Experimental Investigation of Mechanical Properties of Dissimilar Aluminum 5083 And 6082 Alloys By Underwater Friction Stir Welding Technique

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Abstract- *Friction stir welding (FSW) is a solid state joining process and it is an innovative technology for the difficult to weld metals such as aluminium, copper, magnesium etc. The paper is aimed to experimentally investigate the mechanical properties of the underwater dissimilar friction stir welded aluminium AA5083-H111 and AA6082-T6 alloys using Taguchi L9 orthogonal array and Analysis of Variance (ANOVA) technique. The optimum process parameters for the responses Ultimate Tensile Strength (UTS), Yield Strength(YS) and percentage of elongation(%E) are presented.*

Keywords- UWFSW, UTS, YS, elongation, dissimilar alloy.

I. INTRODUCTION

Normal Friction Stir Welding (NFSW) is a novel solid state joining process which finds extensive applications in aerospace, automobile, marine industries. The process overcomes problems arising out of conventional joining methods such as porosity, hot cracking, and alloy splitting. NFSW can make butt or lap joints in broader range of material thickness and lengths. One of the recent advancement in the friction stir welding process is under water friction stir welding (UWFSW). The advantage of the UWFSW as compared to the NFSW process is increase in the mechanical properties of the weld. When the process is carried out under water then heat of the process will regulates the formation of precipitates thus joint becomes strong. A rotating tool with a profiled probe is fed into a butt joint between two clamped work pieces, until the shoulder, which has a larger diameter than the pin, touches the surface of the work pieces. After a short

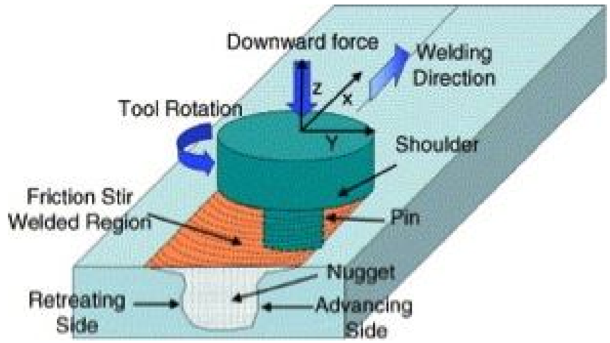

Figure 1 Working principle of FSW

Figure 2 FSW machine

dwell time, the tool is moved forward along the joint line at the pre-set welding speed and generates the heat because of friction between the wear-resistant tool and the work pieces. As the tool is moved forward, a special profile on the probe forces plasticised material from the leading face to the rear, where the high forces assist in a forged consolidation of the weld.

This process of the tool traversing along the weld line in a plasticised tubular shaft of metal results in severe solid-state deformation involving dynamic recrystallization of the base material. The working principle of FSW is shown in Figure No.1 and FSW machine is shown in Figure 2.

II. LITRATURE REVIEW

T. Sakthivel, et al (2009) investigated the effect of welding speed on microstructure and mechanical properties on commercial grade aluminium using 4 samples on 4mm thick plates. The tool rotation speed is kept constant at 1000 rpm and axial force is also kept constant. But the welding speed is varied from 50mm/min to 175 mm/min. The results of the experiments indicated that defects are found through non destructive testing due to insufficient heating. Further at low welding speed of 50mm/min produced high tensile strength of 80MPa, percentage of elongation of 15.09 and produced weld efficiency of 95%. At high welding speed of 175mm/min produced low tensile strength of 71.6MPa, percentage of elongation of 12.08 and produced weld efficiency of 84%.

G Padnamban and V.Balasubramanian (2010) investigated the tensile property on AZ31B Mg alloy for 14 samples on 6mm thickness. The tool used is high carbon steel threaded pin profile. The tool rotation speed is about 1000 to 2000 rpm, But the welding speed is varied from 0.37 to2.25mm/s, and the axial force is about 2 to 4 KN. The result of the experiment showed that high tensile strength of 208Mpa and hardness of 78Hv in nugget zone at 1600rpm,0.67mm/s and 3KN.

