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Friction Welding to join Aluminum EN AW-602 and Low Carbon Steel AISI/SAE 1018 Materials

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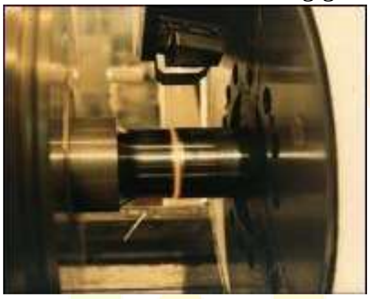
Abstract: Now a days joining of dissimilar materials plays an important role in industrial applications. In this study, joining of dissimilar materials EN AW-6082 and AISI/SAE 1018 is carried out using different parameters on continuous drive friction welding process. Axial shortening, Micro-hardness, Tensile strength like this mechanical properties are found with good results. The process parameters like rotational speed, friction pressure, upset pressure and upset time were varied and friction time kept constant.

Index Terms** – **Friction welding, Axial shortening, Micro-hardness, Tensile strength

1. INTRODUCTION

Friction welding is a solid state welding process that produces a weld under compressive force contact of workpieces rotating or moving relative to one another to produce heat and plastically displace material from the faying surfaces. While considered a solid-state welding process, under some circumstances a molten film may be produced at the interface. However, even then the final weld should not exhibit evidence of a molten state because of the extensive hot working during the final stage of the process. Filler metal, flux, and shielding gas are not required with this process.



(a) Heating Stage

(b) Forging Stage

2. Research Review

i. P. Shiva Shankar, (2013) carried out experimental investigation and statistical analysis of the friction welding parameters for the similar materials copper alloy Cu Zn 30 using Taguchi method for design of experiments. Optimization of parameters for tensile strength and upset (axial shortening) was done. He found that the optimal value of process variables for a higher tensile strength are 1500 r.p.m Speed, 5 sec friction time, 10 Bar friction pressure and 30 Bar forging pressure and the optimum values for less upset are 1400 r.p.m Speed, 4 sec friction time, 10 Bar frictionpressure and 20 Bar forging pressure.

ii. Shubhavardhan R. N. *et.al*, (2012) studied friction welding of stainless steel and aluminium. Investigation suggested that the joint strength increased and then gradually decreased after reaching a maximum value with increasing upset pressure and upset time.

iii. Mumin Sahin, (2010) studied friction welding of different materials, stainless steeland Aluminum, stainless steel and Cu, Aluminum and Cu, found that due to existence of intermetallic phase, welding of nonferrous metals is difficult. Tensile strength for joints was considered as positive result compared with base materials. Sarala

iv. Upadhya *et.al*, (2007) observed microstructure and Mechanical Behavior of Rotary Friction Welded Titanium Alloys. They found that, rotational speed of 1500 rpm can produce a very good weld, while other parameters kept constant.

v. P. Sathiya *et.al*. (2006) studied optimization of friction welding parameters using simulated annealing. The variation between theoretical and experimental values of flash features as flash width, flash height and flash thickness were analyzed with optimization algorithm called simulated annealing.

vi. M. Yılmaz *et.al*., (2003) investigated interface properties of aluminum and steel friction welded components. They found that tensile properties improve for steel-aluminum welds when the intermetallic thickness extends only to 0.2-1 µm, above this value welds with poor strength being produced. Bekir S. *et.al*., (1995) studied friction weldingof Steel and Aluminum as well as Aluminum and Copper, investigation suggested that intermetallic layer thickens at the mid radius and becomes thin at the center and periphery of the weld. The tensile propertiesimprove for a particular thickness of intermetallic layer. Further increase in the thickness of intermetallic layer reduces tensile properties.

In present study, friction welding of EN AW-6082 and AISI/SAE 1018 was done by using continuous drive friction welding machine. The parameters used are rotational speed, friction time, friction pressure, upset time and upset pressure.

