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Investigation of the Structure and Mechanical Properties of Friction Stir Welded Aluminum Alloy

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Abstract **- Friction stir welding is now extensively used in aluminum industries for Joining and Material processing applications. The Technology has gained increasing interest and importance. In the present paper, the Mechanical and Microstructural properties of AA 5083(AlMg4.5Mn0.7) butt joints produced by Friction Stir Welding have been investigated. Different welding trials with two rotating speed of the tool have been done. The Mechanical properties of the welded joints have been evaluated though micro hardness measurements (HV) and Mechanical Tests. Metallurgical characterization has been done by means of optical microscopy to investigate size, morphology and distribution evolution of the metallic matrix and precipitates present in this type of aluminum alloy. The change in microstructure across the welded joints was characterized by the presence of severely deformed grains in the region of the weld nugget.**

Keywords **: AA5083, Friction Stir welding, Structural properties, Mechanical testing, Tool Rotating speed**

I. Introduction

FSW is one of the method in which the heat formed due to friction and plastic deformation is used. The process has been invented and experimentally proven at "The Welding Institute" UK in December 1991[1]. FSW is a technique, which allows aluminum, lead, magnesium, titanium, steel & copper to be welded continuously with a non-consumable tool. A non-consumable rotating tool that stirs the material of welded parts shown in Figure 1, at temperatures well below their melting point produces the joint. Main advantage of FSW is the low welding temperature eliminating many problems of conventional welding processes. Due to the low temperature, materials such as Al-Cu-Mg alloys difficult to weld by fusion processes are easily welded by FSW [2].

A number of different process variables affect the quality of a joint produced by friction stir welding; tool design, tool rotation and travel speed, tool heel plunger depth and tilt angle, welding gap, thickness miss match and plate thickness variation [3]. Higher tool rotation rates generates higher temperature because of higher friction heating and result in more intense stirring and mixing of material.

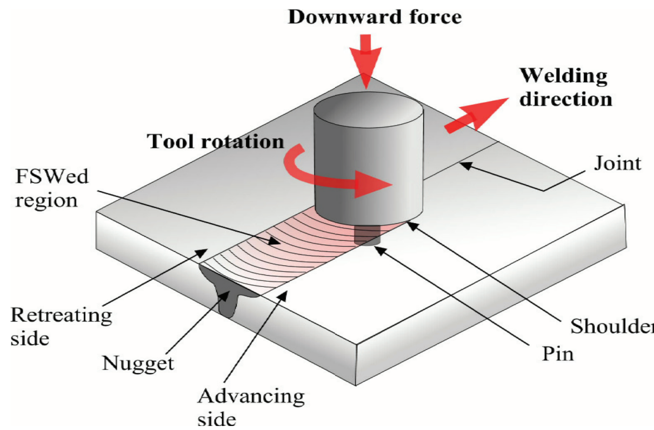

Fig.1 Friction stir welding process

The design of the tool is a critical factor as a good tool can improve both the quality of weld and the maximum possible welding speed [4]. It is desirable that the tool material is sufficiently strong, tough and hard at the welding temperature. Effect of welding speed on microstructure and mechanical properties of friction stir welded aluminum alloy was investigated by Sakthivel *et.al.* [5]. The influence of FSW parameters on the grain size of the stir zone and the formability of friction stir welded 5083 aluminum alloys was examined by Tomotake Hirata *et.al.*,[6]. The Aluminum plates were friction stir welded at various rotational speeds (850-1860rpm) and travel rates of 30 to160 mm/min with welding forces ranging from 2.5 to 10 MPa, using different diameters welding heads was investigated by Wang and Liv [8]. From these experiments it has found that dimensions of the welding head are critical to produce sound weld.

II. Experimental Procedure

A. Fabrication of FSW Tool

FEW tool made of High Speed steel having a pin profile of straight circular was used to weld the joints. Tool has a shoulder of diameter 14mm, a pin diameter of 4mm and a pin length of 4mm.

