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Microstructure and Mechanical Properties of Friction Stir Welded AZ31B Magnesium Alloy

G. Surya Prakash Rao[1], Dr. B. Balu Naik[2]
[1]PhD Scholar, JNTUH College of Engineering, Hyderabad, Telangana.spkash.sbit@gmail.com . 9032077221
[2]Professor, JNTUH College of Engineering, Hyderabad, Telangana

Abstract: **The AZ31B magnesium alloy sheet was welded with friction stir welding (FSW). Friction stir welding (FSW) is carried out at different rotational speeds of 1200 rpm, 1600 rpm. The microstructures and mechanical properties of the welded joint were investigated. The microstructural change in AZ31B magnesium (Mg) alloy after friction stir welding (FSW) was examined. Fractography of tensile fractured surface was studied by SEM. It is observed in this study, the effect of rotational speed on microstructure and mechanical properties of the joint fabricated using H13 tool material at a rotational speed of 1600 rpm obtained higher mechanical properties as compared to those of 1200 rpm.**

Keywords: **Friction Stir Welding, AZ31 Magnesium Alloy, Microstructures and Factography.**

1. INTRODUCTION

Magnesium and its alloys are highly superior to their specific strength resistance to stress corrosion light weight and recyclability made suitable for automobiles, aviation and railways.

Friction Stir Welding was invented at The Welding Institute (TWI) of United Kingdom in 1991 as a solid state joining technique and was initially applied to aluminium alloys (1,2).

The basic concept of FSW is a simple technique. A non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of plates, to be joined and then traversed along the line of joint when the shoulder touches the plates (fig 1).

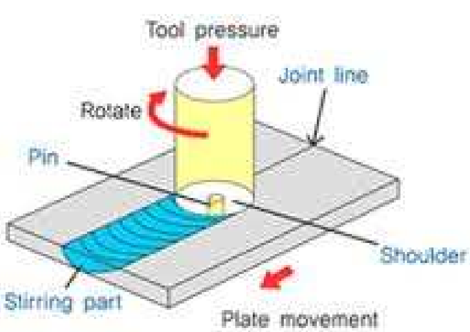

Fig 1: Friction Stir Welding Process

The rotating tool heats the work pieces and moves the material to produce joint. The heating is achieved by friction between the tool and work pieces and by the plastic deformation of the material. Localized heating soften the material around the pin and the combination of the tool rotation and translation results in the movement of the material from the front to the back of the pin. Thus, a welded joint is produced in solid state.

The FSW process is considered to be the most significant development in metal joining in the past decades and is a “green” technique, due to its energy efficiency, environment friendliness and versatility (3). In particular, it can be used to join high strength automotive and aerospace magnesium alloys and other metallic alloys that are hard to weld with conventional fusion welding techniques.

FSW has been introduced into number of commercial welding applications include aluminium, copper (4), steel (5), titanium (6) alloys and dissimilarmetal (7, 8) group welding. Friction Stir Welding is applied in welding magnesium alloys in a solid state process and the travelling speed is fast. Through FSW sound AZ31 friction welded joints will be obtained which shows superior mechanical properties and more attractive microstructures.

In Armco iron and magnesium alloy grain refinement phenomena were found by the torsion straining and Ecap process (9-11). The mechanical properties were affected by the microstructural changes that are mainlyby grain refinement.

The aim of the study is to find grain refinement mechanism of AZ31B magnesium alloy and its mechanical properties by the friction stir welding.

2. EXPERIMENTAL PROCEDURE

In this study AZ31B magnesium alloy is the main base metal used to weld. The thickness of base metal is 4.3mm. The chemical composition of base metal are listed in table-1. The welding tool diameter of the shoulder is 20mm, length of pin is 3mm and diameter of the conical probe is 3mm. The tool axis was tilted by 1degrees with respect to the vertical axis. Welding parameters like rotational speed, feed of tool, and

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mechanical properties of the welded joints were investigated given in Table-2. Torched type thermocouple were utilized to measure temperature at Stir Zone (SZ), Thermal Heat Affected Zone (THAZ), Heat Affected Zone (HAZ) and base metal of AZ31 joint.