Mofid et al. Ufsw has conducted for plates AZ31 and AA5083 H34 in three distinct situations, i.e. air, water and liquid nitrogen by maintaining constant rotational speed and welding speed. They observed cracks in the stir zone due to development of brittle intermetallic phases, and hence, poor mechanical properties of the joint were detected. The vital is to control liquation and development of aluminum-magnesium intermetallic compounds in friction stir welding process. Particularly this submerged fsw is reasonable for those composites that are sensible to overheating. The fracture was observed at the weld nugget and is also known as original joint line with severe plastic deformation.

P.S.De and R.S.Mishra (2011) investigated of joint efficiency on precipitation strengthened aluminium alloy. The result of this experiment is maximum joint efficiency is obtained in narrow heat flux. Low levels of post weld plastic deformation enhance the nucleation density which improves joint efficiency.

Based on the above literature reviews, it is found that the very few works on under water friction stir welding further less works on under water FSW of aluminium 5083 and 6082 alloys is reported. Therefore in this study, an attempt is made to investigate the mechanical properties of dissimilar materials AA5083-H111 and AA6082-T6. are selected for the FSW and based on design of experiments 9 trails were choosen with three varying input factors (tool tilt angle, tool rotational speed, welding speed) at three levels to optimize the output responses, namely ultimate tensile strenth (UTS), yeild strength (YS) and percentage of elongation (POE).

III. MATERIALS AND METHODS

Aluminium 5083-H111 and 6082-T6 alloys of 4mm thick plates procured from the PMC Corporation Bangalore for the experimental work. Both the alloys are machined to perfect dimensions of 140mm x 70 mm. Further, they are cleaned with emery sheets to remove the dust, dirt, oil grease and any oxides from the surface of the material. The chemical composition and mechanical properties of both the alloys are presented in Table 1. The process parameters and their levels are selected based on the literature survey and it is shown in Table 2. The number of experiments is designed based Taguchi L9 orthogonal array to find the optimum process parameters to improve the mechanical properties of the dissimilar friction stir welded joints. The design matrix with actual values is shown in Table. FSW tool made of high speed steel having taper square pin profile with shoulder diameter of 18mm and tool pin length of 3.4mm as shown in Fig. The welding operation is performed as per the design of experiments on the modified milling machine in presence of water, which is shown in Fig and fabricated joints are shown in Fig. The welded specimens are subjected to tensile testing in Universal Testing Machine (UTM) at Hyderabad Engineering Lab, Hyderabad. The tensile specimens are prepared as per American Society of Testing Materials (ASTM-E08) standards and it is shown in Fig. The tensile test results are recorded and it is shown in Table 1.

Table 1 Chemical composition and mechanical property

Composition	AA5083	AA6082
Si	0.28	1.01
Fe	0.37	0.21
Cu	0.07	0.02
Mn	0.59	0.56
Mg	4.7	0.98
Cr	0.09	0.12
Zn	0.09	0.03
Ti	0.04	0.03
Al	Balance	Balance
UTS	299 MPa	333 MPa
YS	164 MPa	285 MPa
% elongation	22	12

Table 2. Process parameters with corresponding levels

S. No	Process parameters	Symbol	Units	Range	Level 1	Level 2	Level 3
1	Tool rotational speed	S	Revolutions per minute (rpm)	560-1120	560	900	1120
2	Welding speed	F	mm/min	40-60	40	50	60
3	Tool tilt angle	A	Degrees	0-2	0	1	2

Table 3.Taguchi L9 orthogonal array

Sl no	Tool rotational speed (rpm)	Welding speed(mm/min)	Tool tilt angle (degree)
1	560	40	0
2	560	50	1
3	560	60	2
4	900	40	1
5	900	50	2
6	900	60	0
7	1120	40	2
8	1120	50	0
9	1120	60	1

