

A Comparative Study Of Tensile And Microstructural Characteristics Of Friction Welded Joints And Conventionally Welded Joints Of Aluminium Alloy 6061

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ABSTRACT

Welding of high strength and low weight materials like Aluminium Alloys without any defects by conventional welding techniques is a major challenge in industries. Hence research on solid state welding techniques like Friction stir welding and Friction welding techniques have got much importance in joining of Aluminium alloys. However most of the industries are not changing conventional techniques as skilled workers are available on that area. Most common conventional welding techniques used for joining of Aluminium alloys are Gas welding and Arc welding. Friction welding is a solid-state welding process that generates heat through mechanical friction between a moving and a stationary component with the addition of a lateral force called “upset” to plastically displace and fuse the materials. In this work, experimental study on tensile and micro structural characteristics of welded joints formed from conventional welding techniques and Rotary friction welding (suitable for weld specimens with circular cross section) has been carried out and the same were compared. The process parameters for arc welding used was 50-70 Amp reverse polarity DC and electrodes of 2.3mm diameter. In Gas welding, the parameters were oxy acetylene neutral flame at 3200°C and 3mm electrodes. In the case of friction welding an axial pressure loading of 3Mpa with 5 MPa as upsetting pressure and 500 rpm were used to obtain good welded joints. Tensile characteristic studies of Arc welded joints and Gas welded joints showed 48% and 60 % variations respectively from the maximum load bearing characteristics of parent metal. In the case of friction welded joint, the variation was found to 46%. Micro structural evaluation of conventionally welded joints exhibited clear distinct zones of various weld regions. In the case of friction welded joint micro structural photographs showed comparable features both in parent metal and welded region. Thus the tensile characteristic study and microstructure evaluations proved that friction welded joints are good in both aspects compared to conventionally welded joints.

NOMENCLATURE

FW	Friction welding
RFW	Rotary Friction welding
AW	Arc Welding
GW	Gas welding
DOE	Design of Experiment

1. INTRODUCTION

The two conventional welding processes used to join Aluminium alloys are Gas welding and Arc welding [1]. While doing such joining process too much care should be taken in order to avoid weld defects. Recent studies proved that friction welding can form good welded joint with mechanical and metallurgical characteristics comparatively similar to that of parent metal.

Friction welding is a class of solid state welding processes that generates heat through mechanical friction between a moving work piece and a stationary component, with the addition of a lateral force called “upset” to plastically displace and fuse the material [2]. Fig 1 shows working principle of Rotary friction welding process.

Friction welded joints are used to fabricate suspension rods, steering columns; gear box forks/drive shafts and engine valves. Hence they find wide application Aircraft, shipbuilding and Automotive industries.

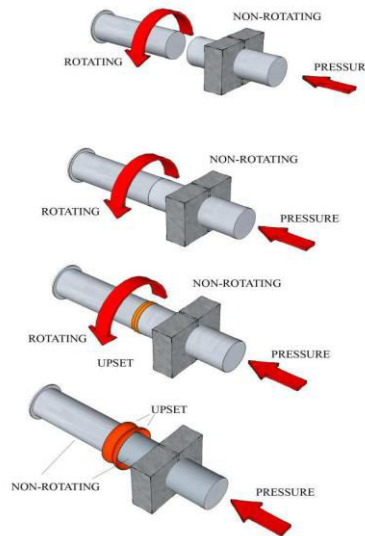


FIGURE 1. PRINCIPLE OF ROTARY FRICTION WELDING PROCESS [2]

Arka Sen and Sudip Mukherjee [3] have done investigations on Arc welding process to study influence on process parameters in the strength of welded joints. S.P.Kondapalli et al. [4] done investigations based on DOE to predict strength of welded joints from conventional welding techniques. D.Katherasan et al.,[5] were carried out Bead-on-plate experiments on AISI 316L (N) austenitic stainless steel (ASS) using flux cored arc welding (FCAW) process. Ahmad Fauzi et al., [6] have described effect of speed variations in the friction welding of alumina-Al6061. Yoshiaki Yamamoto et al. [7] have conducted the Ono's rotary bending fatigue test and the cantilever rotary bending fatigue test on friction-welded 6061Aluminium alloy joints. Eder PaduanAlves et al.[8] have done experimental work to assess the development of solid state joints of dissimilar material AA1050 aluminium and AISI 304 stainless steel, which can be applied in pipes of liquid propellant tanks and other components of the Satellite Launch Vehicle. F. Sassani, J. R. Neelam [9] has adopted a modified method for friction welding of incompatible materials. HazmanSeli et.al [10] and E.Ceretti et al. [11] have performed numerical study of Friction welding Process. M.I.Silis et al [12] has been carried out micro structural studies of Aluminium alloys formed from friction welding

