parameters steady. The customary parametric outline of trial practice is tedious and takes in huge assets. Taguchi's factual outlines are ground-breaking apparatus to distinguish noteworthy factor from numerous by leading generally less number of trials. Be that as it may, this outline in a general sense does not represent the cooperation.

II. Experimental Procedure

In this work AA6061 with (B4C) is utilized by the stir casting process to create composite of measurement 100mm×50mm×5mm plates. The concoction organization of the AA6061 is appeared in TABLE1. Boron carbide having a breadth of 200μm was picked as support particles since they have high wear obstruction. The normal Elasticity esteem utilizing UTM is given in TABLE.2.

Table 1 Composition of "Al6061"

Al	Ti	Zn	Cu	Cr	Fe	Mn	Si	Mg
97.790	0.051	0.082	0.221	0.141	0.71	0.120	0.41	0.80

2.1. Recognizing the Process Parameters and locating the Limits

Prevalent FSW procedure parameters which affect the rigidity of erosion blend welded joints are instrument rotational speed, welding rate and apparatus geometry [7]. The contraptions made of high carbon high chromium steel oil cemented to 62HRC with Hexagonal stick profile was used as a piece of the present work. The geometry of the mechanical assemblies are showed up in Fig.1

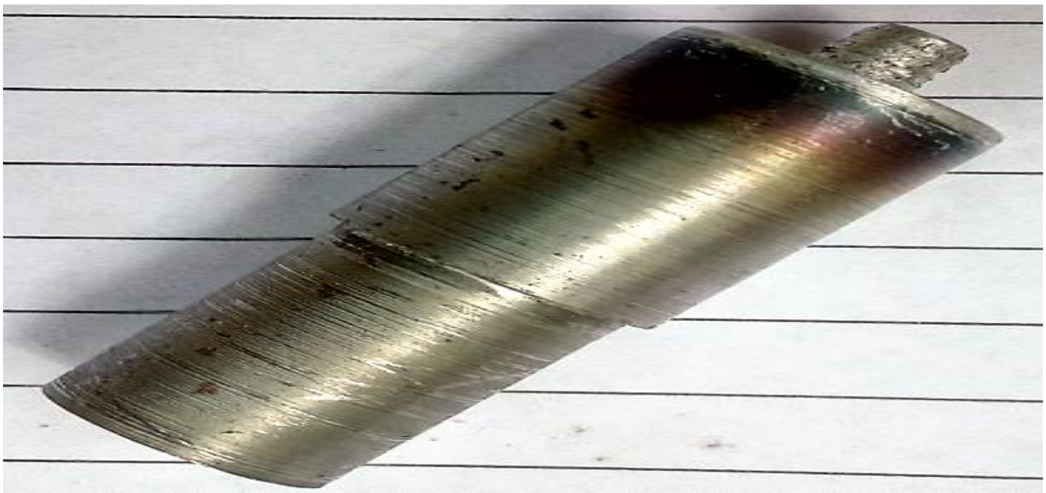

FIG 1 FSW TOOL

Number of welds were completed to settle the working scopes of every chose factor the breaking points of each factor were chosen. The maximum furthest reaches of a factor was coded as +1 and as far as possible was coded as – 1 for the comfort of chronicle and preparing exploratory information. The coded esteems for transitional qualities were computed utilizing the accompanying relationship [8].

$X_i = 2[2X– (X_{max} + X_{min})]/(X_{max} – X_{min})$,

Where Xi is the required coded estimation of a variable X; X is any estimation of the variable from X min to X max; X min, most minimal level of the variable; X max ,largest amount of the variable. The Minitab programming was utilized to think about the measurable investigation for the got comes about. Welding process parameters and their levels are appeared in TABLE 3

Process parameters	Level L1	Level L2	Level L3
Transverse speed	45	55	65
Rotational speed	1100	1200	1300
Tilt angle	0	1	2

Table 3 Optimization of process parameter

2.2. Developing and performing the experimentation

As indicated by outline matrix 9 sets of weld were performed and removed three ductile examples from plates which have been welded to assess tensile strength as far as ASTME8M-08 standard. Every piece welded has to be measured which are appeared in Fig.2. The darken part speaks about joint which was welded by FSW. Tensile strength is evaluated utilizing a mechanized general testing machine. Joint productivity computed by balancing tensile strength of welded plates against the parent material. So as to evaluate impact of variables on reaction, means and signal to noise proportion (S/N are to be computed the examination that have been performed here, S/N ratio was picked by basis, bigger – the better, so as to maximize response[11].

