ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization, Volume 2, Special Issue 1, December 2013

Proceedings of International Conference on Energy and Environment-2013 (ICEE 2013)

On 12th to 14th December Organized by

Department of Civil Engineering and Mechanical Engineering of Rajiv Gandhi Institute of Technology, Kottayam, Kerala, India

Influence of Interface Surface Geometries In The Tensile Characteristics Of Friction Welded Joints From Aluminium Alloys

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ABSTRACT

Friction welding is a solid state joining process that produces coalescence in materials, using the heat developed between surfaces through a combination of mechanical induced rubbing motion and applied load. In rotary friction welding technique heat is generated by the conversion of mechanical energy into thermal energy at the interface of the work pieces during rotation under pressure. Traditionally friction welding is carried out on a dedicated machine because of its adaptability to mass production. In the present work, steps were made to modify a conventional lathe to rotary friction welding set up to obtain friction welding with different interface surface geometries at two different speeds and to carry out tensile characteristic studies. The surface geometries welded include flat-flat, flat-tapered, tapered-tapered, concave-convex and convex-convex. A comparison of maximum load, breaking load and percentage elongation of different welded geometries has been realized through this project. The maximum load and breaking load were found to be highest for weld formed between rotating flat and stationary tapered at 500RPM and the values were 19.219kN and 14.28 kN respectively. The percentage elongation was found to be highest for weld formed between rotating flat and stationary flat at 500RPM and the value was 21.4%. Hence from the studies it is cleared that process parameter like "interfacing surface geometries" of weld specimens have strong influence on tensile characteristics of friction welded joints.

NOMENCLATURE

FW	Friction welding
S	Stationary Specimen
R	Rotating specimen
RFW	Rotary Friction welding
F-F	Rotating Flat and Stationary Flat
F-T	Rotating Flat and Stationary Tapered

T-T Rotating Tapered and Stationary Tapered
CV-CX Rotating Concave and Stationary Convex
CX-CX Rotating Convex and Stationary Convex

1. INTRODUCTION

Welding is one of the most critical processes in industrial manufacture and assembly. This is often done by melting the work piece and adding a filler material to form a pool of molten material that cools to become a strong joint. Many different energy sources can be used for welding, including a gas flame, an electric arc, a laser, an electron beam, ultrasound etc.

Friction welding [1] is a complicated process, which involves interaction of thermal, mechanical and metallurgical phenomenon. It is a solid state joining process that produces coalescence in materials, using the heat developed between surfaces through a combination of mechanical induced rubbing motion and applied load. The resulting joint is of forged quality. Under normal conditions, the faying surfaces do not melt. Filler metal, flux and shielding gas are not required for this process.

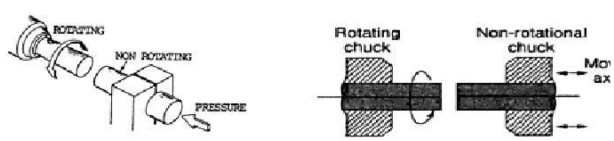
Friction welding techniques are popular nowadays in aerospace, automotive and ship building industries. Friction welding may be linear friction welding [2] and Rotary friction welding [3]. Rotary friction welding technique is very much suitable for materials with circular cross section. It is also suitable for high strength materials like steel and high strength low weight materials like Aluminum alloys. [4].

The main objectives of the present work were to produce FW joints from specimen with different interface geometry and assess their tensile characteristics.

2.THEORY OF ROTARY FRICTION WELDING

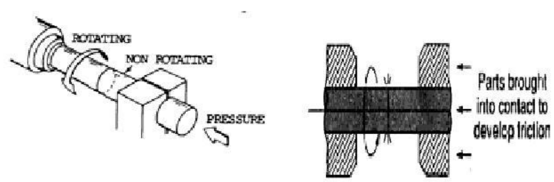
The working procedure of RFW process is as shown in Fig 1. [1]

A



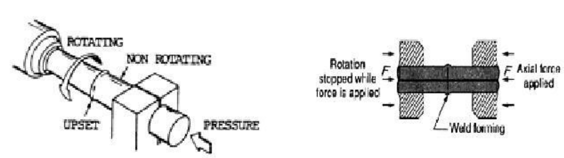
Stationary specimen held in non-rotating chuck is moved axially and is brought into contact with the rotating specimen.

