Evolution of Microstructural and Microhardness Properties of Az31b Magnesium Alloy by FSW-An Experimental Approach

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Abstract — The effect of friction stir welding (FSW), the microstructure, microhardness and mechanical properties of a magnesium alloy AZ31B has been going to analyse. A simple friction stir tool, a specially designed fixture and to perform single-pass friction stir processing experiments on Mg AZ31B alloy. The AZ31B Magnesium alloy, which is lightest structural material having good properties like density, high specific strength, nice recovery, zero pollutions & rich resource. They are widely used in aerospace automobile & Marine industries for the core applications in their fields. This study analyzes the micro hardness, microstructure changes by friction stir processing on the Mg AZ31B alloy at different speeds and different feed rates are used for this experiments. The effects of stirring parameters such as the translational feed, rotational speed, cooling conditions are studied. The resulting microstructure and microhardness from these processes hold a key to the mechanical properties of the alloy. This analysis would help to understand and evaluate the specific aspects of grain size and microhardness that influence the fatigue life of a component.

Index Terms — Friction Stir Welding, AZ31B magnesium alloy, Microstructure, Microhardness, Mechanical properties.

I. INTRODUCTION

FSW expands the innovation of friction stir welding (FSW) developed by The Welding Institute (TWI) of United Kingdom in 1991 to develop local and surface properties at selected locations. FSP is a new and unique thermomechanical processing technique that technique that can be used to produce fine and homogeneous grain structure in thin plates and alters the microstructural and mechanical properties of the material in a multi pass to achieve maximum performance with low production cost in less time. FSW is reported to have enhanced the superplasticity of light-weight materials by producing an equiaxed ultrafine grain structure; thereby enhancing some mechanical properties of the lightweight alloys.

In FSW process, a specially-designed simple tool, which consists of a pin and a shoulder, is used. The tool is held into the spindle of the milling machine and is made to rotate. The rotating pin is first inserted into the material to be processed with a proper tool tilt angle and then move along the designed paths. The pin produces frictional and plastic deformation heating within the processing zone. As the tool pin moves, materials are forced to flow around the pin. Material flows to the back of the pin, where it is extruded and forged behind the tool, consolidated and cooled under hydrostatic pressure conditions.

In the present work an attempt was made on AZ31B magnesium alloy using friction stir processing. Response Surface Methodology (RSM) was used to find the process. The schematic views for FSP are shown in Figure .1

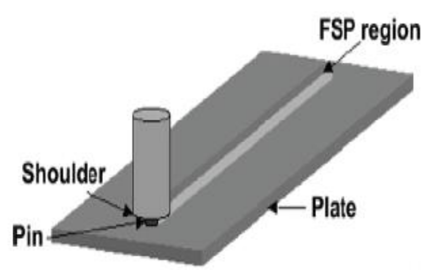

Fig-1 Friction Stir Process

Light weight metallic alloys are the primary concern of the present day automotive, aerospace and electronic industries. The magnesium alloys satisfy the above desire of the industries by its low density and high specific strength. However, the formability and the tribological properties of magnesium alloys are not commendable. To overcome these limitations many researchers attempted to modify the surface of the bare magnesium alloys with several coating techniques like electrochemical plating, conversion coating, plasma coating and anodizing. Recently some researchers have identified friction stir processing (FSP) as a unique surface modification technique.

II. EXPERIMENTAL PROCEDURE

As-received commercial AZ31B magnesium-alloy plate (hot-rolled and soft-annealed) is used in this study, has the nominal chemical composition in weight percent are given in table.1.

Table.1. Chemical Composition of Alloy Plate

Aluminium [Al]	Zinc [Zn]	Manganese [Mn]	Magnesium [Mg]
3.16%	3.11%	0.36%	95.20%

The specimen size of AZ31B alloy was 50x100x6 mm. CNC vertical milling center was used to perform the FSP on the plates. Tool wear is the important considerations in the selection of tool material .The tool profile nomenclatures are listed below the tabulation in Table.2. A shoulder tool of 25mm shoulder diameter and 6mm pin diameter with strait flutes was used. The tool material was HSS (M2) Material and toll weight is 300gm is shown in Fig.2. The AZ31B magnesium plates were clamped on the machine table using a fixture. After activation of preset program in the CNC machining center, the tool performed the FSP on the specimens AZ31B magnesium plate. A constant tool depth of 5.7mm was maintained throughout the process. The tool rotational speed and tool travel speed values used are given in the Table.3, by using Response Surface Methodology.

Table.2.Tool Profile Nomenclatures

Workpiece Material	Tool Material	Tool Shape & size	Operating Parameters
AZ31B Mg alloy, 6 mm	HSS [M2],	SD:25mm SCT PL:5.7mm	1200 rpm 30 mm/min
		PD:6mm	

*SD; Shoulder Diameter; SCT: Straight Circular
PL: Pin Length; PD: Pin Diameter

Table.3.Experimental Design

Exp No.	Tool Rotational Speed [RPM]	Tool Travel Speed [mm/min]
01	900	30
02	1000	30
03	1100	30
04	1200	30

Fig-2 HCS Tool Profile

"HSS" is the standard material used for all ICS HSS cutting tools. M2 has good red-hardness and retains its cutting edge longer than other general purpose high speed steels, not as shock resistant or as flexible as other HSS grade with less tungsten. Generally favoured for high production machine works. The chemical composition of FSP tool and mechanical properties of the base material are shown in Table.3 and Table.4.

