INTERNATIONAL CONFERENCE ON RECENT ADVANCEMENT IN MECHANICAL ENGINEERING &TECHNOLOGY (ICRAMET' 15)
Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

EFFECT OF WELDING PARAMETERS ON FRICTION STIR WELDED DISSIMILAR ALUMINUM ALLOYS 7075 AND 6082 WITH VARIOUS TOOL PIN PROFILES

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ABSTRACT

The aim of the present study is to investigate the effect of different tool pin profiles over Friction Stir Welding of dissimilar AA 6082 –T6 and AA 7075 – T6. The parameters considered were tool rotation speed, welding speed, tool pin profiles and number of passes. The metallurgical and mechanical characterization of friction stir welds of aluminium alloy 6082 – T6 with 7075 – T6 were carried out. Multi pass Friction Stir Welding of the alloys was also performed. This work includes microstructure examination, micro hardness test and tensile tests. The tensile strength for single pass is relatively higher than Multipass FSW. The hardness profile reduces while increasing the number of passes. Grain refinement is observed much in single pass FSW.

Keywords: Friction Stir Welding, AA 6082 – T6, AA 7075 – T6, Microstructure

INTRODUCTION

Friction stir welding 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 Thomas et al (1991). The FSW process is explained using Fig. 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. FSW is immune to the defects and property deteriorations associated with the fusion welding such as melting and coarsening of strengthening phases Mahoney et al (1998). Joints between dissimilar materials of 6082 – T6 and 7075 – T6 in aerospace structures mostly made by riveting which causes stress concentration and increases the weight of the final joints. Dissimilar welding of aluminium alloys is a core demand of the aircraft industries to substitute the traditional joining technologies with low cost and high efficiency ones such as friction stir welding in the future advanced design. Numerous papers can be found in the literature on various studies related to friction stir welding of dissimilar aluminum alloys.

Li and Shen (2012) conducted lap joint of dissimilar AA6063 to AA5052 aluminum alloys using a tool designed from quench hardening $W_9Mo_3Cr_4V$ with some geometric improvements. They placed the two overlap plate of AA5052 on the retreating side which improved the joint integrity of the weld. They demonstrated that improving the degree of the dissimilar Al alloys and promoting the material plastic deformation in the weld zone during the FSW contributed to obtaining high quality lap joints,

Leitao et al (2012) investigated the influence of the high temperature plastic behavior on friction stir weld ability of two aluminum alloys AA5083-H111 and AA6082-T6.They found that the AA6082 aluminum alloy displayed good weld ability in FSW whereas, the AA5083 alloy, had steady flow behavior at increased temperatures, a very poor weld ability was registered under the same conditions of the AA6082 – T6 alloy.

Tran et al (2010) investigated the behavior of friction spot welding between AA5754-O and AA7075 – T6. They showed that, under cyclic loading conditions, the micrographs show that the 5754/7075 and 7075/5754 welds in cross tension specimens mainly failed from the fatigue crack along the interfacial surface and from the fracture surface through the upper sheet material.

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Jun et al (2010) investigated residual strains dissimilar friction welds. The research was conducted using the Eigen strain Reconstruction Method in FSW between AA5083 and AA6082– T3.They further observed that full field residual stress strain distributions can be reconstructed relatively easily based on limited experimental data sets using transparent and straight forward FE modeling frame work.

Moreira et al (2009) produced friction stir butt welds of AA6082-T6 with AA6061 – T6. The welds exhibited intermediate properties and the tensile tests failures occurred near te weld edge line where a minimum value of hardness was observed. Furthermore micro structural changes induced by FSW process were clearly identified.