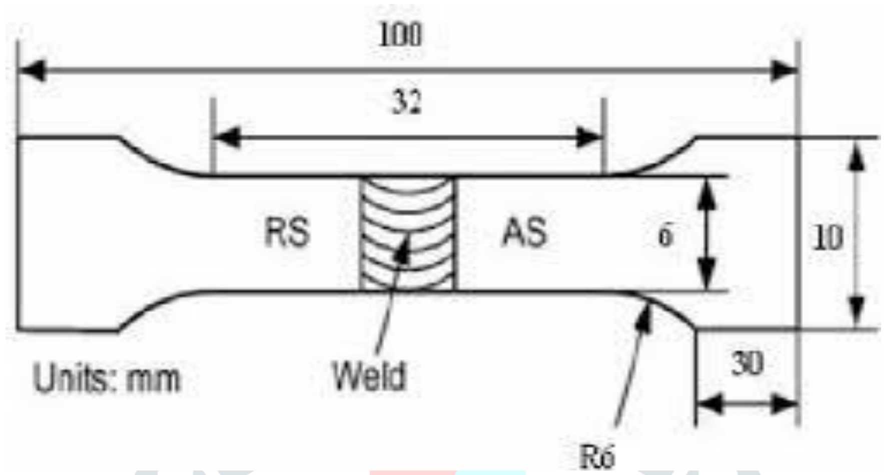

Fig 2 Tensile testing specimen dimensions as per ASTM E8-M08 Standard

III. Results and Discussions

Signals to Noise Ratio

The better, with a specific end goal to boost the reaction, in Taguchi strategy the S/N proportion is utilized to decide the fluctuations of the attributes. The S/N proportion can be communicated as In this work tensile strength and hardness are two of the fundamental qualities

S/N = - 10 log10 {1/n"n (1/y2)}

where n is the quantity of test Considered in portraying the nature of FSW joints. Each control directed, y I is the normal watched information of each test. In the factor can be figured with a specific end goal to evaluate the impact of parameters reaction, methods and signal to noise (S/N) proportions.

The signs are markers of the affect everythings which are taken in to considered reactions and the noise are taken for measuring the effect on the deviations from the affectability of the investigation. In this work, the S/N proportion was picked by the paradigm of the bigger present investigation, the rigidity information were broke down to decide the impact of FSW process parameters. Tensile strength and hardness, SN ratio and Means of FSW composite joints are appeared in TABLE 4.

3.1 PROCESS PARAMETERS FOR TENSILE STRENGTH

SAMPLE NO	TRANSVERSE	ROTATIONAL	TILT ANGLE

	SPEED	SPEED	
1	45	1100	0
2	55	1200	1
3	65	1300	2
4	45	1100	0
5	55	1200	1
6	65	1300	2
7	45	1100	0
8	55	1200	1
9	65	1300	2

Table 4 FSW parameters of AA6061.

S.N	T.S (mm/min)	R.S (RPM)	T.A	Tensile Strength (KN/MM^2)	Signal To Noise Ratio for tensile strength	Mean-1
1	45	1100	0	85	38.5884	85
2	55	1200	1	87	38.7904	87
3	65	1300	2	92	39.2758	92
4	45	1100	1	95	39.5545	95
5	55	1200	2	105	40.4238	105
6	65	1300	0	107	40.5877	107
7	45	1100	2	109	40.7485	109
8	55	1200	0	115	41.2140	115
9	65	1300	1	117	41.3637	117

Table 5 Tensile strength values deliberated from experiments and their S/N ratios nad mean values.

Data Analysis for Tensile Strength

Analysis of variance (ANOVA) exams were done to distinguish procedure parameter which were factually huge. The reason for the ANOVA exam was to research the criticalness procedure parameter that influence the tensile strength and hardness of FSW joint. The ANOVA comes about of elasticity of means and S/N proportions are shown in TABLE 5 and 6. End effects of ANOVA show that the considered procedure parameters are exceptionally critical components influencing the elasticity of FSW composite joints in the request of rotational velocity, welding velocity. Impacts of association between process parameters are not huge.

