

Friction Stir Welding of Rectangular Flat Plates by using Hand Drilling Machine

Mohd Anees Siddiqui¹ K.M.Moeed² S.A.H. Jafri³

^{1,2,3}Department of Mechanical Engineering

^{1,2,3}Integral University, Lucknow, India

Abstract— In the present work, friction stir welding is performed by using experimental setup installed with hand drilling machine. The tool and workpiece materials are selected according to the capacity of hand drilling machine. The mild steel tool and rectangular lead alloy workpiece plates were manufactured in the workshop. The experiments were performed at three weld speeds and butt joint was prepared. The welded butt joint undergone visual inspection and tensile test. Tensile strength, deflection, stiffness and resilience were obtained and graphical analysis was done to study the effect of weld speed on mechanical behaviour. Static structural analysis was also performed in order to investigate maximum stress distribution in the plates during friction stir welding process. The main purpose of this work is to introduce friction stir welding in workshop level for joining of low melting point materials through low cost setup based on hand drilling machine.

Key words: Friction Stir Welding, Fabricated Setup, Hand Drilling Machine, Tool, Workpiece

I. INTRODUCTION

Friction stir welding (FSW) is basically a solid state joining process which consists of rotating tool with a shoulder and a profiled pin which is penetrated into the joining edges of plates and moved forward. This technique is for joining materials with low melting point [1] and it is an environment friendly joining process because of no fumes and any kind of radiation which can heal the wounds of welder health issues [3]. Friction stir welding machines are manufactured by several industries such as ESAB, Manufacturing Solutions Inc., etc which are generally used in manufacturing units but still difficult to avail for research due to their high cost [2]. For the purpose research, milling machine is converted into friction stir welding machine by some modifications [4]. Researchers have also performed pre-experimental simulations of FSW for aluminium alloys [6-10].

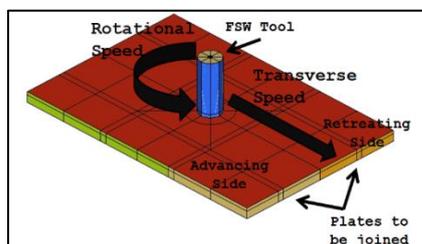


Fig. 1: This figure shows the finite element model for friction stir welding process by using a rotating tool which moves in the direction of joined edges of plates [9].

In order to analyse the capacity of hand drilling machine for friction stir welding, we have fabricated the experimental setup by installing hand drilling machine which was reported in [5]. This work is extension of previous efforts by having some modifications in the

experimental setup for successful welding of lead alloy plates.

The present work includes creation of butt joint of lead alloy plates by friction stir welding process through hand drilling machine, visual inspection and tensile test of welded joint and graphical representation of relation between mechanical properties (Tensile strength, deflection, stiffness, resilience) and weld speed. Static structural analysis is also performed in order to obtain stress distribution.

II. EXPERIMENTAL WORK

This section presents the details of experimental setup used, preparation of workpiece, manufacturing of tool, the steps of performing friction stir welding and finally the testing methods which were used to evaluate the quality of the obtained welded sections.

A. Experimental Setup

The experimental used in the present work installed with hand drilling machine (shown in fig 2). The machine is fixed vertically through clamping. The sliding backing plate is available for providing feed or weld speed. The hand drilling machine has 2600 rpm and consumes 450W.

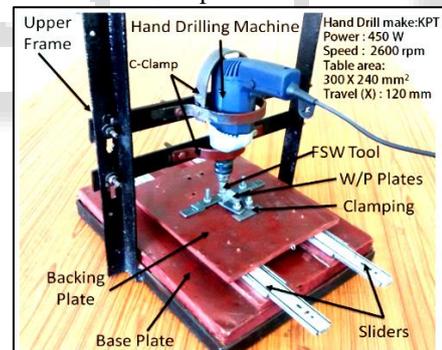


Fig. 2: Experimental setup of friction stir welding process based on hand drilling machine.