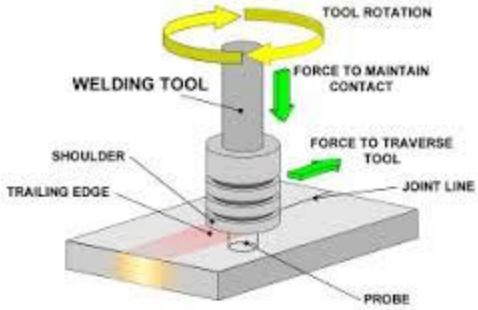


Fig 1. Schematic diagram of FSW process

Similar studies have been performed by few researchers on dissimilar aluminium alloys and the study o dissimilar alloys can be further extended particularly on dissimilar FSW between AA6082 and AA7075. Many studies have been conducted to characterize the resulting microstructure in welds especially in dissimilar aluminium alloys. Many researchers studied and reported the base materials microstructure and its properties. However, they are not enough literatures on microstructural characterization of dissimilar materials especially on aluminium alloys between 6000 and 7000 series. The main aim of this paper is to present and report the effects of welding parameters on macro and micro structural features in single and Multipass FSW of dissimilar aluminium alloys between AA7075-T6 and AA6082-T6 produced at different pin profiles.

Experimental work: Aluminium alloys of AA6082 – T6 and AA7075 – T6 are selected to fabricate dissimilar joints using the FSW both single and multi-pass process. The length, width and thickness of the both the aluminium alloy plates are chosen as 100, 70 and 6.35mm respectively. Chemical composition and the mechanical properties of AA 6082- T6 and AA 7075-T6 are given in tables 1 and 2 respectively. The tools with different pin profiles, weld setup and typical welded plate are shown in fig 2(a), (b) and (c1 & c2).

Table.1.Chemical composition of base aluminium alloys

Base alloys	Al	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti
6082 – T6	95.15	1.3	0.5	0.1	1.0	1.2	0.25	0.2	0.2	0.1
7075 – T6	89.76	0.05	0.1	1.3	0.03	2.69	0.2	0.01	5.78	0.06

Table.2.mechanical properties of base aluminium alloys

Aluminum alloys	Yield strength, (MPa)	Ultimate tensile strength, (Mpa)	Tensile elongation, (%)	Micro hardness (VHN)
6082 – T6	241	300	9	108
7075 – T6	526	583	11.3	171

Dissimilar friction stir welding process is carried out by placing the high strength aluminium alloy AA7075 – T6 at the retreating side, and by placing the aluminium alloy AA6082 – T6 at the advancing side. The process parameters which have the greater influence on the tensile strength of dissimilar FSW joints are identified as rotational speed, welding speed and tool pin profile. Three different pin profiles cylindrical threaded, triangular and simple square tools used were machined from H13 High speed steel. Trail experiments are conducted to determine the working and feasible range of process parameters.

Fig 2 (a) Tool pin profile, (b) FSW setup, (c1&c2) single pass and Multipass FSW welded plates

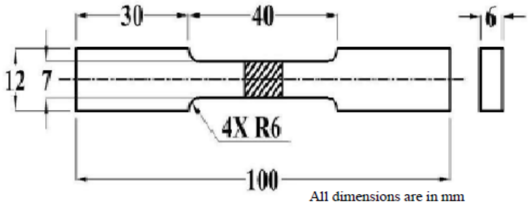
Table.3a.Dissimilar friction stir welding parameters and the selected levels for single pass

S.No	Welding Parameters	Unit	Levels		
			Sample N1	Sample N2	Sample N3
1	Tool rotational Speed	rpm	1250	1250	1250
2	Welding speed	Mm/min	50	50	50
3	Tool pin profile	-	C.T	Square	Triangle

Table.3b.Dissimilar friction stir welding parameters and the selected levels for Multipass

S.No	**Welding Parameters**	**Unit**	**Levels**		
			Sample N11	**Sample N12**	**Sample N13**
1	Tool rotational Speed	rpm	1400,1200	1400,1250	1400,1300
2	Welding speed	Mm/min	44	44	44
3	Tool pin profile	-	C.T	C.T	C.T

The influenced process parameters and their working range for the dissimilar FSW of AA 6082 – T6 and AA 7075 – T6 are presented in table 3a & 3b. The temperature profiles were measured using thermocouple. The thermocouple has a wire probe of 2mm dia. The probe of the thermocouple was moved along the surface of the weld, during welding, and the temperature distribution was recorded for everyn10 sec. the tensile specimen were prepared based on ASTME E8 as shown in the Fig.3. Wire cut EDM machine was employed in preparation of these specimens. The microstructure specimens were subjected to rough polishing and diamond polishing.