3. Materials and Methods

3.1 Dissimilar materials used:

The need of reduction in weight and increase in strength in many engineering applications, increased the interest of fabrication of dissimilar metals. In present experiment, Aluminum alloy EN AW-6082 and AISI/SAE 1018 mild steel were used.

The chemical composition analysis of specimens was carried out for both the metals at Perfect Metallurgical Solution Laboratory, Aurangabad (Maharashtra) India.

Table 1 Chemical composition of EN AW-6082 alloy

Chemical Analysis	Observations	Specified as per DIN EN 573-3:2007
% Mn	0.83	0.40 to 1.00
% Si	0.88	0.70 – 1.30
% Cr	0.20	0.25 max
% Cu	0.07	0.10 max
% Mg	0.86	0.60 – 1.20
% Zn	0.16	0.20 max
% Ti	0.05	0.10 max
% Fe	0.12	0.50 max
% Al	96.83	----------

Remarks : The checked parameters of given sample conforms to “EN AW-6082 “ grade , as per DIN EN 573-3:2007

Table 2 Chemical composition of Mild Steel

Chemical Analysis	Observations	Specified as per ASTM A29/29M-15
% C	0.19	0.15-0.20
% Mn	0.72	0.60-0.90
% P	0.07	0.040 max
% S	0.05	0.050 max

Remarks : The checked parameters of given sample conforms to AISI/SAE 1018 grade, ASTM A29/29M-15

3.2 Geometry of specimens:

Both Aluminum and mild steel specimens were machined to get smooth faying surface, of outer diameter 20mm and approximate length 100mm. Facing operation was done on all the specimens before friction welding, also mild steel specimens were cleaned with Acetone liquid solution and aluminum specimens were cleaned with aluminum cleaner liquid.

3.3 Parameters :

From the literature review the predominant factor which has great influence on the tensile strength of the friction weld (FW) joints were identified. Trial experiments were conducted to determine the working range of the parameters. The feasible limits of the parameters were chosen in such a way that it is not affecting external defects. The important parameters influencing the tensile strength are shown in table 3.

Table 3 Friction welding parameters and their levels

Factor	Level-1	Level-2	Level-3
Rotational speed (rpm)	1300	1400	1500
Friction pressure (bar)	15	20	25
Upset pressure (bar)	32	40	48
Upset time (sec)	2.5	3.0	3.5

The other parameters of the process like friction time 0.5 sec, brake delay 0.3 sec, upset delay 0.1 sec and feed 85% are kept constant.

4. Results and Discussion

4.1 Axial Shortening

Table 4.Taguchi orthogonal Array L9, their responses, mean values for axial shortening.

Runs	Input parameters				Response axial shortening (mm)			Mean (mm)
	RS (rpm)	FP (Bar)	UP (Bar)	UT (Sec)	1	2	3	
1	1300	15	32	2.5	8.6	8.4	8.8	8.6
2	1300	20	40	3.0	8.8	9.0	9.2	9.0
3	1300	25	48	3.5	9.4	9.5	9.5	9.46
4	1400	15	40	3.5	8.2	8.4	8.8	8.46
5	1400	20	48	2.5	10.2	10.4	10.6	10.4
6	1400	25	32	3.0	7.8	7.8	7.9	7.83
7	1500	15	48	3.0	9.4	9.8	9.6	9.6
8	1500	20	32	3.5	7.8	7.8	7.7	7.76
9	1500	25	40	2.5	8.4	8.8	8.8	8.66

In this study for axial shortening L9 orthogonal array is used as we have four parameters and three levels, accordingly nine experiments were conducted and every experiment was repeated for three times and average values are quoted in the table 4.

4.2 Microstructure of Welded Joint

Figure 1 Microstructure photograph of welded joint

The microstructural features of the friction welded joint is observed by using optical and scanning electron microscope. The structural changes takes place more EN AW-6082 in side as compared to AISI/SAE 1018.

