Microstructural And Mechanical Properties Of Friction Stir Welded Aluminium Alloy

[1]Rohit Kumar*, [2]Ratnesh Kumar Raj Singh,[3]Dr. A K Bajpai

[1]M.Tech Student , Department of Mechanical Engineering , Madan Mohan Malaviya Engineering college, Gorakhpur , U.P, INDIA

[2]Research Scholar, Department of Applied Mechanics, IIT Delhi, New Delhi, India

[3]Professor, Department of Mechanical Engineering , Madan Mohan Malaviya Engineering college, Gorakhpur , U.P, INDIA

Abstract: *The aim of present study is to analyze the influence on the microstructure and mechanical properties of friction stir welded butt joint of 6061 aluminium alloy plates in 6 mm thickness. With this aim, welds are produced using EN 31 die steel tools, having cylindrical pin of 7 mm diameter and shoulder of 20 mm diameter. The microstructure of welds are studied by optical microscopy and grain size in different regions are analyzed. Vicker's microhardness test (as per ASTM E384-89) are done in transverse direction of weld to check the hardness distribution in weld nugget. Transverse tensile test (as per ASTM E8 M) are performed to evaluate the weakest portion of weld joints.*

Key words: Friction Stir Welding, Aluminium alloy, Hardness, Tensile testing

1. Introduction

Friction-stir welding (FSW) is an autogenous solid-state welding process in which the material being welded is not melted and recast as in case of conventional fusion welding processes but plastically deformed, extruded and forged to form weld joint at temperatures below melting point [1-2]. In FSW a rotating tool with a shoulder and a specially designed pin, moves along the faying surfaces of two rigidly clamped plates placed on a backing plate (Fig. 1). The localized heating produced by friction at the shoulder and to a lesser extent at the pin surface softens the material around the pin (Fig. 2). This plasticized soft material is transported from the front of the tool to the trailing edge due to tool rotation and translation where it is forged into a monolithic joint [3].

2. Experimental Setup

The dimension of aluminium plates are 200 mm length, 50 mm width and 6 mm thickness. EN31 tool having shoulder diameter of 20 mm and pin diameter of 7 mm is used. Details of Tool are given in Table 1. Four welding sets are taken as per full factorial design of 2 variables (Welding speed and Rotary Speed) and 2 levels for welding of aluminium plates as given in Table 2.

3. Welding

Prior to welding, joint preparation are used when needed by machining, grinding and cleaning (with acetone) of the surfaces to be weld. The plates were clamped tightly against each other by indigenously designed and fabricated fixtures and on the backing plate. The axial plunge depth was manually controlled by dial gauge indicator. tool tilt angle is kept constant and it is around 1.5^0. Initially trial welds are conducted with bead on plate configuration using different welding parameters to set a range of suitable welding parameters for our final welds.

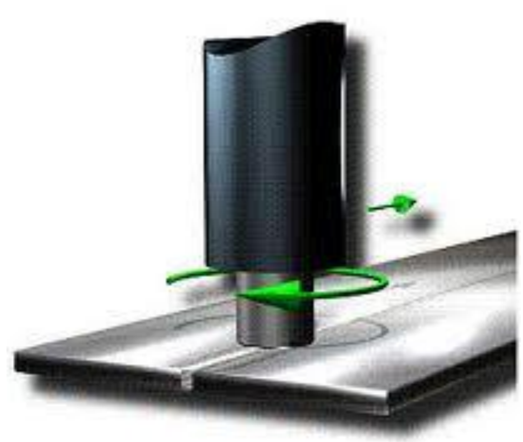


Fig. 1- Schematic diagram of friction stir welding [4]

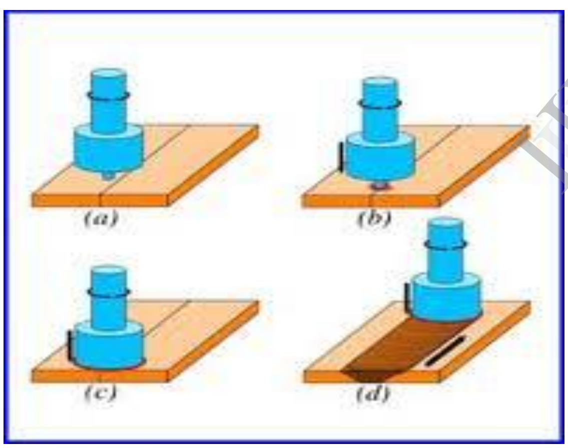


Fig. 2- Friction stir welding steps [5]

4. Sample preparation

The welded pieces are first cut in the transverse direction of weld in required dimensions. Sample for microstructural analysis are polished with different grades of waterproof SiC polishing paper ranging from grade 220 to grade 2000 and finally polished on soft cloth with alumina paste.