The main objectives of the present work was to conduct comparative study on the tensile and micro structural characteristics of welded joints obtained from conventional and friction welding process.

2.EXPERIMENT ON WELDING PROCESS

The conventional welding considered here were Arc welding and Gas welding. A friction welding set up has been developed by modifying a conventional Lathe. The facilities available in College of Engineering Trivandrum (CET) have been utilized for producing welded joints and their tensile characteristic studies. Preliminary Metallurgical studies were also conducted at metallurgical lab of CET. Final stages of micro structural studies have been carried out at NIIST(National Institute of Interdisciplinary Science and Technology,Thiruvananthapuram)

The material used is Aluminium6061, originally called "Alloy 61S" it was developed in 1935 [13]. It is one of the most common alloys ofAluminium for general purpose use. Table.1 shows the temperature dependent Elastic Modulus [14] variation of Al6061. The chemical composition of Al 6061 is presented in Table 2.

TABLE 1 ELASTIC MODULUS OF AL6061

Temperature (°C)	Elastic Modulus (GPa)	Temperature (°C)	Elastic Modulus (GPa)
37.8	68.5	260	54
93.3	66.2	316	47.5
149	63.1	317	40.3
204	59.2	427	31.7

TABLE 2. CHEMICAL COMPOSITION OF AL 6061

Component (WT %)	Component (WT %)
Al	96
Si	2.1
Mg	0.95
Fe	0.33
Cu	0.17
Cr	0.066
Mn	0.04
Ti	0.022
Zn	0.014
Ni	0.014
Ca	0.013
Bal	<0.01

Table 3 and 4 indicates the process parameters fixed for the conventional welding process for the present study

TABLE .2 PROCESS PARAMETERS OF AW USED

Process Parameters	Value
Current Type/Polarity-	DCreversepolarity (electrode positive)
Rod Diameter	2.3mm
Amperage	50-70Amp
Electrode	As4043

TABLE .3 PROCESS PARAMETERS OF GW USED

Process Parameters	Value
Type of gas	Oxy acetylene
Temperature	3200°C
Type of flame	Neutral flame
Filler rod diameter	3mm

In both cases suitable fixtures were used for attaining uniform depth for the weld circumferentially for the specimens Fig 2 shows the joint preparation from Arc welding.

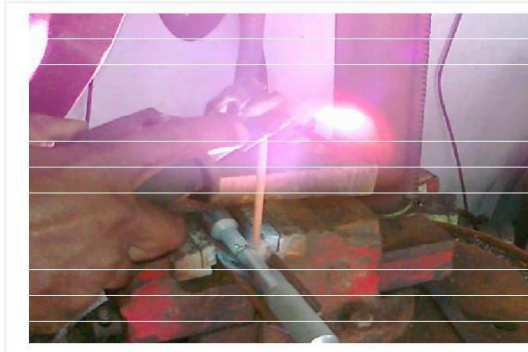


FIGURE .2 ARC WELDING PROCESS

Fig 3 shows the Gas welded joint. In both cases difficulties found while welding as the specimen cross section was rounded one.



FIGURE 3. JOINT OBTAINED FROM OXY ACETYLENE GAS WELDING

Fig. 4 shows the fw setup developed by modifying a conventional lathe



FIGURE 4. FRICTION WELDING SETUP

The specifications of the lathe used for making the friction welding setup is as shown in table 3

TABLE 3 SPECIFICATIONS OF THE LATHE FOR FW SETUP

Specification	Value /Type
Transmission	Geared
Distance between centers	1500mm 2.3mm
Swing over bed	350mm
Spindle bore	41mm
Motor	2.2 KW,1500 RPM