Results and discussion

Hardness measurements: The hardness profile of the FSW joined samples both from single pass and Multipass shows a significant softening in the welding zone. A minimum of hardness can be found inside the HAZ. This softening can be explained by the reduction of needle shaped precipitations caused by the process temperature. Outside the HAZ, the origin hardness of the base material reached again.

Multipass FSW samples: Samples N11, N12, N13 were welded using Multipass FSW with AA 6082 – T6 in the advancing side and AA 7075 – T6 in the retracting side. The axial load that was kept constant for all the three work piece at 14 KN. The hardness values were obtained for samples at H.V @ 0.5 kgf Load. The combined hardness profiles for sample N11, N12, N13 are shown in fig. 4.

From fig. 4 for sample N11 there is no considerable change in the hardness value in the unaffected zone when compared to the base metal. From fig. it is clear that double pass FSW the hardness value decreases at the center of the weld. From fig. 4 for sample N12 the hardness decreases in the center of the weld and it is low when compared to the parent material. From fig.4 for sample N13 the hardness is increasing at the center of the weld when compared to the sample N11 and N12. Therefore sample N13 has higher values than the other two samples in Multipass FSW.

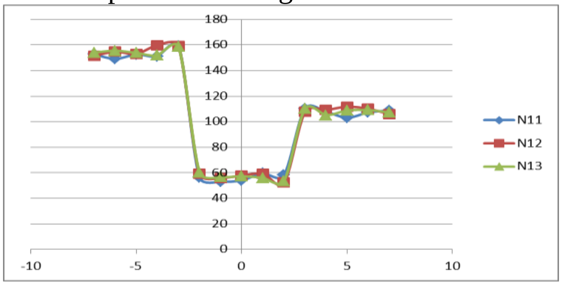


Fig.4.Combined Hardness profiles for samples N11, N12, N13

Single pass FSW samples: From fig.5 for sample N1 the hardness is low in parent material in the advancing side of the weld as well as in the retracting side of the weld. The hardness increases in the HAZ in the advancing side of the weld and it gradually increases in the retracting side of the weld. The hardness is high at the center of the welded area. From fig. 5 for sample N2 the micro hardness decreases in the welded zone when compared to the parent material. The hardness increases in the HAZ in the retracting side of the weld and it gradually deceases in the retracting side of the weld. From fig.5 for sample N3 the hardness decreases in the HAZ of the parent zone considering the advancing side and increases in the HAZ of the retracting side of the work piece.

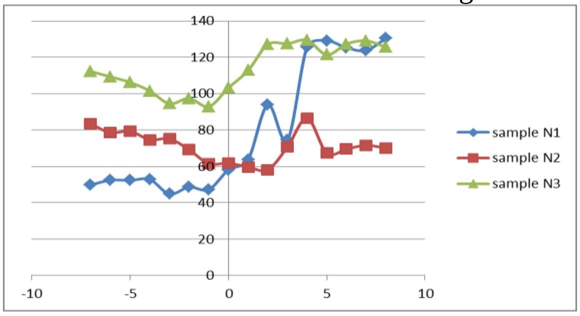


Fig.5.Combined Hardness profiles for sample N1, N2, N3

Micro structure analysis

Sample N1:At a tool rotation speed of 1200 rpm and welding speed of 50 mm/min the 7075 & 6082 undergone fusion resulting the formation of alternate layers in the weld zone as shown in the fig.6 and also the HAZ of the 7075 with transition zone of the parent metal microstructure and the HAZ as shown in the fig.7. The microstructure of the 6082 alloy with fine precipitated particles of eutectic component in aluminum solid solution. The precipitated particles are Mg2Si and Mg – Al2 as shown in the fig.8.