Table 1: Tool Dimension

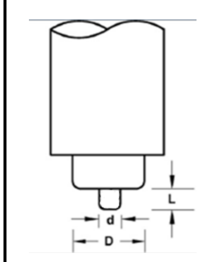
Tool Material- Tungsten Carbide	Tool Drawing
Shoulder diameter (D)- 20mm Pin diameter (d) - 7 mm Pin length (L)- 5.7 mm Axial Plunge of Shoulder- 0.2 mm	

Table 2: Welding Parameter

Weld	Rotation Speed (rpm)	Welding Speed (mm/min)
Weld 1	355	200
Weld 2	355	400
Weld 3	560	200
Weld 4	560	400

5. Optical Microscopy

Optical microscopy is performed using Leica microscope. Samples are first dipped in a polishing solution containing 10 ml NaOH in 90 ml water heated to 70 °C. Then the polished sample are washed in water and then etched with Keller's reagent containing 2.5 ml nitric acid, 1.5 ml HCl and 1 ml HF.

6. Hardness Measurements

Leica's Vicker's micro hardness tester is used to measure the micro hardness of welded samples. The hardness are measured along the transverse direction of the weld in centre of thickness. Indentation force used is 100 gmf and indentation time is 10 seconds, step size used is 1 mm (as per ASTM E384-89).

7. Tensile Tests

The transverse tensile tests of 6 mm thick Al FSW welds are performed using an MTS 810 testing machine according to the standard SFS-EN 895. The standard is for fusion welds, but it is applicable also for friction stir welds. Subsize transverse test specimens according to ASTM E8M-11 were used [6]. The strain rate is 1mm/min. Three samples are tested in each of weld and average is presented. Fig.1, shows the geometry and dimensions of the sub-size transverse tensile test specimens.

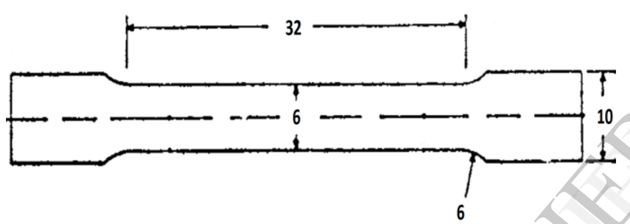


Fig.1 Sub-size transverse tensile test specimens.

8. Results and Discussion

8.1 Welds Obtained

Welds are obtained according to the experimental design. All welds are defect free. The intermixing of metals is also found in the welded samples. During the FSW process, the materials are transported from the retreating side to advancing side behind the pin where the welds are formed.

8.3 Hardness Measurements

Fig.3 shows the horizontal hardness profiles of the Al FSW welds. The hardness in weld nugget is more than the other regions in all the welds. Sample 2 shows the highest hardness values for the nugget zone, which was found to be around 127. Other samples have hardness values of around 85-120 in nugget zone.