B. Preparation of Workpiece

The material selected for the project work is lead alloy due to its low melting point keeping in mind the capacity of drilling machine installed in the friction stir welding setup. The details of dimensions are shown in figure 3. The plate is rectangular with dimension 45 x 30 x 6 mm.

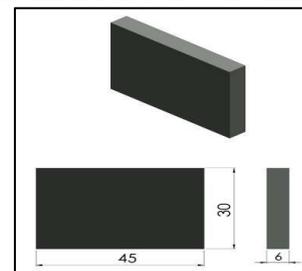


Fig. 3: Dimensions of lead alloy plates

Lead alloys was adopted from the block available in market, it was melted and poured in to the mould of size (90x40x7) mm in order to obtain workpiece plates. Figure 4 shows the procedure adopted for obtaining lead alloy plates.

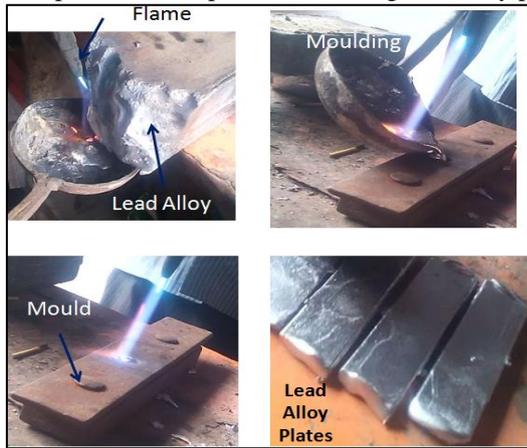


Fig. 4: Moulding process

In order to get desired dimension, cutting was done by using hand hacksaw. Smooth file was used for finishing of the surface of plates. Figure 5 shows the prepared lead alloy plates for friction stir welding by using hand drilling machine.



Fig. 5: Prepared lead alloy plates according to dimensions (45X30X6)

C. Manufacturing of FSW tool

The mild steel is selected as tool material with reference to the workpiece material because the overall strength of tool must be higher than that of plates to be welded. The tooling was designed using Solid Works software to produce detailed engineering drawing and the manufacturing of tool is done in machine shop.

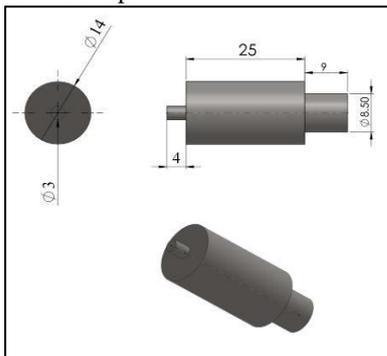


Fig. 6: Dimensions of friction stir welding tool of mild steel.

The steps of manufacturing of FSW tool in lathe machine are as follows:

- 1) Step1: A length of 60 mm was cut from a cylindrical rod of length 100 mm and with diameter 14 mm that was bought in order to make this tool.
- 2) Step 2: A length of 4 mm was reduced in diameter to reach a diameter of 3mm using a turning process on a lathe machine
- 3) Step 3: A length of 9 mm was reduced in diameter to reach a diameter of 8.5 mm from the other side for holding in chuck of FSW machine.

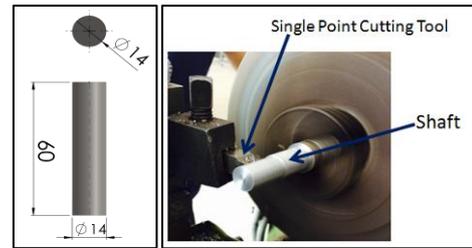


Fig. 7: Turning operation of cylindrical mild steel rod in lathe machine to manufacture friction stir welding tool

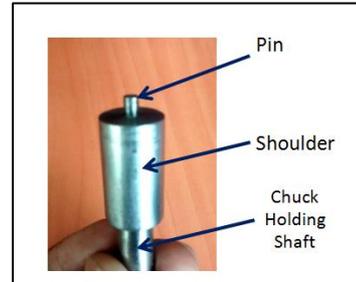


Fig. 8: Finished Tool

D. Preparation of Experimental Setup

The experimental setup was prepared for friction stir welding process by using hand drilling machine. The preparation includes the proper clamping of the working plates on backing plate and proper fitment of friction stir welding mild steel tool by using appropriate equipments as shown in figure 9.