Sources of Variations	Degree Of Freedom	Adjustment Of Squares	Adjustment Of Mean squares	F-Value	P-Value
TS	2	7.49218	3.74609	376.79	0.003
RS	2	0.93954	0.46977	47.25	0.021

TA	2	0.11273	0.05637	5.67	0.150
Error	2	0.01988	0.00994		
Total	8	8.56433			

Table 6 ANOVA table for tensile strength

Regression Equation

TS	=	40.0607 - 1.1759 TS_45 + 0.1279 TS_55 + 1.0480 TS_65 - 0.4303 RS_1100 + 0.0820 RS_1200 + 0.3483 RS_1300 + 0.0693 TA_0 - 0.1579 TA_1 + 0.0886 TA_2

3.1.1 Optimizing the Tensile Strength Properties

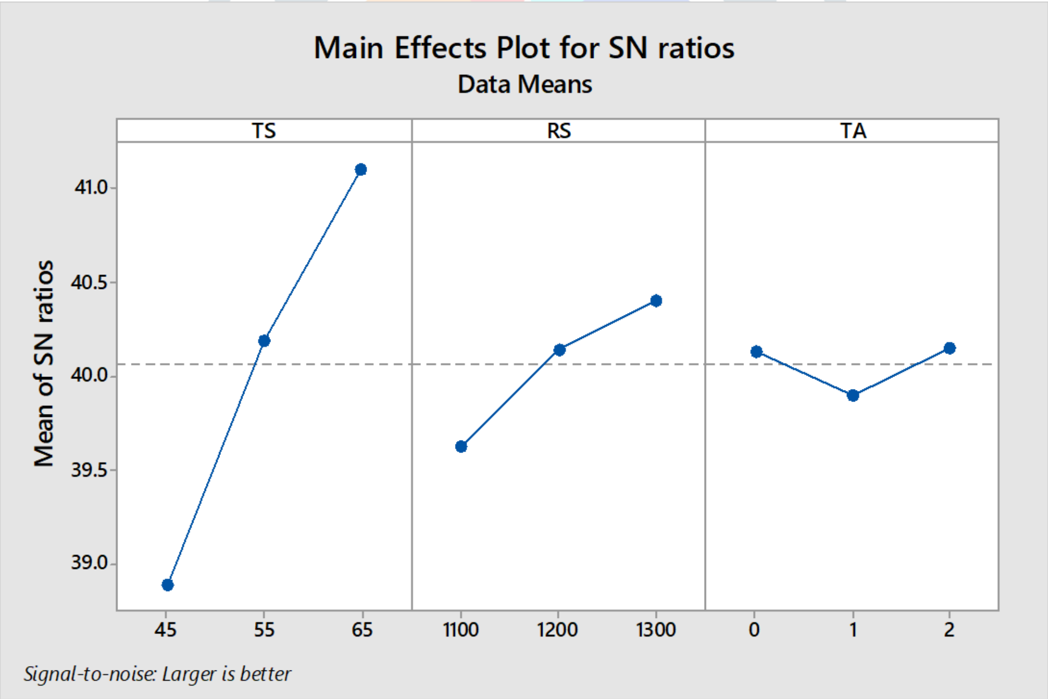

Fig 3 Graphical representation of Main effects for S/N ratio for tensile strength