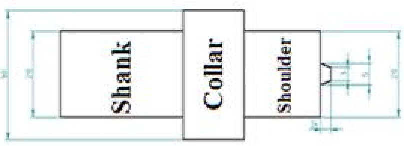

Figure 1 FSW tool

Table 4 Experimental results

Exp.No	S RPM	F mm/min	A Degrees	UTS (MPa)	YS (MPa)	%E	S/N ratio of UTS	S/N ratio of YS	S/N ratio of %E
1	560	40	0	53.64	30.65	1.6	34.58	29.72	4.08
2	560	50	1	190.6	129.13	3.94	45.60	42.22	11.90
3	560	60	2	179.50	121.69	1.50	45.08	41.70	3.52
4	900	40	1	196.40	139.85	6.98	45.86	42.91	16.87
5	900	50	2	191.66	138.16	6	45.64	42.80	16.56
6	900	60	0	192.24	177.10	5.08	45.67	44.96	14.11
7	1120	40	2	191.56	169.46	6.16	45.64	44.57	15.76
8	1120	50	0	196.94	171.28	6.06	45.88	44.67	15.64
9	1120	60	1	164.6	107.79	7.64	45.32	40.65	17.66

Figure 4 Fabricated joints

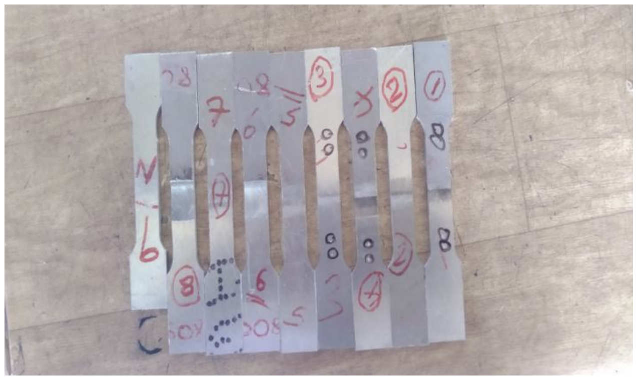

Figure 5 Tensile specimens as ASTM

Table 5 ANOVA table for Ultimate Tensile Strength (UTS)

Source	DOF	Sum of Squares	Mean Squares	F-test	P-test	% Contribution
S	2	4662	2331	1.15	0.378	27.66
F	2	3304	1652	0.73	0.520	19.6
A	2	2925	1462	0.63	0.564	17.36
Error	2	5960				
Total	8	16851				

Table 6.Response Table for UTS

Level	S	F	A
1	41.76	42.03	42.05
2	**45.73**	**45.71**	45.27
3	45.29	45.03	**45.46**
Delta	3.97	3.62	3.41
Rank	1	2	3

Table 7 ANOVA Table for Yield Strength

Source	DOF	Sum of Squares	Mean Squares	F-test	P-test	% Contribution
S	2	6455	3227	2.02	0.214	40.22
F	2	1688	844.2	0.35	0.716	10.52
A	2	587.5	293.7	0.11	0.894	3.66
Error	2	7318.5				
Total	8	16049				

Table 8 Response table for YS

Level	S	F	A
1	37.88	39.07	39.79
2	**43.56**	**43.23**	41.93
3	43.30	42.44	**43.03**
Delta	5.68	4.16	3.24
Rank	1	2	3

Table 9. ANOVA table for %Elongation

Source	DOF	Sum of Squares	Mean Squares	F-test	P-test	% Contribution
S	2	31.985	15.993	13.29	0.006	81.58
F	2	0.5654	0.2827	0.04	0.957	1.44
A	2	6.561	3.281	0.60	0.577	16.73
Error	2	0.0956				
Total	8	39.207				

Table 10. Response table for % E

Level	S	F	A
1	6.505	12.232	11.283
2	15.519	**14.374**	**15.483**
3	**16.349**	11.767	11.607
Delta	9.844	2.607	4.200
Rank	1	3	2

IV. RESULTS AND DISCUSSION

1. Ultimate Tensile Strength

From the ANOVA Table 5 we can conclude that the tool rotational speed has a contribution of 27.66% followed by welding speed which has a contribution of 19.6%. Among these three, tool tilt angle has the lowest percentage of 17.36. The optimum process parameter can be found by response Table 6.