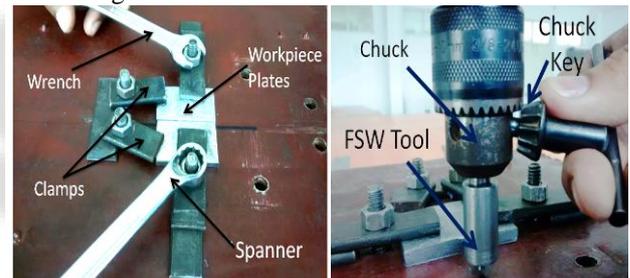


Fig. 9: Clamping of Workpiece plates in Backing Plate (left) and Fitment of FSW tool in Drill machine chuck (right).

Friction Stir Welding Parameters considered in the present work are rotational Speed of 2600 rpm, weld speeds: 0.25 mm/s, 0.4 mm/s, 1.2 mm/s and axial load of 17.64 N which is taken as the weight of drilling machine i.e. 1.8 Kg. Figure 10 shows the start of friction stir welding process of lead alloy plates by using mild steel tool through hand drilling machine.

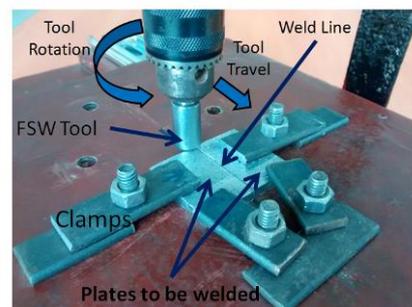


Fig. 10: Start of FSW Process

Figure 11 shows the process of friction stir welding with tool at mid position of lead alloy plates. The experiment was conducted for different weld speeds of 0.25 mm/s, 0.4 mm/s, 1.2 mm/s in order to analyse the variation of mechanical properties with respect to welding speed.

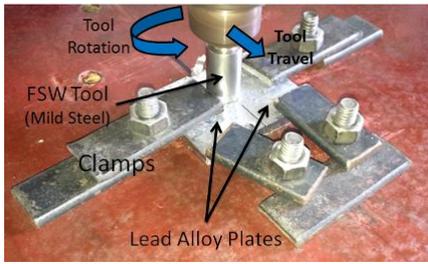


Fig. 11: Friction Stir Welding Process

III. RESULTS AND DISCUSSION

This section represents the results of visual inspection and tensile test followed by calculation of tensile strength, stiffness, resilience of joint. The graphical relationship is also obtained between mechanical properties (Tensile strength, deflection, stiffness, resilience) and weld speed during the friction stir welding process by using hand drilling machine.

A. Visual Inspection

After the friction stir welding process, the welded plates undergone visual inspection and it is observed that some defects are present such as (shown in fig.12)

- Lack of surface filling
- Key hole defect
- Ribbon flashing
- Tunnel defect
- Irregular surface
- Material deposition

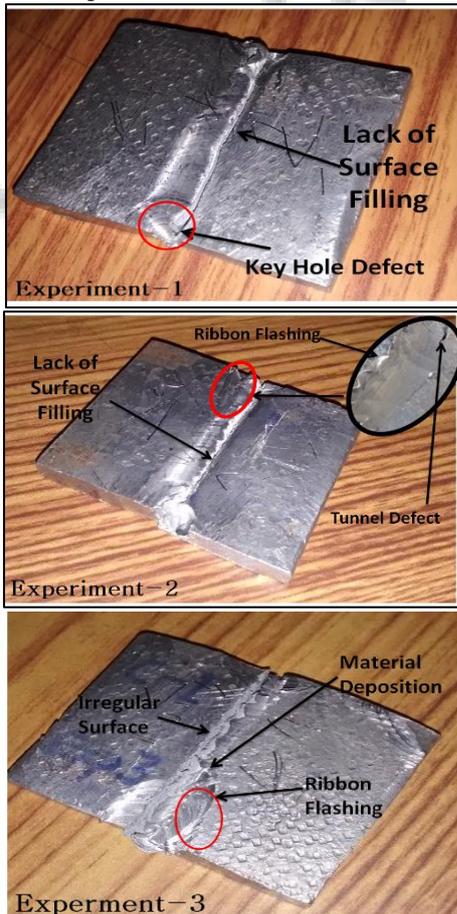


Fig. 12: Defects observed by visual inspection in all three welded butt joints of lead alloy plates.