B.Friction Stir Welding of Aluminum Alloy

The aluminum alloy AA 5083 was selected for friction stir welding process. The chemical composition of Aluminum Alloy AA 5083 is as shown in Table I. Test plates of size 125mm*60mm*6mm were prepared from AA5083 alloy.

Table I Chemical Composition Of The 5083 Aluminum Alloy (In Wt %)

Composition of AA5083		
Mg	4.5	ISO AlMg4.5Mn0.7
Mn	0.7	
Fe	0.4	
Si	0.4	
Zn	0.25	
Cr	0.15	
Ti	0.15	
Cu	0.1	
Al	Rem	

The experimental set up consists of a Friction stir welding machine as shown in Figure 2. The plates are positioned in the fixture, by using mechanical clamps so that the plate will not be separated during welding. The machine can be operated over a wide range of tool rotational speeds, welding speeds & tool axial forces.

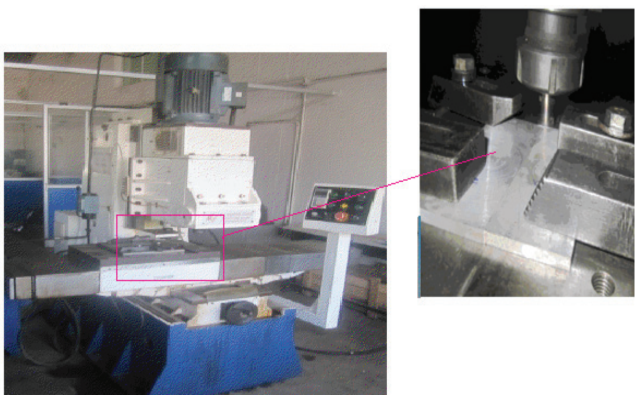

Fig.2 Friction stir welding machine

C. To Assess The Mechanical And Structural Properties of FSW Joints

Eight jobs were produced at two different speeds by using FSW tool. The welding parameters are presented in Table II. A sample of a friction stir welded plate is shown in Figure 3.

Fig.3 Friction stir welded joint

Table II Welding Parameters Of Fs Welding

Sl. No	Speed (RPM)	Load (Tons)	System Pressure (Kg/cm^2)
B1	650	2.45	30
B2	650	2.36	30
B3	650	2.4	30
B4	650	2.37	30
B5	750	2.26	30
B6	750	2.21	30
B7	750	2.19	30
B8	750	2.32	30

1. Tensile Test

The Tensile test specimens were prepared according to the ASTM E8 standard & the transverse tensile properties of the FS welded joints were evaluated using a computerized UTM (Universal Tensile Machine). For each speed welded joint, three tensile specimens were prepared & tested.

2.Structural Analysis

For Microstructural Studies, the samples were polished & etched with chemical solution(Keller's reagent) that contained 90ml distilled water, 5ml nitric acid, 3ml hydrochloric acid and 2ml hydrofluoric acid for about 80 seconds before being observed under the microscope. The micro structural details of the welded and HAZ were studied with the help of Optical Metallurgical microscope (model: NIKON Epiphot 200).

3.Micro Hardness

Micro hardness values along the cross sections (transverse to weld direction) of samples was measured by using Vickers micro hardness testing machine. Hardness measurements were taken at different points for an applied load 100gms using Vickers micro hardness testing method IS: 1501-2002.

III. Results And Discussion

A. Tensile Test

A typical three specimens from a job has been drawn to evaluate transverse tensile properties of the welded joint. The specimens prepared for tensile test are shown in Figure 4. The results obtained from those specimens are tabulated and presented in Table III.