The rotating specimen was fitted to the headstock chuck. The stationary specimen was fitted to the chuck attached to the hydraulic loading unit. Process starts with rotating one specimen in contact with a second motionless specimen. An axial pressure of 3 M Pa was then applied. Plastic state for the contacting surfaces was achieved within a short time. At a precise moment, the rotation is stopped and axial forging pressure of 5Mpa is then applied. Flashing of the metal was observed during the weld formation, which actually provided us an idea about the weld formation. Fig.5 represents the close view of the FW joint obtained



FIGURE 5. FRICTION WELDED JOINT

All welded joints were evaluated for their mechanical characteristics through tensile testing. The standard specimen dimensions as per the ASTM standards used for tensile testing are as shown in Fig.6.

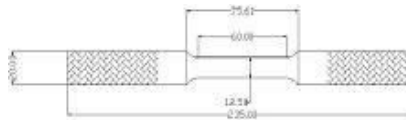


FIGURE 6. DIMENSIONS (IN mm) OF THE TENSILE TEST SPECIMEN

Microstructure analyses were carried out using standard metallographic techniques. The gradations of the particles from outer to the inner periphery in the welded joints were analyzed using Leica optical microscope.

Initially test samples were cut from the welded joints. The portions 2cm equal distance from the centre of the welded joint has been considered. They then longitudinally cross sectioned. The inner surfaces of the same were initially faced with shaper and after that the same subjected to polishing using finer emery papers of grid size 100,220,400,600 and 1000.

The specimens then washed thoroughly using soap and water while going to next grid size and the orientation of polishing surfaces was changed by 90°. The disc polishing has been carried out in a rotating wheel fixed with silver cloth (around 300rpm) with a gentle applied pressure and using diamond paste of varying size ranging from 6, 3, 1 and 0.25µm to get final mirror like finish .



FIGURE 7. VARIOUS ZONES IN WELDED JOINT

The specimen was dipped in etching solution for 20 seconds. Hydrogen fluoride was used for etching process. Fig.7 shows the specimen prepared for the micro structural studies.

3. RESULTS AND DISCUSSION

Result from welding processes, tensile and micro structural studies are as follows

3.1 Results from the tensile characteristic studies For each welding processes 6 joints have been taken, out of which best three were selected for tensile characteristic studies. Table 4 indicates the tensile characteristics found for the parent metal and all welded joints

TABLE 4. TENSILE TEST RESULTS
(a) Parent metal.

Si.No	Maximum Load(kN)	Breaking Load(kN)	Percentage Elongation (%)
1.	27.849	25.14	2.2
2.	27.85	25.14	2.2
3.	27.847	25.14	2.2
Avg.V	27.849	25.14	2.2
(b) Electric arc welded joints			
1.	14.4	14	3.1
2.	14.3	13.8	3.2
3.	14.1	13.9	3.3
Avg.V	14.3	13.8	3.2
(c) Gas welded joints			
1.	11.18	11.02	1.4
2.	11.17	11.01	1.5
3.	11.19	11.03	1.3
Avg.V	11.18	11.02	1.4
(d) Friction welded joints			
1.	15.06	13.14	6.2
2.	15.05	13.13	6.0
3.	15.07	13.15	6.4
Avg.V	15.06	13.13	6.2

The percentage variation of maximum load and breaking load of each welded joint with respect to parent metal has been presented in Fig.8

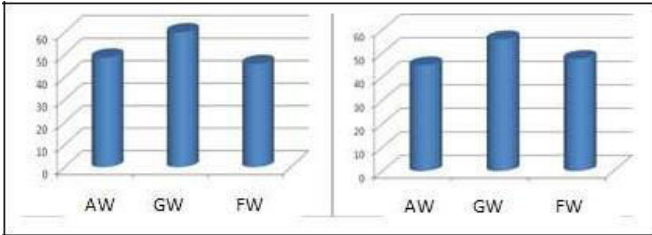


FIGURE 8. PERCENTAGE VARIATION OF MAXIMUM LOAD AND BREAKING LOAD FOR F EACH WELDED JOINT WITH RESPECT TO PARENT METAL.

It is seen that that maximum load bearing capacity is found to be more in the case of FW joints. But breaking load was found higher for Arc welded joints.