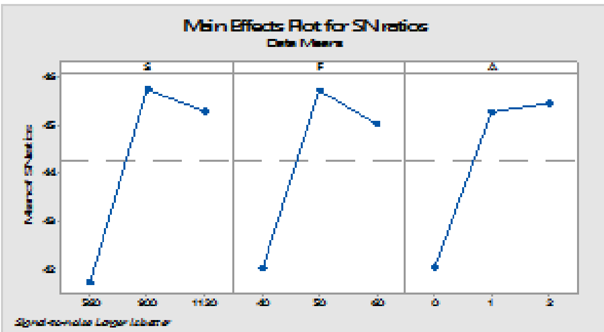

Figure 6 Main Effects of SN ratio for UTS

From the Table 6 and Figure 6 it can be concluded that tool rotational speed of 900 r.p.m, welding speed of 50 mm/min and Tool tilt angle of 2 degree is the optimum machining condition to get a good ultimate tensile strength.

2. Yield strength

From the ANOVA Table 7 we can conclude that the tool rotational speed has a contribution of 40.22% followed by welding speed which has a contribution of 10.52%. Among these three, tool tilt angle has the lowest percentage of 3.66. The optimum process parameter can be found by response table 8.

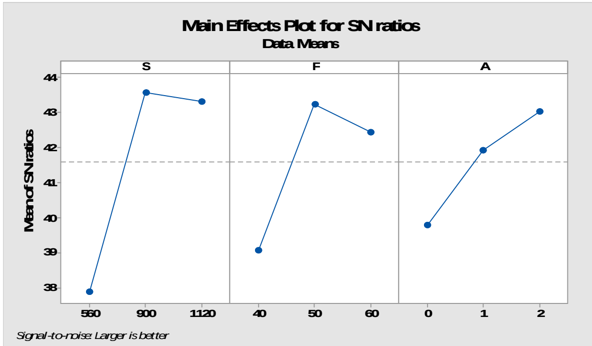

Figure 2 Main Effects of SN ratio of YS

From the table 8 and figure 7 it can be concluded that tool rotational speed of 900 r.p.m, welding speed of 50 mm/min and Tool tilt angle of 2 degree is the optimum machining condition to get a good yield strength.

3. % Elongation

From the ANOVA Table 9 we can conclude that the tool rotational speed has a contribution of 81.58 % and tool tilt angle which has a contribution of 16.73. Among these three welding speed has the lowest percentage of 1.44 %. The optimum process parameter can be found by response table 10.

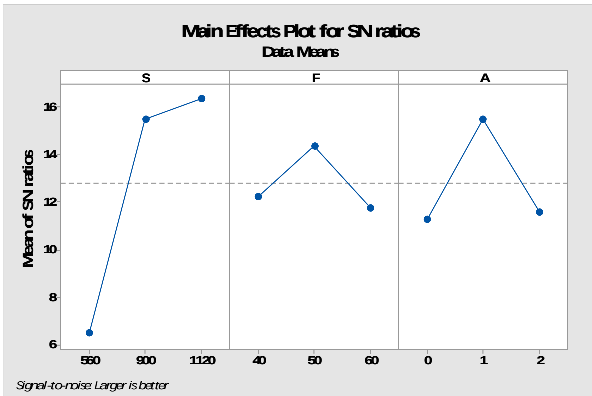

Figure 3 Main Effect of SN ratio of % Elongation

From the Table 10 and figure 8 it can be concluded that tool rotational speed of 1120 r.p.m, welding speed of 50 mm/min and Tool tilt angle of 1 degree is the optimum machining condition to get a good % elongation.

V. CONCLUSION

Dissimilar Aluminum 5083-H111 and 6082-T6 alloys are successfully welded by underwater friction stir welding technique by Taguchi method of optimization and following are the conclusions are drawn from the research work

a) Optimum process parameters to improve the UTS: tool rotational speed of 900rpm, welding speed of 50mm/min and tool tilt angle of 2°.
b) Optimum process parameters to improve the YS: tool rotational speed of 900rpm, welding speed of 50mm/min and tool tilt angle of 2°.
c) Optimum process parameters to improve the % elongation: tool rotational speed of 1120 rpm, welding speed of 50mm/min and tool tilt angle of 1°.

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