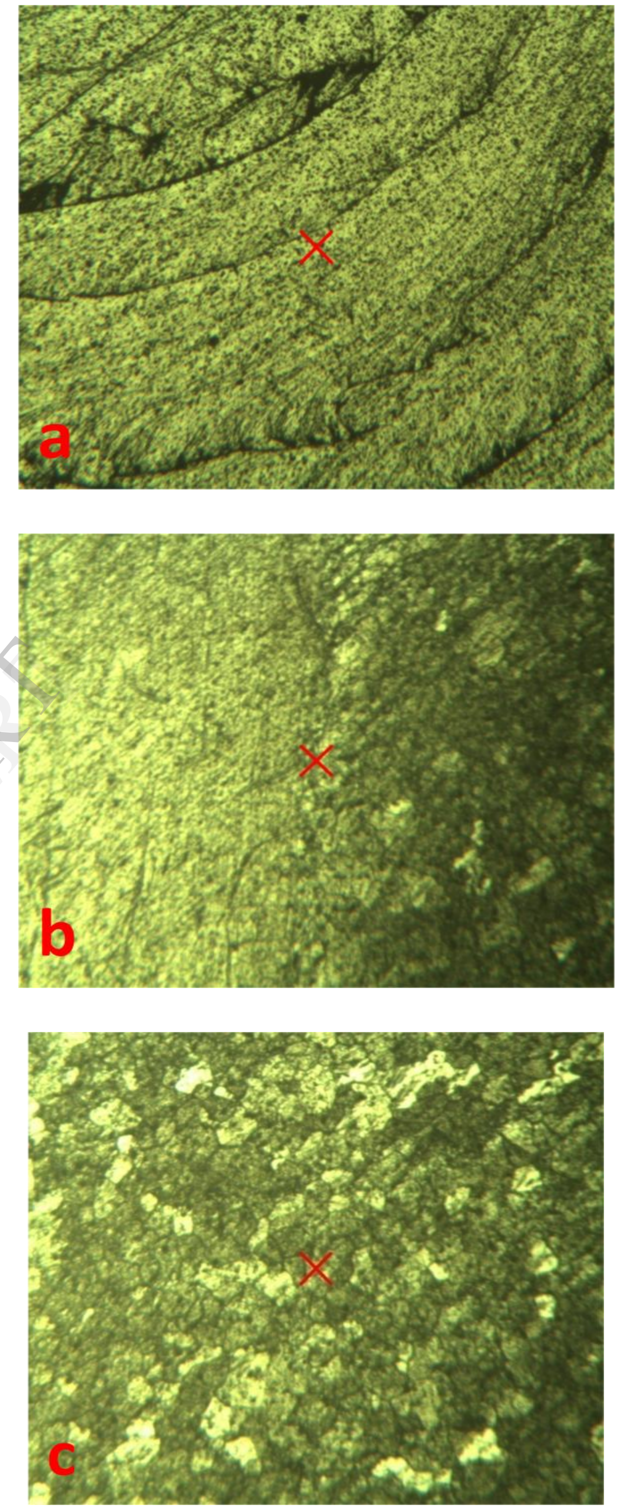


Fig.3 Microstructure of (a) NZ (b) Interface and (c) Base metal

8.2 Microstructural Characteristics

Microstructure of weld shows distingue feature in different zone (Fig. 3). Weld nugget have very fine grains (Fig. 3a) than the base metal (Fig. 3c). It also have very clear onion ring pattern. No distinguish TMAZ were found in both side of weld (Fig. 3b).

8.4 Tensile Test

Average tensile properties of friction stir weld joints of are given in Table 3. Sample 2 has the higher ultimate tensile strength of 256.3 MPa.

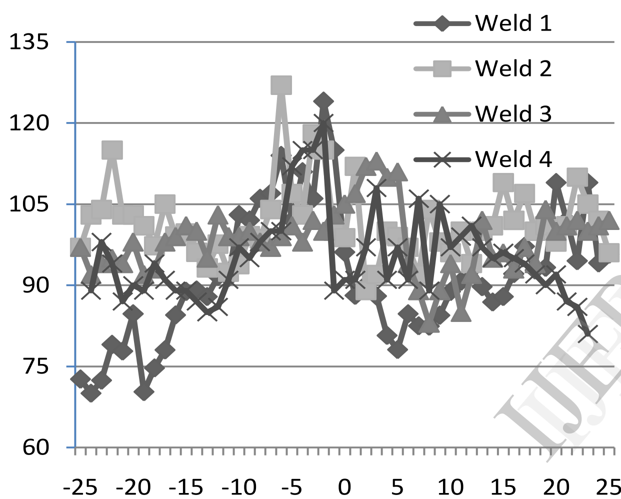


Fig.4 Hardness profiles horizontally along the centre line of the sample

9. Conclusions

All welds are defect free and no tool metal inclusions are seen by optical microscopy. Microstructures of weld are shown different regions, like Nugget Zone. Microhardness in weld nugget is higher than base metal and no significant difference found in other regions. Tensile strength of weld is poor as compare to both of the base metals and all welds were failing from the HAZ. Weld 2 (High Welding Speed and Low Rotary Speed) show the highest strength.

Table 3: Tensile test data

	Ultimate Tensile Strength (MPa)	Yield Strength (MPa)	Strain (%)
Base	**305**	**207**	**12.5**
Weld 1	**195.8**	**105.4**	**7.5**
Weld 2	**256.3**	**137.6**	**12.2**
Weld 3	**116.9**	**94.4**	**4.7**
Weld 4	**211.6**	**121.7**	**8.8**

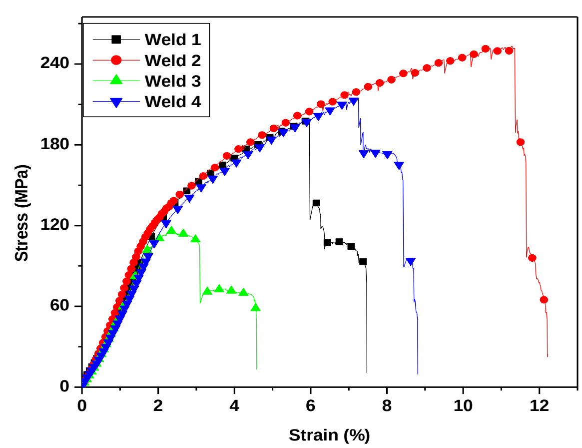


Fig.5 Engineering Stress-Strain diagram of different welds

References:

[1] Sun Y. F., and Fujii H., 2010, "Investigation of the welding parameter dependent microstructure and mechanical properties of friction stir welded pure copper," Materials Science and Engineering: A, **527**(26), pp. 6879-6886.

[2] Lee W.-bae, and Jung S.-boo, 2004, "The joint properties of copper by friction stir welding," Materials Letters, **58**, pp. 1041-1046.

[3] Amanciofilho S., Sheikhi S., Dossantos J., and Bolfarini C., 2008, "Preliminary study on the microstructure and mechanical properties of dissimilar friction stir welds in aircraft aluminium alloys 2024-T351 and 6056-T4," Journal of Materials Processing Technology, **206**(1-3), pp. 132-142.

[4] Kati Savolainen, 2012, "Friction Stir Welding of Copper and Microstructure and Properties of the Welds," DOCTORAL DISSERTATIONS.

[5] Kumar R., Singh K., and Pandey S., 2012, "Process forces and heat input as function of process parameters in AA5083 friction stir welds," Transactions of Nonferrous Metals Society of China, **22**(2), pp. 288-298.

[6] Mishra R. S., and Ma Z. Y., 2005, "Friction stir welding and processing," Materials Science and Engineering: R: Reports, **50**(1-2), pp. 1-78.