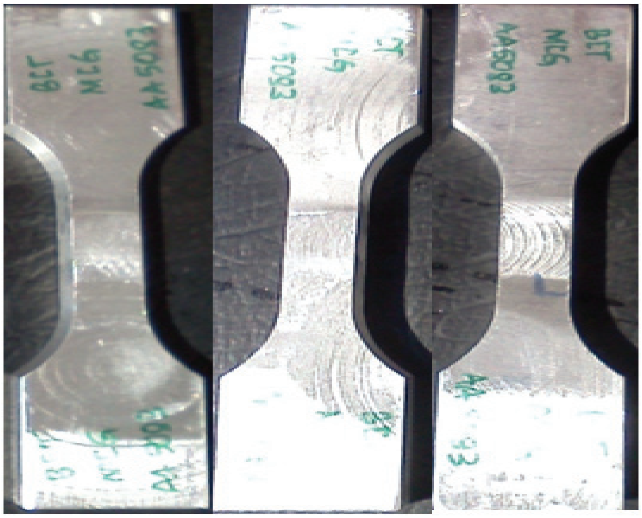

Fig.4.Specimen made for tensile test

Table III tensile Test Results of AA 5083

Specimen No.	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)
1	53.77	105.65
2	93.67	116.15
3	138.31	182.83