B



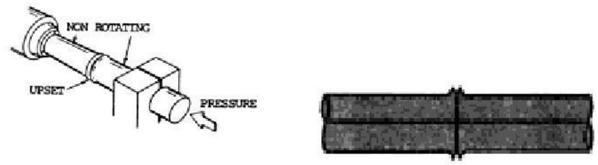
Heat is generated at the contact interface due to friction.

C



When metal in the joint zone reaches plastic state due to high temperature and heat generation, because of friction, rotation is stopped and axial pressure is increased instantly.

D



Rotary friction welded joint is formed.

FIGURE 1. WORKING PROCEDURE-RFW

Thus the Friction welding Process Parameters are

- Speed of rotating specimen
- Effect of axial pressure
- Time taken for heat generation
- Mating surface condition of specimens
- Geometry of the specimen
- Material property of the specimen
- Upsetting pressure
-

V.M. Radhakrishnan [5], described the welding methodology and design aspects of welding. He described friction welding as a special case of welding in which the friction between the two weld surfaces develops heat to form welded joints. S.Gowri, P.Hariharan and A.Suresh Babu [6], has investigated the influence of rotational speed, axial pressure and heating in a FW process. I .Kubiszyn and A. Pietrasto [7] carried out a three-dimensional, numerical analysis of the FW process. E. Ceretti et al.[8] did the numerical modeling of the linear friction welding process. Lindeman et al.[9] did the modeling of thermo-mechanical effects in the FW process of corundum ceramics which contains 97% of Al_2O_3 and aluminum. Mum in Shin [10], made studies on the simulation of friction welding. He also did studies on friction welded joints having equal and different diameters of AISI 1040 (medium carbon steel).Wendy Li , Taejon Ma and Jingling Li [11], did numerical simulation of the linear FW process of titanium alloy to investigate the effect of process parameters. L.-E. Lindgren [12], described the application of the finite element method to predict the thermal, material and mechanical effects of welding using Computational Welding Mechanics (CWM). .Haman Selig et al. [13], carried out mechanical and thermal modeling of the friction welding of mild steel and aluminum G. Karan Kumar et al..[14], did modifications to a medium duty lathe and obtained FW joint and proved that a simple engine lathe can perform friction welding up to 12mm diameter Hamlet Z. Shin et al.[15] did analysis of the friction welding of copper and steel bars. M.N. Ahmad Faze .et al [16] described effect of speed variations in the friction welding of Alumina-Al 6061.

3. EXPERIMENTAL STUDIES

Experimental studies included production of friction welded joints from Aluminum Alloy rods with various interface geometries. After that the same were subjected to tensile test characteristic studies

3.1 About the friction welding setup used

The basic frame work of the friction welding setup is a medium duty lathe. The tail stock of the same was replaced with chuck with adequate hydraulic system as per the requirement of the friction welding process.

FIGURE 2. FRICTION WELDING SETUP

Special fixtures were arranged to hold the hydraulic loading system unit. Fig. 2 shows the friction welding set up used.

The specifications of the lathe used for making the FW setup is as shown in Table 1

TABLE 1. DETAILS OF LATHE USED FOR THE RFW SETUP

Specification	Value/ Type
Type of Transmission	Geared
Distance between centres	800mm
Swing over bed	170mm
Spindle bore	41mm
Motor power and rpm	2.2 KW,1500 RPM

The RFW set up is suitable to hold work pieces diameter ranges from 0.75mm to 20 mm. Hydraulic system can provide a pressure up to 30 MPa.

3.2 Material used

The material used is **Aluminum 6061.** It has good mechanical properties and exhibits good weld ability. The chemical composition of the Al 6061 is given in table 2.

TABLE 2. CHEMICAL COMPOSITION OF AL 6061

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

3.3 Experimental procedure

Work piece of 120 mm length and 20 mm diameter with interface surface geometries as mentioned in Table 3. Has been prepared prior to FW process

TABLE 3. DIFFERENT COMBINATIONS OF SURFACE GEOMETRIES CONSIDERED

ROTATING	STATIONARY
Flat	Flat
Flat	Tapered
Tapered	Tapered
Concave	Convex
Convex	Convex

Two different speeds; 500 RPM and 775 RPM.