4.3 Experimental Results for Micro-hardness Test

Table 5. Results of Micro-hardness Test

RUN	Base Al	0.1mm from FW line Al side	On FW line	0.1mm from FW line MS side	Base MS
1	72	80	109	261	257
2	70	79	110	232	240
3	68	72	108	274	266
4	72	80	101	270	263
5	72	89	100	273	263
6	66	74	106	270	264
7	68	72	110	274	270
8	65	74	106	268	272
9	68	72	105	272	270

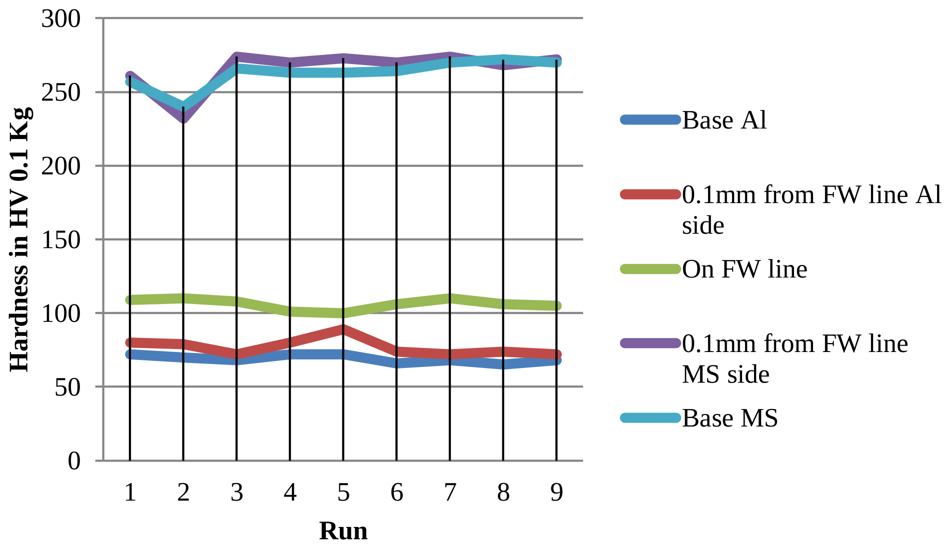


Figure 2 Hardness graph

For micro hardness testing Vickers hardness testing machine was used. In this test a square based pyramid type diamond indenter was used and the hardness variation on the weld interface as well as along with it, across the weld interface on both the parent materials was obtained by applying a constant load of 100 gm. The indentations were made at the weld interface and on both the sides along the axis of the shaft at the regular intervals of 0.1 mm apart so as to find out the effect of heat on the hardness values.

The hardness obtained at HAZ is more than base aluminum alloy hardness.

There is very little change in hardness at base Aluminum and base Mild steel.

The hardness obtained on 0.1mm from FW line Al side is more compared to base aluminum. The hardness obtained on 0.1mm from FW line MS side is more compared to base mild steel.

4.4 Experimental Results for Tensile Strength

Table 6. Tensile Strength test results

Run	Breaking Load (N)	Tensile Strength (N/mm^2)	Fractured at
1	48600	153.62	Weld
2	44000	144.47	Weld
3	54000	140.42	Weld
4	47000	145.72	Weld
5	40400	155.87	Weld
6	42000	138.54	Weld
7	40400	136.20	Weld
8	46000	146.82	Weld
9	46800	148.22	Weld

5. Conclusion

i. With the help of different mechanical tests, it was found that friction processed joint exhibited comparable strength with the base material.
ii. It is observed that upset pressure is most important parameter for axial shortening, as upset pressure increases axial shortening also increases.
iii. It is observed that tensile strength is dependent on selected parameters, but at the same time there are also other influencing factors affecting the tensile strength like temperature at the weld zone, intermetallic compounds formed at the interface, amount of friction at the interface and friction time etc.
iv. The microstructural features of the friction welded joint is observed by using optical and scanning electron microscope. The structural changes takes place more in side EN AW-6082 as compared to AISI/SAE 1018.
v. The hardness obtained at HAZ is more than base aluminum alloy hardness.

6. Acknowledgment

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