Research Paper Engineering

EFFECT OF TOOL PARAMETERS ON UNDERWATER FRICTION STIR WELDMENT

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ABSTRACT

In order to weaken the negative effect of thermal cycles on the heat-affected zone (HAZ) and improve the mechanical properties of the joints, external liquid cooling has been applied during FSW in several investigations. Benavides et al [1] developed FSW experiment of 2024 aluminum alloy using liquid nitrogen cooling to decrease the initial temperature of plates to be welded from 30 to 30 LC. It was found that the hardness of the HAZ was remarkably improved, but void defect was formed in the weld nugget zone (WNZ) and the hardness-microstructure relation-ship was not clarified. Fratini et al [10] and we are considering water as the cooling liquid to exert an in-process heat treatment on welding samples during FSW. Likewise, a notable hardness improvement was observed. As found in various literatures the welding parameters plays a major role that effects the weldment quality .The same will be true for the case of underwater friction stir welding but it never found in literatures. Thus, it requires considerable attention of researchers to elaborate effect of three tool parameters on mechanical properties of the weldment.

KEYWORDS HAZ, TAGUCHI METHOD, FSW

1. INTRODUCTION

Friction stir welding (FSW), as a solid state joining process, has been successfully utilized to weld various precipitate hardened aluminum alloys However, it has been demonstrated that FSW tends to create a softening region in the joints due to the dissolution or growth of the strengthening precipitates during the welding, thus leading to a degradation of mechanical properties of the joints The softening region consists of the weld nugget zone (WNZ), the thermal mechanically affected zone (TMAZ), and the heat-affected zone (HAZ). Generally, the HAZ is the weakest location of the joints since it experiences the greatest coarsening and transformation of meta-stable precipitates but does not achieve the sufficient temperature for reprecipitation. Accordingly, improving the mechanical properties of the HAZ is crucial to the optimization of the whole joint performances. In order to weaken the negative effect of thermal cycles on HAZ and improve the mechanical properties of the joints, external liquid cooling has been applied during FSW in several investigations. It has been developed FSW experiment of 2024 aluminum alloy using liquid nitrogen cooling to decrease the initial temperature of plates to be welded from 30 to 30 LC. It was found that the hardness of the HAZ was remarkably improved, but void defect was formed in the WNZ and the hardness-microstructure relation-ship was not clarified.

2. LITERATURE REVIEW

FSW is a solid state joining process and gives better material properties, fewer weld defects lower residual stresses and improved dimensional stability [2]. Minton ***et*** al [3] demonstrated the use of a common milling machine with a less optimal tool for FSW of aluminum alloys. Ericsson et al [4] studied the influence of welding speed on fatigue strength of aluminum alloy 6082 welded by FSW and predicted that weld speed in the tested range has no influence on fatigue properties of the friction stir weld. The influence of stirrer geometry on bonding and mechanical properties of A1018 alloy metals was studied by Mustafa Boz et al [5] and it was found that a 0.85 mm screw pitched stirrer had given the best bonding and mechanical properties. Yan-hua Zhao ***et*** al [6] studied the influence of stirrer geometry on bonding and mechanical properties of aluminum alloy 2014, and reported that joint welded by taper screw thread pin had the best tensile properties. Scialpi et al [7] studied the effect of tool shoulder geometry on mechanical and microstructural properties of friction stir welded 6082-T6 alloy. Results showed that there was no considerable change in transverse tensile strength of the weld due to shoulder geometry. Santella et al [8] illustrated the potential of friction stir processing (FSP), to improve the mechanical properties of cast aluminum alloys A356 and A319. They suggested that FSP is a viable alternative to the hot isostatic pressing of the casting. Ceschini et al [9] studied the effect of friction stir welding on microstructure, tensile and fatigue properties of AA7005/10 vol. % Al_2O_3 composite, and reported that the tensile test had evidenced a FSW joint efficiency of 80% compared to ultimate tensile strength.

3. WELDING TOOL PROPERTIES & PROFILE:

The tool profile also plays a crucial role in producing the quality joint .thus, the tool with hexagonal , square and triangular profile are used in the experiment process and effects are analyzed the tools with different profile.

Table1.1: The Composition of Welding Tool Material SS304 Used

C	Mn	Si
0.06	1.5	0.60
P	S	Cr
0.035	0.025	19.0
Ni	N	Fe
9.8	0.08	rest

4. UNDER WATER FSW PLATE MATERIAL:

The various similar and dissimilar materials can be easily welded using Friction Stir Welding Process. For the analysis of Underwater FSW process feasibility and its optimization the base material plates of aluminium 6062 alloy are used which are butt welded the plates its composition.

Table1.2:The composition of 6062 Aluminium Alloy Plates Used

Fe	Si	Mg
0.27	0.72	0.90
Mn	Cr	Zn
0.30	0.03	0.07
Ti	Cu	Al
0.02	0.95	Bala.

5. TAGUCHI METHOD

"Orthogonal Arrays" (OA) provide a set of well balanced (minimum) experiments and Dr. Taguchi's Signal-to-Noise ratios (S/N), which are log functions of desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results.