3.2 Result from Microstructure studies

The various photographs showing microstructure of parent metal, various zones of conventionally welded joints and friction welded joints etc from the micro structural studies has been presented in Fig 9A to 9D.

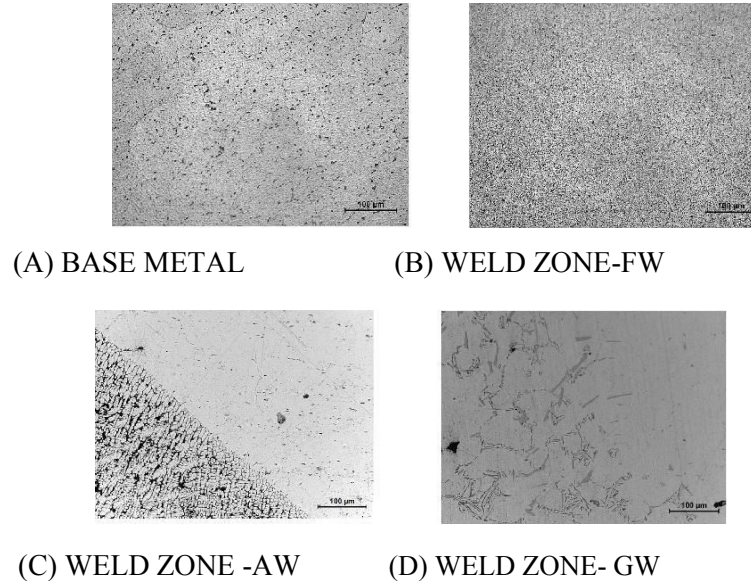


FIGURE 9. DIFFERENT ZONES OF WELDED JOINTS

Optical microscopic views of the parent metal show dendritic structure with dispersion of SiC particle. In the case of conventionally welded joints all the regions were clearly visualized. Especially for arc welded joints. The fusion zone of arc welded joints can be clearly distinct from the parent metal. It may be due to the sudden heating and cooling of joining portion with the addition of filler material. It is also clear that this black eutectic region is filled with significant amount of Al and Si as the filler –As4043 contained abundant Si particles. In the case of Gas welded joint the heat affected zone, fusion zone are clearly visible. In the fusion zone the dendritic structure seen as compressed and dispersed manner. Near to the thermo mechanically affected zone and fusion zone it is seen that large extension for dendritic structure has been occurred. In both cases residual stresses may be presented at the weld region.

In the case of FW joints, it is inferred that both welded region as well as parent metal region were having almost similar grain structure. However weld region possessed with denser grain structure compared to parent metal. It is also seen that grains are equiaxed at the welded region. This may be due to the dynamic recrystallization occurred during friction welding process.

Thus from the microstructure studies also it is cleared that FW is more suitable for the joining of Aluminium alloy rods as it resemble almost parent metal.

5. CONCLUSION

Various conclusion made from this study are as follows.

FW process has been found effective for the joining of Aluminium rods even though initial setting time is more compared to the conventional welding processes. Irregular surface has been observed in the conventionally welded joints. This may be due to the sudden heating and cooling occurred. In addition as the material was Aluminium alloy in order to with stand the high fusion temperature intervals had to be given during welding process .In the case of FW joints the weld region were found uniform.

FW has been occurred at plasticized stage followed with grain transfer instead of phase changes as in conventional welding processes. However the weld region was found harder compared to the parent metal region, but lesser than conventional welded joints had.

From Tensile characteristic studies it is seen that the FW joint were strong compared to the parent metal. Percentage variation of maximum load carrying capacity for Arc, Gas and FW joints were 48.7%, 60% and 45.9% respectively. But breaking load value was found less for FW joints, may be due to the loosening of the grains when loading beyond the maximum load bearing capability of the joint.

Micro structural photographs of conventionally welded joints exhibited clear distinct zones of various weld regions. In the case of FW joints it showed comparable features both in parent metal and welded region. Geometry of particles was also found same. These lights on the material transfer during friction welding process at plasticized stage. However near to the weld region particles are seen in large density. Thus all these studies reveals the suitability of FW techniques for the effective joining of Aluminium Alloys.

ACKNOWLEDGEMENT

Authors indebted to the help from Sri. Madhavan Kutty and Sri. Prasad in Engineering workshop of CET

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