Experimental Study Analysis of Wear Properties in Friction Stir Welded Dissimilar Aluminium Alloys

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Abstract:

The wear is one of the main issues in Friction stir welding (FSW) of dissimilar aluminium alloys. Comparing to the base materials the two dissimilar metals welded in FSW have the different mechanical, metallurgical and chemical properties.. So the wear resistance is an important property in the FSW welds. In this, AA7075-T6 and A384.0-T6 Aluminium alloys of 6.35 mm thicknesses are selected to conduct the FSW. A design matrix was developed by using a MINITAB-17 Software for the FSW. The Friction Stir welded pieces are made as test specimens and the Ultimate Tensile Strengths (UTS) are found out. In this the maximum and the minimum UTS specimens are taken for the wear resistance property analysis. The obtained results are compared to the base metals wear resistance properties. In this, keeping the revolutions per minute (rpm), time and sliding velocity as constant and varying the load applied, the results are obtained. The rpm, time and the sliding velocity was 500, 10 minutes and 2.61 m/s respectively. The different applied load was 20N, 40N and 60 N. The conclusion is the wear in the Friction Stir weld is less comparing to the base metal of A384.0-T6 aluminium alloys in any applied loads. And also the wear is more comparing to the base metal AA7075-T6 Aluminium alloys.

Key words: *Wear resistance: Dissimilar aluminium alloys: Friction Stir Welding: Base metals: Wear resistance parameters.*

1. Introduction

FSW is the solid state green welding techniques. It was invented, developed and patented in the year 1991 by, The Welding Institute, U.K [1]. In which, to be welded plates are placed adjacent to each other and the same was clamped in a fixture. A tool was fitted in a chuck and the chuch was fitted in the spindle of the FSW machine. The FSW machine was shown in Figure-1. A rotating tool was inserted in between the two plates with a thrust force and horizontal movement. So in the plates stirring action takes place, heat is developed and the metals are plastically deformed and joined together [2].The principle of operating the FSW process is shown in Figure-2. After the FSW the mechanical, metallurgical, thermal and chemical properties are changed comparing to the base

materials properties. In this, the wear properties are analyzed. LingyuGuo et.al [3] analyses the lubrication effect of annealed

$Fe_{78}Si_9B_{13}$ glass particles in FSW process of the metal AA6061and found the particles plays an important role for improving the wear resistance. Syed Khaja Naimuddin et al [4] conducted the experimental study analysis of FSW in similar and dissimilar joints of welds in the materials of (AA6061-AA6061), (AA6082-AA6082) & (AA6061-AA6082) under T6 conditions to find the wear behaviours. They conclude low wear and low wear resistance in FSW welds. Adel Mahmood Hassan et al [5] experimentally studied, the wear characteristics in Aluminium Matrix Composites reinforced with graphite and silicon carbide particles in FSW Techniques. The result shows the process parameters greatly affects the wear resistance of the welded joints.

To take the decisions of FSW weld quality, many welding parameters like the tool rotational speed, welding feed, axial load, tool pin profile etc. are plays an important role [7].

Metals/ Elements	Mg	Mn	Pb	Zn	Fe	Cu	Si	Cr	Ni	Al
AA 7075-T6	2.29	0.047	0.004	5.44	0.20	1.45	0.071	0.24	0.006	Bal
A 384.0-T6	0.11	0.24	0.54	1.83	0.96	1.54	10.15	0.031	0.099	Bal

Figure-1: FSW Machine

Many of the researchers are very much interested to optimize the FSW process parameters [8]. At the same time most of the researchers analyzed the FSW tool design parameters with the welding strength of the joints [9 -12].

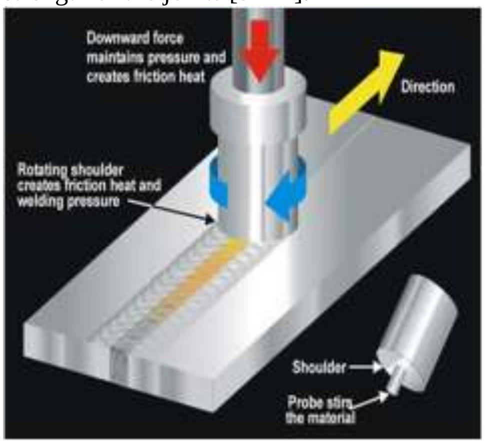

Figure-2: FSW Process principle [6]

Kumar.R. et al [13] experimentally studied the wear characteristics and the defects in FSW process in AA6061-T6 Aluminium alloys with the different welding tool rotational speed and the welding speed. In this study, they conclude, comparing to the base material the wear resistance is increased in the FSW joints.