The specimen, fixed as rotating part, was fitted to the headstock chuck. The specimen, fixed as stationary part, was fitted to the chuck attached to the hydraulic loading unit. Speed regulation was done with the help of levers, provided at the lathe. The axial loading was given 3MPa and upsetting pressure was given 5MPa. . Samples of various combinations of friction welded joints obtained are shown in Fig 3

Flat (R)-Flat (S) - 500RPM

Flat (R)-Tapered (S) 500 RPM

Tapered (R)-Tapered S-

500 RPM

Concave(R)--Convex (S) 500 RPM

Convex (R) –convex (S) at 500 RPM

FIGURE . 3 VARIOUS COMBINATIONS OF FRICTION WELDED JOINTS OBTAINED

The same combinations were also carried out for 775 RPM.

All the welded joints were then subjected to tensile characteristic studies. Fig 4 represents the tensile specimen prepared from these combinations as per ASTM standards(B557M). The average value obtained for Maximum load, breaking load and percentage elongations were then tabulated. For the parent metal the values found were 27.849kN, 25.4kN and 22 respectively. Table 4 and 5 represent the results obtained for the welded joints with different combination of interface surface geometry with respect to two speeds.

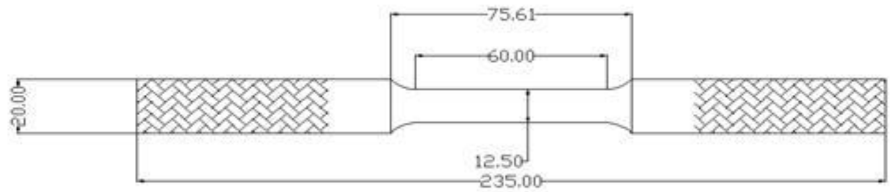


FIGURE 4. STANDARD SPECIMEN FOR TENSION TEST

Fig 5 to 7 represents the comparison of Maximum load, Breaking load (as percentage variation) and combination of welded joints with speed of 500 RPM , compared with parent metal.

TABLE 4. TENSILE CHARRECTERESTICS OF FW JOINTS FORMED AT 500 RPM

Profile	Maximum load(kN)	Breaking load(kN)	% elongation
Flat-Flat	14.580	10.22	21.4
Flat-Tapered	19.219	14.28	10.0
Tapered-Tapered	14.600	6.92	17.0
Concave- Convex	7.432	6.30	5.4
Convex- Convex	14.260	14.24	8.4

TABLE 5. TENSILE CHARRECTERESTICS OF FW JOINTS FORMED AT 775 RPM

Profile	Maximum Load(kN)	Breaking Load(kN)	% elongation
Flat-Flat	6.800	6.79	3.0
Flat-Tapered	10.210	9.60	4.2
Tapered-Tapered	15.600	11.38	4.2
Concave- Convex	Weld failed during tensile test specimen preperation		
Convex- Convex	13.745	7.12	6.4

Fig 8 to 10 represents the comparison of Maximum load, Breaking load (as percentage variation) and percentage of elongation obtained for various combination of welded joints with speed of 775 RPM , with parent metal.

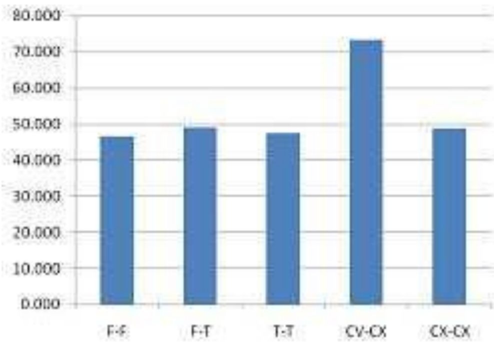


FIGURE 5 . PERCENTAGE VARIATION OF BREAKING LOAD(AT 500 RPM)

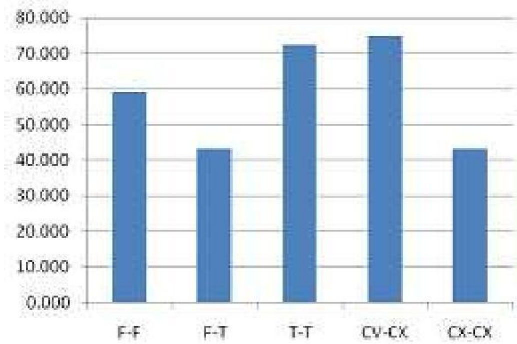


FIGURE 6. PERCENTAGE VARIATION OF BREAKING LOAD(AT 500 RPM)