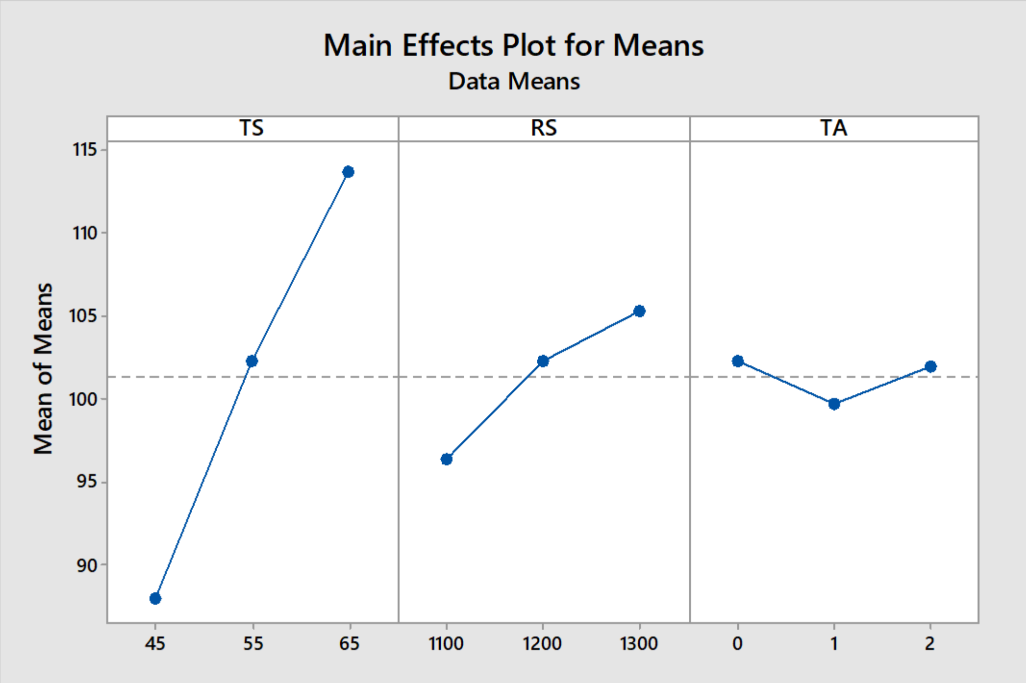

Fig 4 Graphical representation of Main effects graph for MEAN ratio for tensile strength

Response Table of Signal to Noise Ratios of tensile

Larger is better

Level	TS	RS	TA
1	38.88	39.63	40.13
2	40.19	40.14	39.90
3	41.11	40.41	40.15
Delta	222	0.78	0.25
Rank	1	2	3

Table 7 response table of Signal to Noise Ratios of tensile

Response table for S/N ratio indicates main effect plot for S/N ratio for tensile strength. It shows that tensile strength will be maximum when transverse speed will be TS3, rotational speed will be at RS3 and tilt angle will be at TA3 i.e value for transverse speed, rotational speed and tilt angle if are 65mm/min, 1300RPM, 2.

Response Table for Means

Level	**TS**	**RS**	**TA**
1	88.00	96.33	102.33
2	102.33	102.33	96.67
3	113.67	105.33	102.00
Delta	25.67	9.00	2.67
Rank	1	2	3

Table 8 Response Table for Means

Response table for mean indicates the main effect graph for mean for tensile strength. It shows that tensile strength will be maximum when transverse speed will be TS3, rotational speed will be at RS3 and tilt angle will be at TA1 i.e value for transverse speed, rotational speed and tilt angle if are 65mm/min, 1300RPM, 0.

4.1 PROCESS PARAMETERS FOR HARDNESS

S.NO	TS mm/min	RS RPM	TA	HARDNESS	S/N Ratio for Hardness	Mean
1	45	1100	0	57	35.1175	57
2	55	1200	1	59	35.4170	59
3	65	1300	2	62	35.8478	62
4	45	1100	0	65	36.2583	65
5	55	1200	1	67	36.5215	67
6	65	1300	2	70	36.9020	70
7	45	1100	0	72	37.1466	72
8	55	1200	1	75	37.5012	75
9	65	1300	2	77	37.7298	77

Table 9 Hardness values deliberated from experiments and their S/N ratios and mean values

ANOVA Table for Hardness

Sources of Variations	Degree Of Freedom	Adjustment Of Squares	Adjustment Of Mean squares	F-Value	P-Value
TS	2	7.49218	3.74609	379.79	0.003
RS	2	0.93954	0.46977	47.25	0.021
TS	2	0.11273	005637	5.67	0.150
Error	2	0.01988	0.00994		
Total	8	8.56433			

Table 9 ANOVA Table for Hardness

Regression equation

Hardness (HAZ)	=	36.4935 - 1.0327 TS_45 + 0.0670 TS_55 + 0.9657 TS_65 - 0.3194 RS_1100 - 0.0136 RS_1200 + 0.3330 RS_1300 + 0.0134 TA_0 - 0.0252 TA_1 + 0.0118 TA_2