B. Microstructure for AA5083

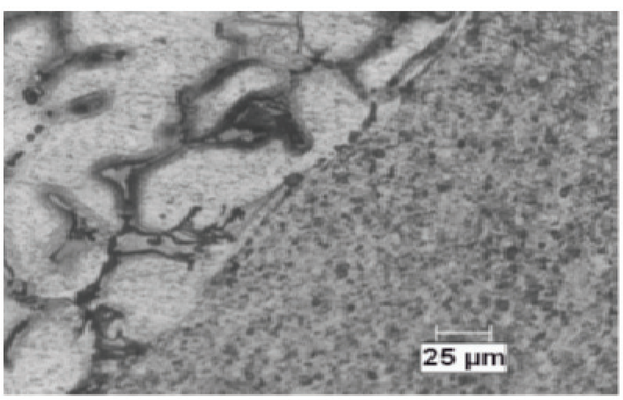

Fig.5 Microstructure of HAZ & Weld

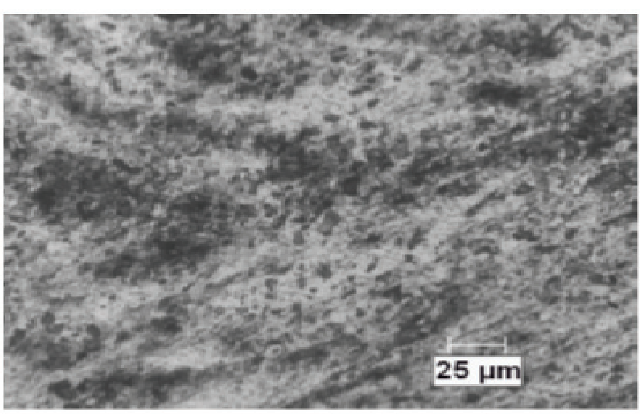

Fig.6 Microstructure of Welded part

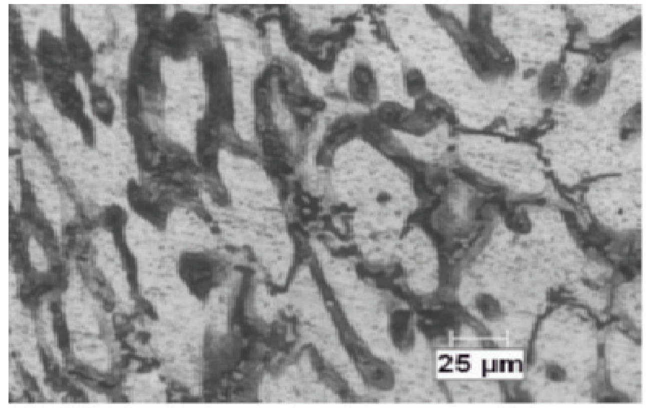

Fig.7 Microstructure of HAZ

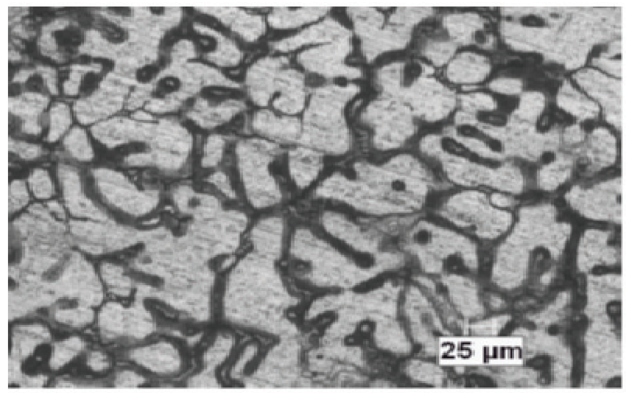

Fig.8 Microstructure of Base Metal

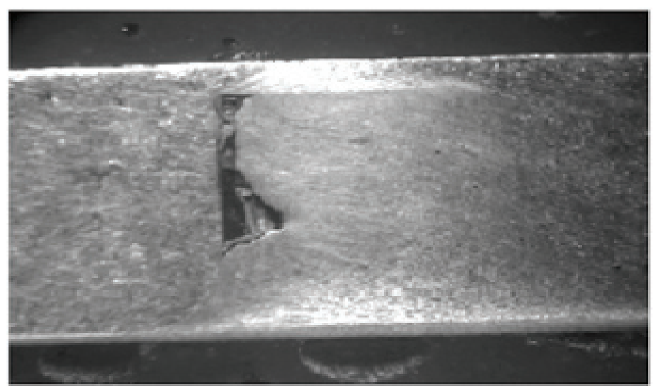

Fig.9 The macrostructure of the welded specimen

Figures (5), (6), (7) and (8) show the microstructure of the specimen with the positions of micro-structural zones. Figure (9) show the macrostructure of the specimen. Characteristic structural zones of FSW can be clearly identified from recorded images of microstructure and different zones. Those zones are: unaffected material or parent metal, heat affected zone - HAZ, thermo-mechanically affected zone - TMAZ, and so called “weld nugget” zone – NZ, which provide a clearer view of the observed structure of welded joints, as well as the grain size. Macrostructure consists of fine precipitates of alloying elements along the grain boundary in the matrix of aluminum solid solution, in the base metal and fine columnar grains at the weld zone.

C. Micro Hardness Tests

It is observed that the Hardness is minimum at the weld centre i.e. at the centre of the weld nugget. Markings are made at a distance of 10 mm from centre of the weld on either side. Hardness values are shown in table 4. The results of the Vickers micro hardness are presented in Figure 10.

Table IV Micro Hardness Measurement For Fsw Welded Specimen

Sl.No	Distance,mm	Hardness,HV0.05
1	-40	76.4
2	-30	73.6
3	-20	74.2
4	-10	71.2
5	0	69.4
6	10	76.4
7	20	73.6
8	30	74.2
9	40	71.2

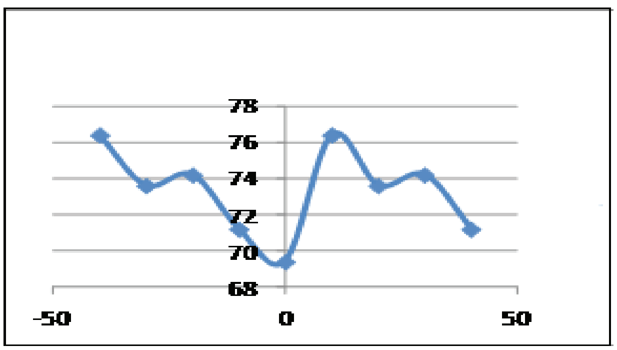

Fig.10 Micro hardness profile of AA 5083

IV. Conclusion

On the basis of the experimental characterization conducted on FS welded joints of AA 5083, the following Conclusions can be drawn:

- It was found that the weld imperfections significantly reduce the tensile strength and hardness of welded joints.
- Hardness was found to be lower in the weld region compared to TMAZ, HAZ & BM regions.
- Micro-Structure of the parent metal shows dendrites of aluminum solid solution and the grains are fined columnar at weld zone.

Acknowledgements

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