Four samples obtained from various rotational speeds and feeds were cut by using milling machine after the welding process. Using an Optical Microscope (OM), microstructures of the cross sectional area of welded joints were observed.

Table 1: Base material AZ31 Chemical Composition

Element	Zn	Mn	Si	Fe	Cu	Ni	Mg
Percentage	0.72	0.30	0.08	0.005	0.05	0.005	Reminder

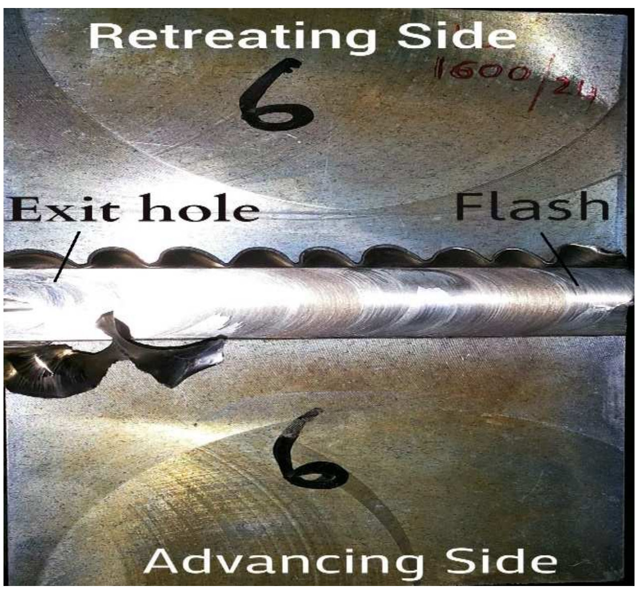


Fig 2: FSW Joint of AZ31B Mg alloy

Table 2: Mechanical Properties of FSW joint at Normal Atmospheric Temperature Around (35°-40°C)

	Speed (RPM)	Feed (mm/min)	Tensile Strength (MPA)	Percentage of Elongation (%)	Bend Test Failed at	Hardness HBW	Impact strength J
1	1600	28	76	0.42	90°	57	3
2	1200	24	120	1.06	Do	57	4
3	1600	24	148	1.96	Do	95	4.5
4	1200	28	148	1.18	Do	63	4.5

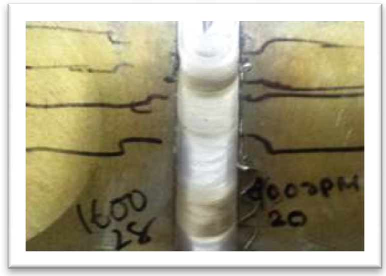


Fig 3: (a) Friction Stir Welded Piece

Fig 3: (b) Mechanical test piece for UTM
Fig 3: (C) Mechanical test piece after UTM

3. RESULT AND DISCUSSION

The macrostructure AZ31 joint shows different zones.

Fig 4: Macroscopic images of the welded joint showing the evolution of FSW zones.

Among the four runs, rotational speed of 1600rpm and feed rate of 24mm/min obtained high mechanical properties such as tensile strength, percentage of elongation, hardness and impact strength.

The frictional heat and deformation due to rotation of the tool and feed leads to the formation of Weld Stir Zone (WSZ), Thermo Mechanically Affected Zone (TMAZ) and Heat Affected Zone (HAZ). The Stir Zone had dimensions which closely matched with shoulder and pin of the tool used. The top surface receives high heat and rejects less heat than bottom surface of the plates.

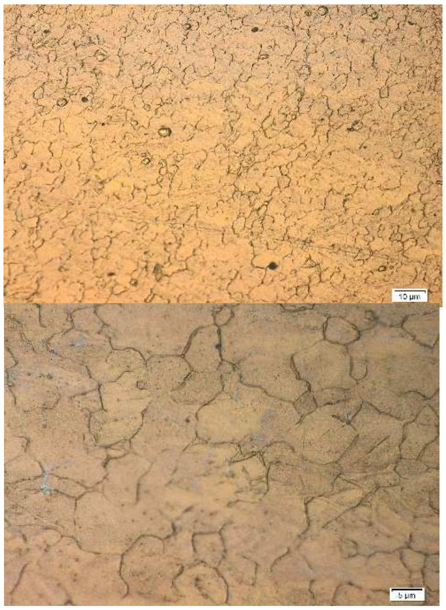
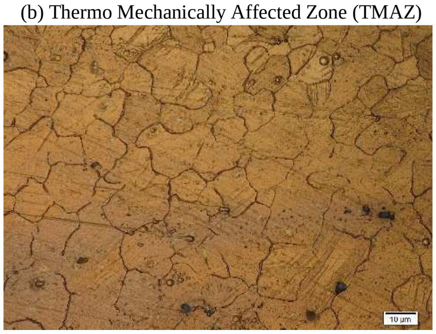


