Mechanical Characterization of Dissimilar Friction Stir Welded Aluminium Alloys

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***Abstract*—Aluminium alloys have gathered wide acceptance in the fabrication of light weight structure requiring a high strength to weight ratio and good corrosion resistance modern structural concept demand reduction in both the weight as well as the cost of the production and fabrication of the material. This project work present non destructive evaluation and corrosion studies of dissimilar alloys which are widely used in marine, automotive, aircraft and aerospace industries. Compare with fusion welding processes, friction stir welding process is a solid state joining process is suitable for joining these two alloys. Dissimilar friction stir welded joints are fabricated by varying the process parameters rotational speed, welding speed with the taper cylindrical threaded profile tool keeping axial load and tilt angle constant. The mechanical properties tensile strength, impact strength and hardness of the dissimilar friction stir welded specimens were tested and compared with the base metals. All the joints fractured in the heat affected zone side of 6061 alloy side correspond to the minimum values in micro hardness profiles and it is observed that the weld parameters have a significant effect on mechanical and micro structural properties of the welds.**

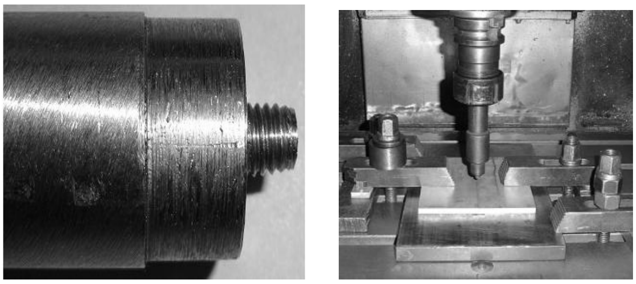
***Index Terms*— dissimilar joining, friction stir welding, tensile strength, impact strength, hardness, pin profile**

I. Introduction

Friction stir welding (FSW) process is a solid state joining technique considered to be the significant development over the past two decades which was invented and validated at the welding institute (TWI), United Kingdom in the year 1991[1]. In this process no melting occurs and the heat is generated internally by means of friction between the material-tool interface and the plastic deformation takes place without pre or post heating. Materials with different aluminum alloys can be welded together with a least alteration in mechanical properties due to no melting [2-7]. P Bahemmat et al [8] investigated the mechanical, micro and macro structural characteristics of dissimilar friction stir welding of AA6061-T6 and AA7075-T6; and reported that because of the higher strength of the SZ compared with the HAZ and the TMAZ, the specimen was not fractured in the SZ and the fracture occurred in the TMAZ–HAZ interface on the AA6061 side, which has lower hardness and strength in the weld cross-section. It is observed that very few experimental works are carried out in dissimilar FSW of aluminium alloys [9-21]. In the very few studies performed on dissimilar FSW, researchers have not yet been drawn to study about dissimilar FSW of AA6061-T651 and AA7075-T651.The present research work reports the effects of process parameters (rotational speed, welding speed and types of tool pin profile) on tensile strength were analyzed on the basis mechanical and micro structural properties of dissimilar friction stir welds.

II. Experimental Work

Aluminium alloys of AA6061-T651 and AA7075-T651 are selected for to fabricate dissimilar joints using the FSW process; where T651 heat treatment consists of solution heat treated, stretched and artificially aged. The FSW machine (Hydraulic power pack motor of 2.2kW /440V with 3000 rpm maximum rotational speed; 5000 mm/min as X axis rapid traverse speed and maximum axial thrust as 50kN) used for the dissimilar welding of the above alumimium alloy plates. The tool with a taper cylindrical threaded pin profile (TCT), weld set up is shown in Fig. 1(a) and (b). The thickness of the both aluminium alloy plates are 6.35 mm. Chemical compositions and the mechanical properties of AA6061-T651 and AA7075-T651 are given in Tables 1 and 2 respectively. The plates are placed in a butt configuration of 100 mm length; 50 mm width and the FSW process is carried out normal to the direction of the plates. Dissimilar friction stir welding process is carried out by placing the high strength aluminium alloy AA7075-T651 at the retreating side (RS), and by placing the aluminium alloy AA6061-T651 at the advancing side (AS); since if the weaker alloy is located at the RS, the fabricated weld will become weaker than when the weaker alloy is at the RS [8].



(a) (b)

Figure 1. (a) Tool pin profile (TCT), (b) FSW set up

TABLE I.
CHEMICAL COMPOSITION FOR 6061-T651 & 7075-T651 ALUMINIUM ALLOYS

Alloying elements	AA 6061-T651	AA 7075-T651
Si	0.68	0.05
Fe	0.17	< 0.10
Cu	0.17	1.30
Mn	0.04	0.03
Mg	1.04	2.69
Cr	0.06	0.20
Ni	< 0.01	< 0.01
Zn	0.06	5.78
Ti	0.06	0.06
Pb	< 0.01	< 0.01
Sn	< 0.01	< 0.01
Al	97.70	89.77

TABLE II.
MECHANICAL PROPERTIES FOR 6061-T651 & 7075 -651ALUMINIUM ALLOYS

	AA 6061-T651	AA 7075-T651
UTS (Mpa)	302.71	583.34
YS (Mpa)	286.95	526.24
% of Elongation	17.20	11.26
Hardness(HV) 300gm	108.2	183.9