B. Tensile Test

The tensile test of friction stir welded joint of lead alloy plates was conducted on tensile testing machine and the values of tensile load were obtained in order to calculate tensile strength, stiffness and resilience. Figure 13 shows the welded joint testing for tensile load of fracture of joint.

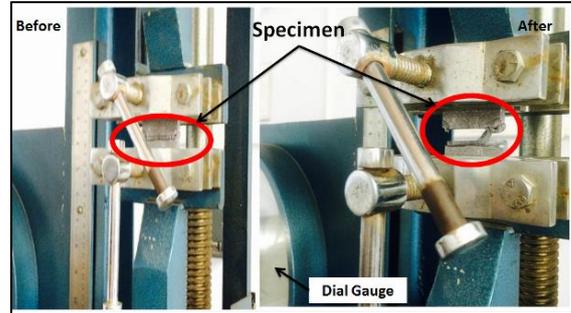


Fig. 13: Tensile testing of friction stir welded joint at central workshop, Integral University, Lucknow.

Table 1 show the observed values of load and deflection which are obtained during tensile test on tensile testing machine on dial gauge. The tensile load observed for different weld speed was tabulated. Table 2 shows the values of tensile strength, stiffness and resilience calculated by using the mathematical relations:

$$\sigma = W/A \quad (1)$$

$$S = W / \delta l \quad (2)$$

$$R = 1/2(W \times \delta l) \quad (3)$$

Where

W is tensile load in Newton, A is area in mm², δl is deflection in mm, S is stiffness in N/mm and R is resilience in N-mm

Weld Speed (mm/s)	Load (Kgf)	Load W (N)	Deflection δl (mm)
0.25	19.68	192.86	1.4
0.4	37.125	363.83	1.9
1.2	103.5	1014.3	2

Table 1: Observed values of tensile load and deflection

Tensile Strength $\sigma = W/A$ (N/mm ²)	Stiffness $S = W / \delta l$ (N/mm)	Resilience $R = 1/2(W \times \delta l)$ (N-mm)
0.71	137.76	135.00
1.35	191.49	345.63
3.76	507.15	1014.3

Table 2: Calculated values of tensile strength, stiffness and resilience

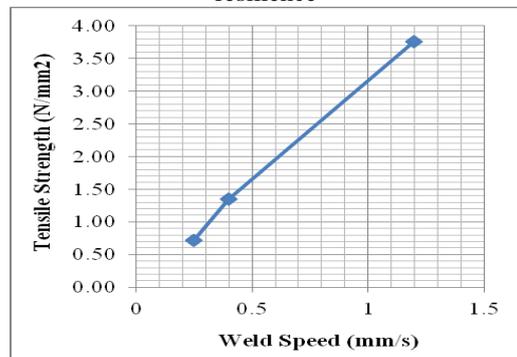


Fig. 14: Graph shows the variation of tensile strength of butt joint with respect to weld speed in friction stir welding of lead alloy plates

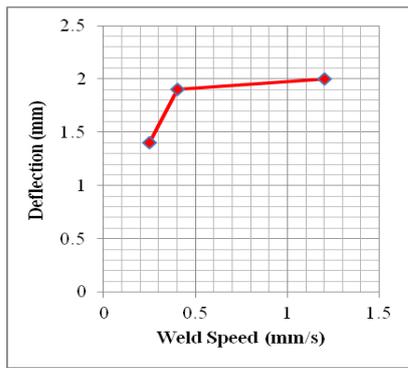


Fig. 15: Graph shows the variation of deflection of butt joint with respect to weld speed in friction stir welding of lead alloy plates.