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2. Experimental Setup

The selected base materials are wrought aluminium of AA7075-T6 and cast aluminium of A384.0-T6 with 6.35 mm thickness. The metal aluminium and its alloys have low densities and high strength to weight ratio. Therefore these materials are used in various fields [14, 15]. The wrought aluminium of AA7075-T6 was purchased with 6.35 mm thickness and made by 100 X 50 X 6.35 mm by using a Saw machine. The cast aluminium of A384.0-T6 was casted as an ingot and made by 100 X 50 X 6.35 mm by using a Saw machine and Lathe. The base materials chemical compositions and the mechanical properties are tested and tabulated in Table-1 and Table-2 respectively.

Table 1.Chemical compositions of the base metals

Table 2.Mechanical properties of the base metals

Base Metals	UTS (MPa)	YS (MPa)	Elongation (%)	Hardness (HRB)
AA 7075-T6	581.1	379.8	11.7	92.0
A 384.0-T6	102.0	-	1.0	35.8

By using MINITAB-17 software a design matrix was developed for 3 variables and 5 levels. The welding parameters or the variables selected for this was the tool rotational speed in rpm, the welding speed in mm/min and an axial load in kilo newton. This was shown in Table-3 After making the different FSW welds as per the design matrix the Ultimate Tensile Strength (UTS) are tested and tabulated in Table-4.

Table-3.Welding Parameters

PROCESS PARAMETERS	UNIT	SYMBOL	LEVELS				
			-1.682	-1	0	1	1.682
TOOL ROTATING SPEED	RPM	N	800	900	1000	1100	1200
WELDING SPEED	MM/MIN	S	30	35	40	45	50
AXIAL LOAD	KN	F	6	7	8	9	10

Table-4.Design matrix & the result of UTS in MPa

Run no.	Design matrix FSW Process parameters			UTS
	N	F	S	MPa
1	-1	1	-1	181
2	0	0	0	186
3	**1**	**-1**	**-1**	**210**
4	1	-1	1	208
5	-1	-1	-1	163
6	1	1	-1	154
7	1.682	0	0	141
8	**-1.682**	**0**	**0**	**115**
9	**0**	**0**	**-1.682**	**126**
10	1	1	1	144
11	0	1.682	0	177
12	-1	-1	1	136
13	0	0	1.682	166
14	-1	1	1	167
15	0	-1.682	0	155
16	0	0	0	186
17	0	0	0	186
18	0	0	0	186
19	0	0	0	186
20	0	0	0	186

From the above Table-4, The Minimum UTS is, in Run number-8 of 115 MPa. And the Maximum UTS is, in Run number-3 of 210 MPa. These Two FSW welds are taken for further analysis of the wear resistance test, and also the Run number-9 has UTS of 126MPa. In these FSW welds the wears are compared and analyzed with the parent base materials wear resistance of AA7075-T6 and A384.0-T6.

The wear is the removal process of material from solid surfaces in solid state contact. The outer surfaces of the components wear occurs. In this study, Pin-on-disk wear testing method is followed. The Pin-on-disk wear testing apparatus is shown in Figure-3 and Figure-4.During this test, a stationary disk articulates against rotating pin while applied load is constant [16]. The Pin-on-disk wear testing apparatus, normal load range and the frictional force range was up to 200N.The sliding speed is 0.26m/s to 12m/s and the disk speed is 100 rpm to 2000 rpm. The wear disk diameter is 165 mm and is made by En31 material with the disk hardness of 58 – 60 HRC. The wear disk track diameter is 10 mm to 140 mm. The specimen pin diameter or diagonal is diameter 3 mm to 12 mm and the length of the specimens pin is 25 mm to 30 mm.

The size of the specimen prepared for this research was 30 X 12 X 6.35 mm in the base metals of AA7075-T6 and A384.0-T6. In the dissimilar combination, the minimum and maximum UTS obtained welded plates are made as the specimens in the weld nugget area for the wear test.

Figure-3.Pin-on-disk Wear test apparatus

Figure-4.Pin-on-disk Wear test apparatus

The experimental wear tests are conducted under the dry sliding conditions at the normal room conditions. The specimens before wear tests and after wear tests are shown in Figure-5 and Figure-6 respectively.

Figure-5.Specimen before wear test

3. Results and Discussions

While conducting the wear test the time duration and the revolution per minute of the disc as kept constant of 600 seconds and 500rpm respectively for the base metals of AA7075-T6 and A384.0-T6 and the combination of these FSW welds. By varying the Base material and the applied loads the wear in microns are tabulated in Table-5. Also by varying the FSW material and the applied loads the wear in microns are tabulated in Table-6.