TABLE III.
FRICTION STIR WELDING PARAMETERS COMBINATIONS

Trial Run	Rotational speed (rpm)	Welding speed (mm/min)	Pin profile
1	800	90	TCT
2	800	100	TCT
3	800	110	TCT
4	900	90	TCT
5	900	100	TCT
6	900	110	TCT
7	1000	90	TCT
8	1000	100	TCT
9	1000	110	TCT

The influenced process parameters and their working range for the dissimilar FSW of AA6061-T651 and AA7075-T651 are presented in Table 3. After the welding, the transverse tensile specimens are prepared with reference to ASTM E8M-04 standard. The room temperature tensile test was carried out with reference to ASTM D 557 M- 94 at a crosshead speed of 1.5 mm/min using a computer-controlled testing machine (Associated Scientific Engg. Works, New Delhi) and their ultimate tensile strength are measured from the averages of the three specimens. Vickers microhardness distribution conducted under the load of 500g.f. for 10s at 1mm neighbouring distances.

III. Results And Discussions

Table 4 shows the micro hardness values in SZ in addition to the tensile test results of all the dissimilar friction stir welded specimens including the impact strength values for the nine runs. It is observed that of all the welded plates, the plate welded with 900rpm tool rotational speed, 100mm/min welding speed and TCT tool shows better micro hardness and impact strength value at the SZ and higher tensile strength. It is observed that most of the specimens failed in the HAZ region of the AA6061 side and a few of them failed in SZ region. The joints fabricated with 800 rpm tool rotational speed, 90mm/min welding speed with the same tool showed low tensile strength. Tensile strength increases with increase in rotational speed up to 900rpm, after that it decreases. The tensile strength first increases to a maximum value and afterwards show a decrease with increasing the rotational speed at a given welding speed of the friction stir welded joints. Generally the tensile strength is poor at lower rotational speeds due to inadequate tool stirring action. With the increase of rotational speed for a certain range the strain hardening effect induced by tool stirring action increases tensile strength but the tensile strength lowers significantly with an increase of rotational speed to a rather high value due to excess heat input results in re-precipitation, reduction in dislocation density and coarsening of strengthening precipitates. The variation in tensile strength value at different rotational speed for a tool pin profile is due to the variation of material flow and frictional heat generated. For a given rotational speed the increase of welding speed increases the tensile strength to a certain value, and further increase of welding speed results in the decrease in the tensile strength of the friction stir welded joints.

TABLE IV.
TEST RESULTS FOR PARAMETERS COMBINATIONS

Trial Run	Ultimate tensile strength (Mpa)	Impact strength in Joules	Hardness (VHN)
1	172.12	3.3	109.34
2	185.23	4.1	111.98
3	182.36	3.9	111.36
4	192.12	4.9	113.12
5	201.36	5.5	113.87
6	196.32	5.1	112.98
7	181.36	3.7	110.12
8	186.52	3.8	111.23
9	175.63	3.4	111.56

Figure 2. Tensile testing machine

Figure 3. Impact testing machine

The tensile testing machine has the testing load range with a 5 ton capacity from Associated Scientific Engg. Works, New Delhi with the Digital Encoder make Auto Instruments – Kholapur of Gear rotation speed, 1.25, 1.5 & 2.5 mm /min. The transverse tensile specimens are prepared for each welded plate as shown in Fig 3.7 with reference to ASTM E8M-04 standard. The tensile test was carried out at room temperature based on ASTM D 557 M-94 with a cross head speed of 1.5 mm/min.

Figure 4. Hardness testing machine

Impact tests were conducted for the 9 joints fabricated with the process parameters from 800 to 1000 rpm as rotational speeds and welding speed from 90 to 110 mm/min. Since all the nine joints have the tunnel defect the tendency of failing is highly prone to this defect. The impact specimens are prepared with reference to ASTM standard. The impact test was carried out at room temperature based on ASTM D-256-10 standard.

Hardness tests were conducted for the 9 joints fabricated with the process parameters 800 to 1000 as rotational speeds and welding speed from 90 to 110 mm/min. in the nugget area. Five readings are taken in the nugget area and the averages of the five readings are displayed in Table 4. The hardness test was carried out at room temperature based on ASTM-E-92-82 standard. Hardness was measured in Vickers Scale @ 0.5 Kg Load condition. The hardness gradually increased from 800 to 900 rpm and thereby it was decreased when the rotational speed increases to 1000 rpm.

CONCLUSIONS

In this study, it has been found that the joining of the aluminum alloys with dissimilar condition can be done by the friction stir welding process with the range of process parameters. Based on the experimental results of this study, the following conclusions can be drawn:

- Dissimilar aluminium alloy plates are welded by friction stir welding process with the range of process parameters with 3 sets of rotational speeds from 800 to 1000 rpm and 3 sets of welding speeds from 90 to 110 mm/min keeping axial load as constant with 15 kN .
- From the Tensile test using ASTM D 557 M-94 standard the maximum ultimate tensile strength was identified as 201 MPa for the rotational speed 900 rpm and the minimum strength as 172 MPa for the rotational speed 800 rpm with the welding speeds 90 & 100 mm/min.
- From the impact testing using ASTM D-256-10 standard the maximum impact strength was identified as 5.5 J for the rotational speed 900 rpm and the minimum strength as 3.3 J for the rotational speed 800 rpm with the welding speeds 90 & 100 mm/min.
- From the hardness testing using ASTM-E-92-82 standard the maximum hardness was identified as 113.87 VHN for the rotational speed 900 rpm and the minimum strength as 109.34 for the rotational speed 800 rpm with the welding speeds 90 & 100 mm/min.

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