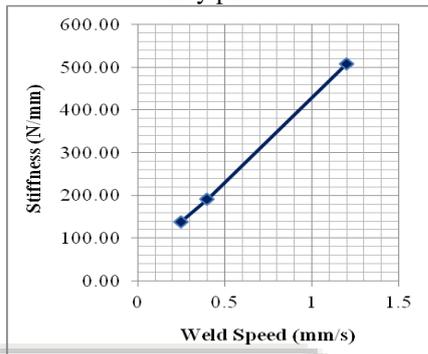


Fig. 16: Graph shows the variation of stiffness of butt joint with respect to weld speed in friction stir welding of lead alloy plates.

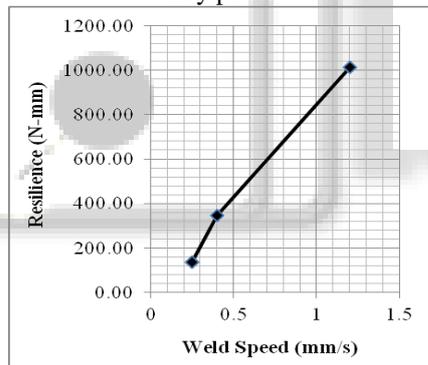


Fig. 17: Graph shows the variation of resilience of butt joint with respect to weld speed in friction stir welding of lead alloy plates

From the graphs (fig.14-17), it is observed that the tensile strength, deflection, stiffness and resilience of friction stir welded joint increases with increase in welding speed. Although the maximum value of tensile strength 3.76 MPa for weld speed of 1.2 mm/s is around one third of the base plate (12 MPa) that can be improved by controlling more parameters but still this technique of friction stir welding by hand drilling machine opens the door for joining low melting point materials at workshop level

C. Stress Analysis

The static structural analysis was performed in order to investigate the area of maximum stress. The model of tool and plates were developed by using modeling package SolidWorks

The model was imported to ANSYS for static structural analysis for identification of maximum stress area (von-mises) which will decide the clamping force required

for working plates during the process. The meshed model of friction stir welding tool and lead alloy plates with coarse span angle centre has 21523 nodes and 5101 elements (shown in fig.17).

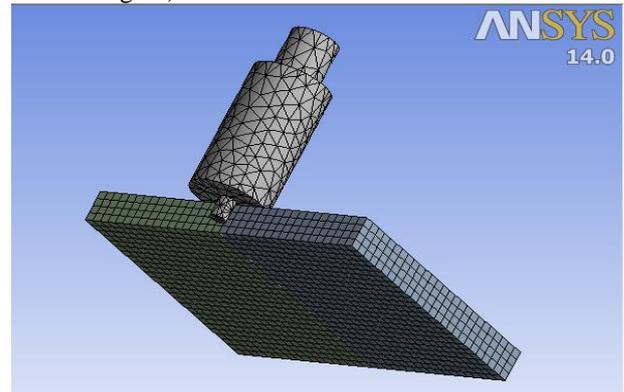


Fig. 18: Meshed model of friction stir welding mild steel tool and lead alloy plates

The boundary conditions were applied in accordance with the experimental situations of rotational speed of tool, clamping of plates, etc. The analysis showed that maximum stress developed in the joining edges of plates (shown in fig. 19) due to the rotation of tool which tries to separate the plates, for this reason the proper clamping force is required in order to fix the plates for smooth welding process.

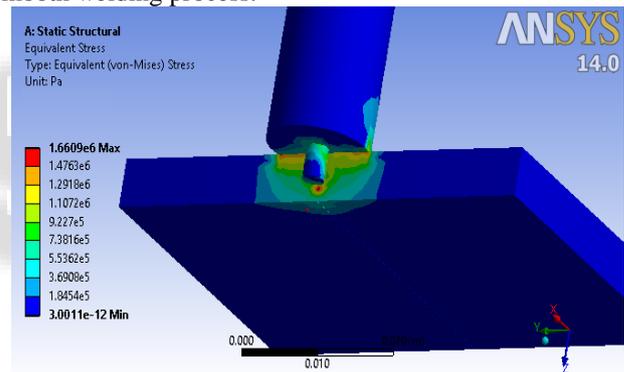


Fig. 19: Static structural analysis for stress distribution with maximum value at the joining edges of plates.