4.1.1 OPTIMIZING THE HARDNESS PROPERTIES

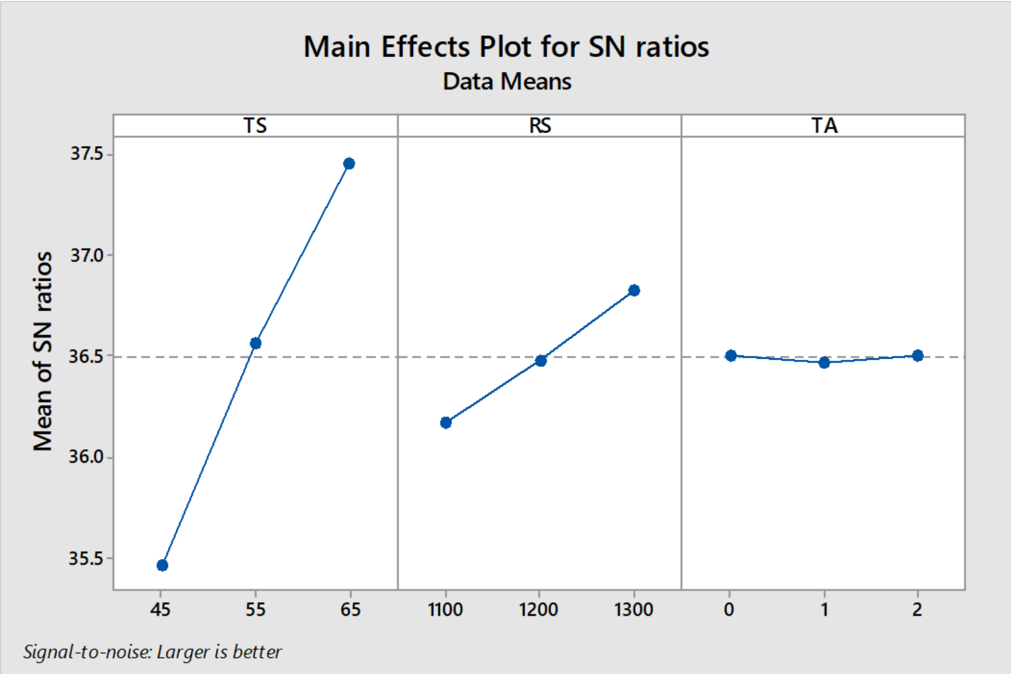

Fig 5 Graphical representation of Main effect for SN ratio for Hardness

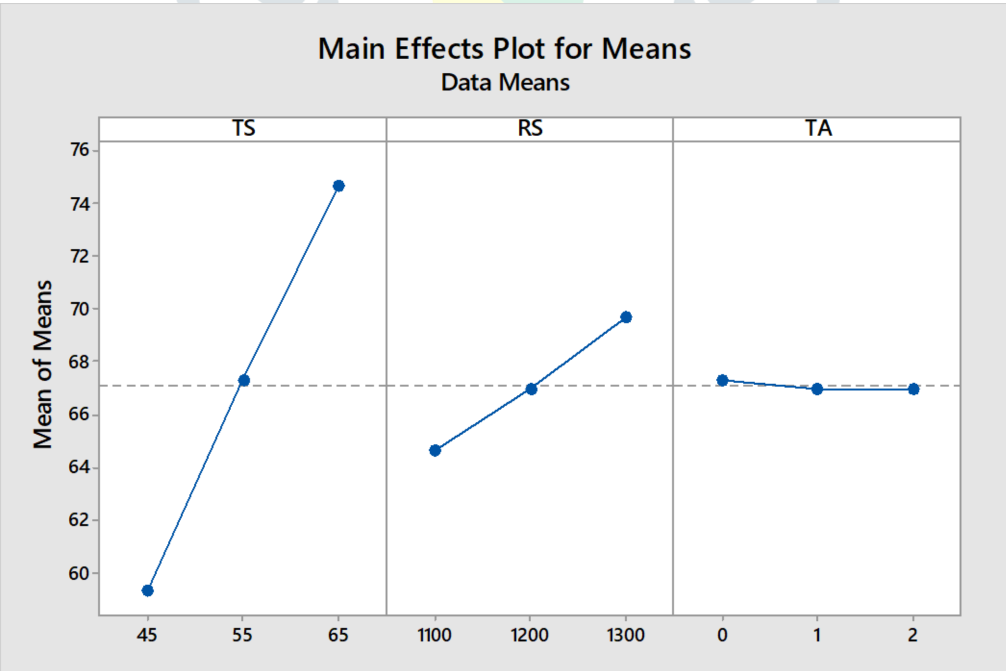

Fig 6 Graphical representation of Main effect plot for means for Hardness

Response table for hardness

Response Table for Signal to Noise Ratio

Larger is better

Levels	TS	RS	TA
1	35.46	36.17	36.51
2	36.56	36.48	36.47
3	36.46	36.83	36.51
Delta	2	0.65	0.04
Rank	1	2	3

Table 10 Response Table for Signal to Noise Ratios for Hardness

Response table for mean indicates the main effect graph for mean for hardness. It shows that tensile strength will be maximum when transverse speed will be TS2, rotational speed will be at RS3 and tilt angle will be at TA1 or TA3 i.e value for transverse speed, rotational speed and tilt angle if are 65mm/min, 1300RPM, 0 or 2.