6. THE STEPS:

A. SECTIONING:

Test samples are carefully sectioned to section out the structure of intrest from the welded materials. The abrasive saw is used, and the sample is sectioned perpendicular to the direction of welding and is cooled with coolant water so it doesn't burn or overheat. The section of size (50x30x6) mm is taken out.

B. GRINDING:

The grinding is done using Emery paper of grade 600, 1000,1200 .The sand paper consists of SiC Silicon Carbide Particles

C. POLISHING:

The polishing step removes the last thin layer of the deformed metal. The polishing is done with Alumina suspension

D. ETCHING:

The final step done is used is etching to show the microstructure of the test sample. The test sample piece is inserted in the etachant used i.e Keller's reagent of following concentrations (i) Conc. HNO_3: 2.5 mL (ii) Conc. HCL: 1 mL (iii) Conc. HF: 2 ML (iv) H_2O: 180 mL

7. MICROGRAPH STUDY AND ANALYSIS

Microstructure analysis reveals that the joint is clearly visible. Very small amount of porosity is observed No cracks was observed No voids was observed. No unwanted element is present at the joint.

8. TENSILE TEST

Tensile tests of 3mm thick section s are drawn transversal to weld line performed according to ASTM E8-M in order to determine the properties elongation, tensile strength of welded and base materials, using a 25mm gage length and 1mm/min cross head speed. The reduced section length is 60mm and its width is 12.5mm. The specimen is obtained by CNC machining. The test in performed on the Universal Tensile Testing machine..

8.1.TENSILE TEST RESULT

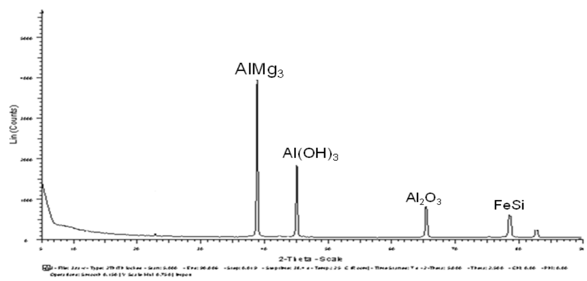
Table 2: Tensile Test Result Analysis

Exp. no.	Rotational speed	Angle	Profile	Strength	Elongation
1	1200	2	T	310	5.570
2	1200	3	H	350	8.446
3	1200	4	S	360	9.867
4	1300	2	H	390	10.034
5	1300	3	S	420	13.636
6	1300	4	T	400	12.336
7	1400	2	S	295	5.140
8	1400	3	T	285	5.461
9	1400	4	H	320	7.210
Average :				347.78	8.633

9. XRD TEST

X-ray diffraction (XRD) is a nondestructive technique for characterizing crystalline materials. Typically, XRD is used for the identification of a crystalline phase or mineral. However, it can also provide information on structures, preferred crystal orientation, and other structural parameters, such as average grain size and strain distribution.

9.1. XRD TEST RESULT ANALYSIS:



XRD Test Analysis

No unwanted element is present at the joint.XRD analysis improves the mechanical properties of the joint.

10. SOFTWARE USED:

For the analysis of the result and to determine the optimized parameters by Taguchi Method the software MINITAB 16 is used.

11.OPTIMIZATION USING TENSILE STRENGTH.

In this research experiment were conducted at different parameters. For this taguchi L_9 orthogonal array was used, in which nine rows corresponds to number of tests, with three columns at three levels. L_9 OA has 8 DOF, in which 6 assigned to 3 factors (each has 2) and 2 assigned to the error. For the purpose of observing the influence of process parameters in underwater FSW 3factors, each at 3 levels are taken and corresponding values of tensile strength is taken into account as sown in the table.

Table 3: Strength versus rotational speed, angle, profile.

Exp. no.	rotational speed	Angle	Profile	strength	SNRA1	MEAN1
1	1200	2	T	310	49.8272	310
2	1200	3	H	350	50.8814	350
3	1200	4	S	360	51.1261	360
4	1300	2	H	390	51.8213	390
5	1300	3	S	420	52.4650	420
6	1300	4	T	400	52.0412	400
7	1400	2	S	295	49.3964	295
8	1400	3	T	285	49.0969	285
9	1400	4	H	320	50.1030	320
	Net average			347.78	44.9215	

Linear Model Analysis: SN ratios versus welding speed, angle, profile

The table 3 shows how the input parameter affects the tensile strength of the joint. These estimates are the deviations of the mean of negative settings to the mean of the positive settings for respective factor. Thus, if we change the factor rotational speed from 1200 to 1300 the tensile strength is increased by 1.35, if the value of tool offset angle is set to high then tensile strength increased by 0.063 and changing tool profile from triangular to hexagonal the tensile strength increases by 0.183.