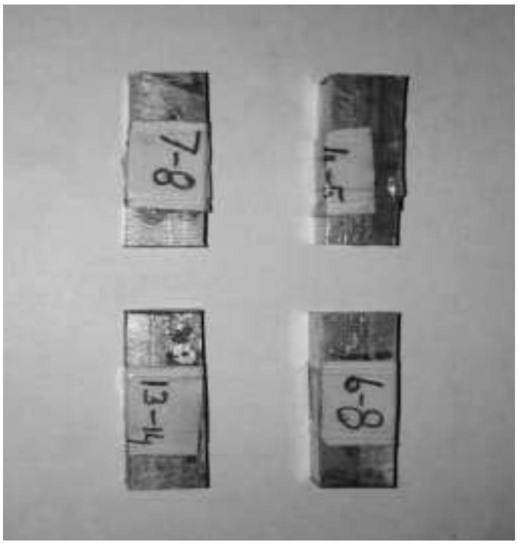

Figure-6. Specimen After wear test

Table-5.Wear Test Report for the Base materials

By using the above Table-5, On the basis of the same applied loads the wears in microns are discussed. The 20N loads in the materials are grouped in one category. In the Base material A384.0-T6 wear is more, comparing to the base material AA 7075-T6. Because the hardness of the base material AA 7075-T6 is have high hardness of 92 HRB. Whereas the base material of A384.0-T6 is have low hardness of 35.8 HRB.

The 40N loads in the materials are grouped in another category. In this also wear is more in A384.0-T6 comparing to the base materials of AA 7075-T6 and dissimilar weld combinations of AA7075-T6 and A384.0-T6.

The 60N loads in the materials are grouped as a third category. In this also wear is more in A384.0-T6 comparing to the base material of AA 7075-T6 and dissimilar weld combinations of AA7075-T6 and A384.0-T6. The wear in base material AA7075-T6 and the dissimilar Friction stir weld are more or less equal.

Table-6.Wear Test for FSW welds

Sl.no.	**FSW Weld No.**	**RPM**	**Load (N)**	**Time in Sec.**	**Sliding Velocity**	**Wear in micron**	**COF Avg**	**Frictional Force (N) Avg**
1	4-5	500	20	600	2.61 m/sec	63.83	0.4489	8.978
2	4-5	500	40	600	2.61 m/sec	84.95	0.4470	17.883
3	4-5	500	60	600	2.61 m/sec	135.17	0.4229	25.37
4	7-8	500	20	600	2.61 m/sec	113.95	0.4984	9.968
5	7-8	500	40	600	2.61 m/sec	68.69	0.4537	18.149
6	7-8	500	60	600	2.61 m/sec	91.07	0.4436	26.618
7	8-9	500	20	600	2.61 m/sec	67.28	0.4760	9.520
8	8-9	500	40	600	2.61 m/sec	72.04	0.4730	18.921
9	8-9	500	60	600	2.61 m/sec	75.27	0.4292	25.756
10	13-14	500	20	600	2.61 m/sec	97.23	0.4586	9.172
11	13-14	500	40	600	2.61 m/sec	69.72	0.4543	18.175
12	13-14	500	60	600	2.61 m/sec	73.68	0.4460	26.76

Sl.no.	**Material**	**RPM**	**Load (N)**	**Time in Sec.**	**Sliding Velocity**	**Wear in micron**	**COF Average**	**Frictional Force (N) Average**
1	7075	500	20	600	2.61 m/s	54.68	0.4469	8.93
2	7075	500	40	600	2.61 m/s	86.14	0.3768	15.07
3	7075	500	60	600	2.61 m/s	76.34	0.3538	21.23
4	384	500	20	600	2.61 m/s	181.02	0.3450	6.90
5	384	500	40	600	2.61 m/s	127.54	0.4156	16.62
6	384	500	60	600	2.61 m/s	124.92	0.3354	20.12

4. Conclusions

Wear is one of the important major mechanical properties in any material. In this experimental study the base materials of AA7075-T6 and A384.0-T6 Aluminium alloy materials, wears are discussed and analysed with the analyses of the dissimilar welds of the combination of AA7075-T6 and A384.0-T6 Aluminium materials. AA7075-T6 aluminium alloy have more hardness of 92 HRB and A384.0-T6 aluminium alloy have hardness of 35.8HRB. In these combinations FSW welds, the hardness is between 35.8 HRB and 92 HRB. In the same way, the wear is more in A384.0-T6 aluminium alloy and the wear is less in AA7075-T6 aluminium alloy. In these combinations FSW welds the wear is in-between the base materials wear amount. Therefore the hardness of the materials and the amount of wear are the inter-related parameter. In this experimental study, it is also proved.

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