Fig.6.Weld Zone

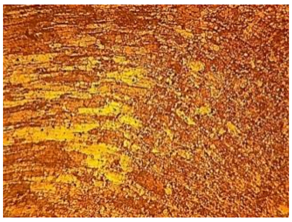


Fig.7.HAZ

Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

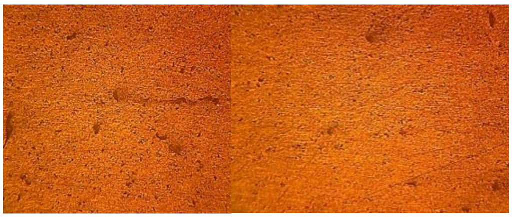


Fig.8.Microstructure of 6082

Sample N2: At a tool rotation speed of 1200 rpm and welding speed of 50 mm/min with the constituents of 7075& 6082 which have completely fragmented and formed one matrix due to dynamic re-crystallization as shown in the fig.9 and also the HAZ of the 7075leading to the formation of alternate layers as shown in the fig.10.

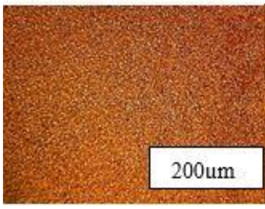


Fig.9 weld zone

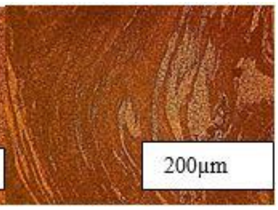


Fig.10 HAZ

Sample N3: At a tool rotation speed of 1200 rpm and welding speed of 50 mm/min the parent metal 7075 near the FSW zone leading to formation of TMT grains and HAZ of 7075 as shown in the fig.11. The fig. 12 shows the thermo mechanically transformed zone of the 7075. The nugget zone where the constituents of 6082 & 7075 have coagulated and formed fine fragmented grains as shown in the fig.13.

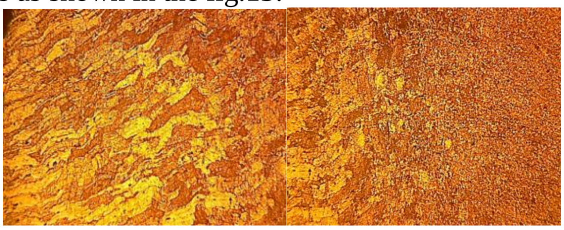


Fig.11.FSW zone

Fig.12.TMHAZ

Fig.13.Nugget zone

Tensile testing: The tensile strength properties of the FSW joints are presented in fig.14. from the fig.14 it is clear that samples N1, N2, N3 possess better tensile strength than samples N11, N12, N13. This shows that the tensile strength is found to be very high in single pass FSW than Multipass FSW.

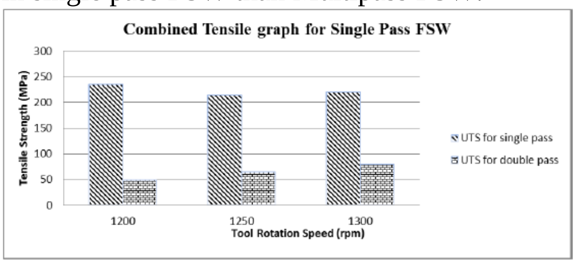


Fig.14.Combined Tensile test graph for single pass FSW

Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

CONCLUSION

The welding experiments of FSW butt joints for AA 6082 – T6 and AA 7075 – T6 plates were performed using various welding parameters and influences of welding parameters on the properties of FSW welds were investigated. The main conclusions are listed as follows;

1. The tensile properties were found to be decreasing in Multipass FSW when compared to single pass FSW.
2. The hardness value is found to be decreasing in square pin in single pass FSW. The hardness profile is found to be decrease in Multipass FSW when compared to single pass FSW at HAZ.
3. For cylindrical threaded tool pin and triangular pin profiles the microstructure consists of good flow of alloy and fragmented particles.

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