Table 4: Estimated Model Coefficients for SN ratios

Term	Coef	SE Coef	T	p

Constant	50.7509	0.03553	1428.45	0.000
rotation 1200	-0.1394	0.05025	-2.774	0.109
rotation 1300	1.3582	0.05025	27.032	0.001
angle 2	-0.4026	0.05025	-8.013	0.015
angle 3	0.0635	0.05025	1.263	0.334
profile t	-0.4292	0.05025	-8.541	0.013
profile h	0.1843	0.05025	3.668	0.067

S = 0.1066 R-Sq = 99.8% R-Sq(adj) = 99.2%

In Table 4 it is seen that even through this model has 3 parameters, one for each component, this model has only 2 degree of freedom. This is because of the overall mixture constraint, that the sum of all component values is constant. The simultaneous test for all parameters of this model is statistically significant as $p < 0.5$. Also it indicates that the largest contribution to the total sum of squares is 89.2% made by tool rotational speed, second largest contribution to the total sum of squares is 7.1% made by the tool angle, largest contribution to the total sum of squares is 7.10% made by the tool profile.

Table 5: Analysis of Variance for SN ratios

Source	Rotational Speed	Angle	Profile	Residual Error	Total
DF	2	2	2	2	8
Seq SS	10.0492	0.8434	0.8343	0.0227	11.7497
Adj SS	10.0492	0.8434	0.8343	0.0227	
Adj MS	5.02460	0.42172	0.01136		
F	442.28	37.12	36.72		
P	0.002	0.026	0.027		
%PC	89.2	7.17	7.10		

Linear Model Analysis: Means versus rotational speed, angle, profile

Shows how the input parameters affect the mean tensile strength of the joint. These estimates are the deviations of the mean of negative settings to the mean of the positive settings for respective factor. Thus, if we change the factor rotational speed from 1200 to 1300 the tensile strength is increased by 55.65, if the value of tool offset angle is set to high then tensile strength increased by 3.89 and changing tool profile from triangular to hexagonal the tensile strength increases by 5.56.

Table 6: Estimated Model Coefficients for Means

Term	Coef	SE Coef	T	P
Constant	347.778	1.470	236.606	0.000
rotation 1200	-7.778	2.079	-3.742	0.065
rotation 1300	55.556	2.079	26.726	0.001
angle 2	16.111	2.079	-7.751	0.016
angle 3	3.889	2.079	1.871	0.202
profile t	-16.111	2.079	-7.751	0.016
profile h	5.556	2.079	2.673	0.116

S = 4.410 R-Sq = 99.8% R-Sq(adj) = 99.2%

It is seen that even though this model has three parameters, one for each component, this model has only two degrees of freedom. This is because of overall mixture constraint, that the sum of all component value is constant. The simultaneous test for all the parameters of this model is statistically significant as $p <0.5$. Also it indicates that the largest contribution to the total sum of squares is 86.6% made by tool rotational speed, second largest contribution to the total sum of squares is 6.76% made by the tool angle, largest contribution to the total sum of squares is 6.41% made by the tool profile.

Table 7: Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P	%PC
rotational speed	2	16288.9	16288.9	8144.44	418.86	0.002	86.6
Angle	2	1272.2	1272.2	636.11	32.71	0.030	6.76
Profile	2	1205.6	1205.6	602.78	31.00	0.031	6.41
Residual Error	2	38.9	38.9	19.44			
Total	8	18805.6					

Response Table for Signal to Noise Ratios And Means:

performance characteristics, a greater S/N ratio show the better performance. Therefore, the optimum level of welding parameters is the level with greatest S/N value. Based on the analysis of the S/N ratio, the optimum welding for tensile strength was obtained at level 2 at tool rotational speed 1300, at level 4 at tool angle 4^0 and at level 3 tool profile square.

Table 8: Response table foe S/N ratio - Larger is better

Level	Rotational speed	angle	profile
1	50.61	50.35	50.32
2	52.11	50.81	50.94
3	49.53	51.09	51.00
Delta	2.58	0.74	0.67
Rank	1	2	3

Table 9: Response table for means - Larger is better

Level	Rotational speed	angle	profile
1	340.0	331.7	331.7
2	403.3	351.7	353.3
3	300.0	360.0	358.3
Delta	103.3	28.3	26.7
Rank	1	2	3

14. CONCLUSION

The following conclusions can be:

Microstructure analysis reveals that proper joining takes place and very small amount of porosity is observed.

No voids and cracks are observed at the joint in microstructure analysis.

XRD analysis indicates that there were no unwanted compounds which become hindrance during machining. These compounds improve the mechanical properties of the joint.

It was observed that the mechanical property in UFSW is approximately 20% increased than the FSW.

5. Tool rotation speed 1300rpm.

Tool offset angle 4^0 Tool profile square.

15. FUTURE WORK

Further work can be done on underwater FSW process:

Wear characterization of the joint can be done for future work.

Weld defects during UFSW can be reviewed.

HAZ formed during the welding can be investigated.

The parameters other than tool rotational speed , tool tilt angle and tool profile can be reviewed to study and correlate the effect on quality of joint welded.

16. REFERENCES

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