Fig 5: Optical Microscopic image of (a) Stir Zone (SZ) ; (b) Thermo Mechanically Affected Zone (TMAZ)



(c) Heat Affected Zone (HAZ) (1600rpm/ 24 mm/min)

a) Stir Zone: The elongated grains in the base metal have become equiaxed and recrystallized in the Stir Zone. The evaluation of recrystallized grain structure in the StirZone is due to severe plastic deformation and frictional heat is introduced by the rotating tool pin and its shoulder in the Stir Zone during the welding (12-14).

b) TMAZ: Large grains are surrounded by small grains which showed mesh structure. The grains in TMAZ has also become equiaxed and recrystallized which different from some magnesium alloys (12)

c) HAZ: The heat affected zone is adjacent to TMAZ and outside the tool shoulder. In HAZ material is affected by heat generated due to friction between material and tool

d) Base metal: In base metal grains are elongated and varying size which are randomly distributed

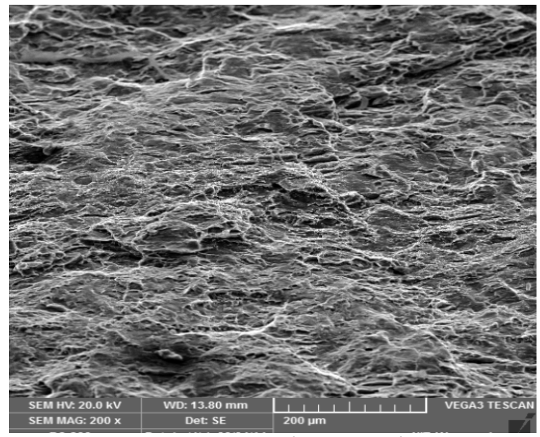


Fig 6: (a) showing typical SEM fractograph of Base metal

The base metal exhibits mainly features of elongated dimples together with some tear ridges, as shown in Fig. 6a. Presence of dimples are an indication of locally ductile fracture (15). Both dimple-like characteristics (Fig. 6 b) and cleavage-like features (Fig. 6 c) can be seen in different areas on the fracture surfaces after FSW

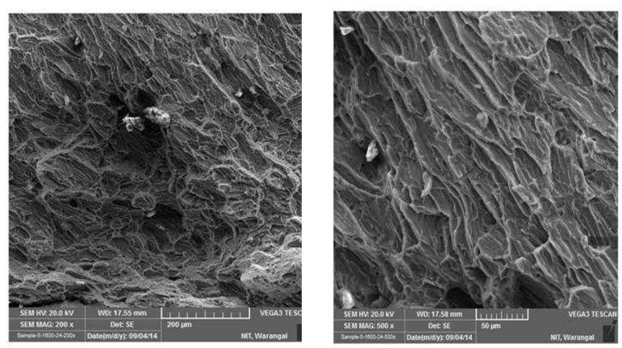


Fig 6: (b) & (c) SEM fractographs of tensile tested FSW joint (1600rpm/24 mm/min)

4. CONCLUSION

AZ31B Mg alloy is readily weldable by FSW process. Mechanical properties of AZ31B Mg alloy after friction stir welding at rotational speed and feed of 1600/24 mm/min, tensile strength, percentage of elongation, hardness and impact strength is high compared to other speed and feed.

Microstructural examination of 1600/24 mm/min after FSW revealed that the grain in the Stir Zone (SZ) and Thermo Mechanically Affected Zone (TMAZ) exhibits recrystallization and grain growth. The grain shape has become equiaxed. Smaller grain sizes were observed in the Stir Zone at a higher welding speed and lower feed.

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