IV. CONCLUSIONS

After successful friction stir welding of lead plates by using hand drilling machine, it can be concluded that the low melting point metals can be successfully welded by using hand drilling machine at workshop level which is difficult to weld with Arc welding. Tensile strength of butt joint of lead plates increases with increase in weld speed in friction stir welding by using mild steel tool. Deflection, Stiffness and Resilience of butt joint of lead plates also increases with increase in weld speed in friction stir welding by using mild steel tool. There is successful joining of two metallic plates without any fumes, radiations, harmful gases, flames, etc.

REFERENCES

- [1] Mohd Anees Siddiqui, Temperature Distribution in Friction Stir Welding of Aluminium Alloy, ISBN 978-3-659-85807-9, LAP LAMBERT Academic Publishing, Germany.

- [2] Mohd Anees Siddiqui, S.A.H. Jafri, S. Alam, Study of Friction Stir Welding Technique as a Solid-State joining of Metallic Plates, World Scientific and Engineering Academy and Society Press ISSN: 2227-4588, pp. 215-218, January 2015.
- [3] Mohd Anees Siddiqui, S.A.H. Jafri, Shahnawaz Alam, Friction Stir Welding (FSW)-An Environment Friendly Joining Process, Abstract book, National Seminar on Industry University Partnership, AMTSG-2015, pp.24
- [4] Mohd Anees Siddiqui, S.A.H. Jafri, P.K. Bharti, Pramod Kumar, Friction Stir Welding as a Joining Process through Modified Conventional Milling Machine: A Review, International Journal of Innovative Research & Development, ISSN 2278-0211, Vol3 Issue7, Jul 2014.
- [5] M.A. Siddiqui, et. al, Friction Stir Welding Through Fabricated Setup By Using Conventional Hand Drilling Machine, Vol. 2- Issue 05, IJRDO- Journal Of Mechanical And Civil Engineering, ISSN-3855-0154, pp. 82-86, May-2015.
- [6] Mohd Anees Siddiqui, S.A.H. Jafri, S. Alam, Study of Simulated Temperature of Butt Joint during Friction Stir Welding of Aluminium Alloy by Using Hyperworks, International Journal of Engineering Research and Applications, ISSN: 2248-9622 Vol. 5 - Issue 1, pp.117-121, January - 2015.
- [7] Mohd Anees Siddiqui, S.A.H. Jafri, Shahnawaz Alam, Study of Static & Dynamic Simulation of Friction Stir Welding Process, Vol. 1 Issue 1, Journal of Advanced Research in Mechanical Engineering and Technology, pp. 37-43, February 2015.
- [8] Mohd Anees Siddiqui, S. A. H. Jafri, Shahnawaz Alam, Validation of Maximum Temperature during Friction Stir Welding of Butt Joint of Aluminium Alloy by using HyperWorks, Vol. 4 - Issue 04 (April - 2015), International Journal of Engineering Research & Technology, ISSN: 2278-0181, pp.817-821
- [9] Mohd Anees Siddiqui, S.A.H. Jafri, K.M.Moeed, S.Alam, Investigation of Effect of Process Parameters on Maximum Temperature During Friction Stir Welding of Aluminium Alloy, International Journal for Scientific Research & Development, ISSN 2321-0613, Vol. 3, Issue 10, Dec 2015.
- [10] Mohd Anees Siddiqui, S. A. H. Jafri, K. M. Moeed, Effect of process parameters on temperature distribution, strain rate and flow-stress during friction stir welding of aluminium alloy, International Journal of Mechanical Engineering Research, Forex Publications, Vol.4, Issue 01, March 2016.