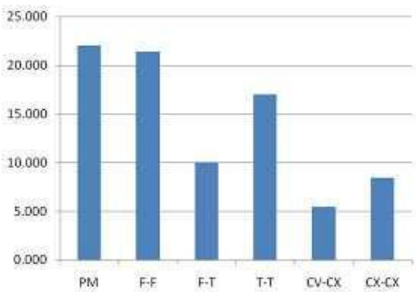


FIGURE 7. PERCENTAGE ELONGATION OF FW JOINTS (AT 500 RPM)

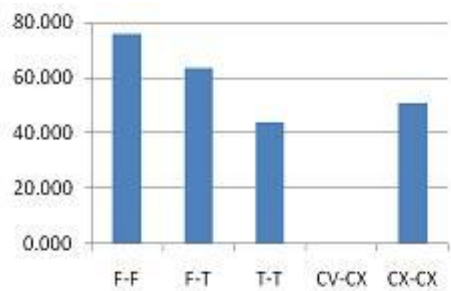


FIGURE 8. PERCENTAGE VARIATION OF LOAD(AT 775 RPM)

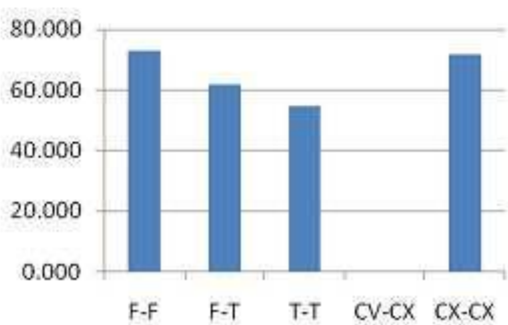


FIGURE 9. PERCENTAGE VARIATION MAXIMUM OF OFBREAKING LOAD (AT 775 RPM)

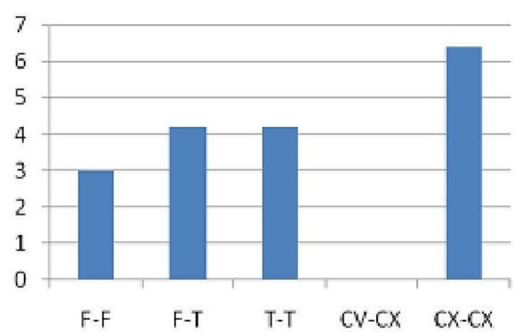


FIGURE 10 . PERCENTAGE ELONGATION FW JOINTS ,(AT 775 RPM)

From the tension test carried out, the maximum load bearing capacity and the value of breaking load was found to be highest for rotating flat and stationary tapered at 500rpm and for rotating tapered and stationary tapered at 775rpm. This is due to gradual increase in contact area with application of pressure in appropriate amount at suitable time. However the percentage elongation was found to be highest for rotating flat and stationary flat at 500rpm and for rotating convex and stationary convex at 775rpm. This is an indication of good weld with properties comparable with the parent metal

4.CONCLUSION

Strong friction welded joints for different surface interfaces were obtained and mechanical characteristic studies of the same were carried out. The major concluding remarks obtained from the present works are as follows.

1. Optimum parameters to obtain friction welded joint from the present setup were found out and good friction welded joints were obtained.

2. The maximum load and breaking load were found to be highest for friction weld formed between rotating flat and stationary tapered(19.29kN and 14.28kN) at 500rpm and for friction weld formed between rotating tapered and stationary tapered(15.6kN and 11.38kN) at 775rpm. This indicate that in the first case frictional heat has been developed equally from the centre to outer radially which enhanced the one to one material transfer and further bonding.

3. Percentage elongation was found to be highest for friction weld formed with rotating flat and stationary flat (21.4%) at 500 rpm. In the case of 775 rpm for all combinations it was found less.

Thus from this experimental study it is inferred that interfacing surface geometries have strong influence on the tensile characteristics of friction welded joint.

ACKNOWLEDGEMENT

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

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