Response Table for Means

Levels	TS	RS	TA
1	59.33	64.67	67.33
2	67.33	67.00	67.00
3	74.67	69.67	67.00
Delta	15.33	5.00	0.33
Rank	1	2	3

Table 11 Response Table for Means for Hardness

Response table for mean indicates the main effect plot for mean for hardness. It shows that hardness will be maximum when transverse speed will be TS3, rotational speed will be at RS3 and tilt angle will be at TA1 i.e value for transverse speed, rotational speed and tilt angle if are 65mm/min, 1300RPM, 0.

5.1. Conclusion

After an audit of forecast and improvement models of FSW, the Taguchi enhancement of a FSW procedure was directed on a temperature field for the 6061 aluminum composite. The (assistant) full factorial examination of the procedure affirmed that the consequence of the Taguchi analysis is proficient and no critical communication impacts are pre-sent at the point when the target work includes temperature field attributes of the weld, for example, the HAZ separation to the weld line or potentially the pinnacle temperature in the workpiece. Commitments of the procedure parameters on the two criteria were observed to be practically identical in the directed contextual analysis; to be specific, the instrument rotational speed demonstrated the most elevated importance, taken after by the typical power and the welding transverse speed. The variety of the rotational speed of the apparatus brought about a 51% commitment on the HAZ remove to the weld line. The limited pinnacle tem-perature of 458.9oC for the situation think about demonstrated a 91oC temperature lessening from the ostensible (starting) estimation of 550oC. The ANOVA technique for the Taguchi L9 plan and the full factorial investigation yielded comparable parameter commitments. While the utilization of advancement systems on FSW uncovers an expanding pattern in the writing, it is vital to perceive pragmatic impediments of the procedure parameters. A case of such issue is intemperate welding speed which can for all intents and purposes mean the danger of void creation in the weld line. Such marvels can't be displayed with, e.g., unadulterated warm or CFD models and a given analyzer may overestimate the down to earth scope of the welding procedure. Therefore, while care ought to be taken in characterizing reasonable scopes of process factors amid numerical streamlining schedules, additionally explore is required on progressing multi-scale limited component displaying procedures to incorporate FSW process surrenders.

REFERENCES

[1] G. Çam, M. Koçak, Progress in joining of advanced materials, Int. Mater. Rev. 43 (1) (1998) 1–44.

[2] A.M. Hassan, M. Almomani, T. Qasim, A. Ghaithan, Effect of processing parameters on friction stir welded aluminum matrix composites wear behavior, Mater. Manuf. Process. 27 (12) (2012) 1419–1423.

[3] K. Suryanarayanan, R. Praveen, S. Raghuraman, Silicon carbide reinforced alumini- um metal matrix composites for aerospace applications: a literature review, Int. J. Innov. Res. Sci. Eng. Technol. 2 (11) (2013).

[4] M.B.D. Ellis, Joining of aluminium based metal matrix composites, Int. Mater. Rev. 41 (2) (1996) 41–58.

[5] R.Y. Huang, S.C. Chen, J.C. Huang, Electron and laser beam welding of high strain rate superplastic Al-6061/SiC composites, Metall. Mater. Trans. A Phys. Metall. Mater. Sci.

32 (10) (2001) 2575–2584.

[6] W.M. Thomas, D.G. Staines, I.M. Norris, R. de Frias, Friction stir welding tools and developments, Weld. World 47 (2003) 10–17.

[7] R. Rai, A. De, H.K.D.H. Bhadeshia, T. DebRoy, Review: friction stir welding tools, Sci. Technol. Weld. Join. 16 (4) (2011) 325–342.

[8] Y.N. Zhang, X. Cao, S. Larose, P. Wanjara, Review of tools for friction stir welding and processing, Can. Metall. Q. 51 (3) (2012) 250–261.

[9] P.L. Threadgill, A.J. Leonard, H.R. Shercliff, P.J. Withers, Friction stir welding of aluminium alloys, Int. Mater. Rev. 54 (2) (2009) 49–93.

[10] R.S. Mishra, Z.Y. Ma, Friction stir welding and processing, Mater. Sci. Eng. R Rep. 50 (1–2) (2005) 1–78.

[11] Rajkumar, Dr vineet kumar, OPTIMIZATION OF PROCESS PARAMETER FOR STIR CASTED AA6063 METAL MATRIX COMPOSITE ON HARDNESS, TENSILE STRENGTH AND IMPACT ENERGY, International Journal of Mechanical Engineering and Technology (IJMET) Volume 8, Issue 12, December 2017, pp. 108–117.