Table.3. Chemical Composition of FSP Tool

Materials	Composition
Carbon	0.85%
Tungsten	6.00%
Molybdenum	5.00%
Chromium	4.00%
Vanadium	1.90%
Hardness	63-65

Table.4.Mechanical properties of base metal

S.No.	Properties	Values
01	Yield Strength	154.10

02	Ultimate Tensile Strength(Mpa)	250.56
03	Elongation (%)	15.33
04	Hardness	58

FSP has been utilized for LMW KODI 40 CNC Machining Center. Fig. 3 shows FSp setup. AZ31B Mg plates are located by a slotted base plate of fixture. It constrains the movement of Magnesium plates against the tool rotation and also provides accurate and unique position of the plates every time. AZ31B Mg plates should be fully constrained at all times to prevent any movement. Clamps provide locking forces to hold the magnesium plates in place, once they are located. A totally restrained magnesium plates are able to remain in static equilibrium to withstand all possible processing forces or disturbance.

Fig-3 FSW Setup

Trial experiments have been conducted to determine the working range of the parameters. Feasible limits of the parameters have been chosen. The four specimens have been fabricated as per the American Society for Testing of Materials ASTM E8M-04[9] standards to evaluate the tensile strength of the processed zone by using universal testing machine. The test specimen and fractured to Vicker’s microhardness testing machine was employed for measuring the hardness of the Processed region. And the processed AZ31b Magnesium Alloy plate is in Fig.4.

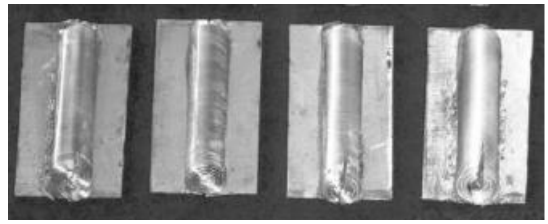

Fig-4 Processed Alloy Plates

III. RESULTS AND DISCUSSION

As received material (Fig. 5a) showed a classical cast structure with floating crystals, embedded in the eutectic phase, formed by the very fast cooling. Optical microscopy was performed on the transverse crosssections of the specimens. The FSP AZ31b magnesium alloy revealed the classical formation of the elliptical “onion” structure in the centre of the specimen. This is a structure characterized by reasonably fine and equiaxed recrystallized grains (Fig. 5b).

The measured size of the lamellar colony that existed in the fully stirred zone was ca. 2.0µm.The higher temperature and severe plastic deformation results in grains recrystallized with a strongly different structure respect to the as-cast as received material.

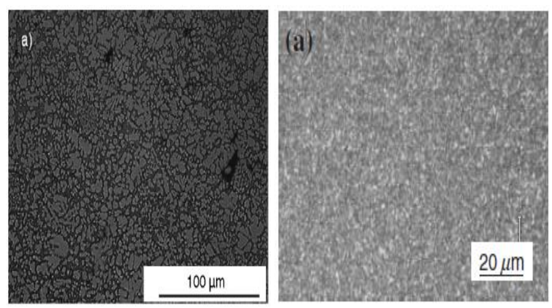

Fig -5 Microstructure behaviour due to FSP - (a)Parent Material ,(b)Stirred Recrystillized Zone

The FSP zone is free from typical defects such as tunnel, pin hole, piping and worm hole. The process parameters employed in this work are adequate to generate sufficient frictional heat to plasticize the AZ31b Magnesium Alloy and form a defect free FSP zone. The macrostructure consists of parent composite, heat affected zone, thermo mechanically affected zone and FSP zone. The FSP zone displays a homogeneous distribution of A31Zr particles. The morphology and distribution of particles are significantly changed subsequent to double pass FSP. The needle shape A31Zb particles are fragmented due to severe plastic flow during FSP and the stirring action of the rotating tool. The average size of A31Zb particles observed in the FSP zone is 500 nm. FSP induces high plastic strain which redistributes A31Zb particles. Inter granular distribution of Al3Zb particles is changed into intra granular distribution subsequent to FSP. The structural view of stired zone Fig.6.is shown below.

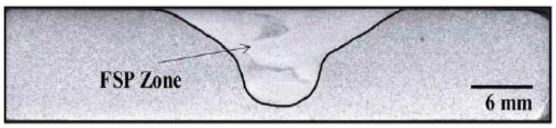

Fig-6 Structural View of Stireed Zone

The microhardness of as cast and friction stir processed AZ31b is shown in Fig. 7. It is evident from the figure that FSP significantly improved the microhardness of the cast alloy AZ31b. The average hardness of as cast and friction stir processed AMC are respectively 58 Hv and 70 Hv. The percentage improvement in hardness is 35. The improvement in microhardness after double pass FSP can be attributed to the increased dislocation density of the AZ31b as explained below.

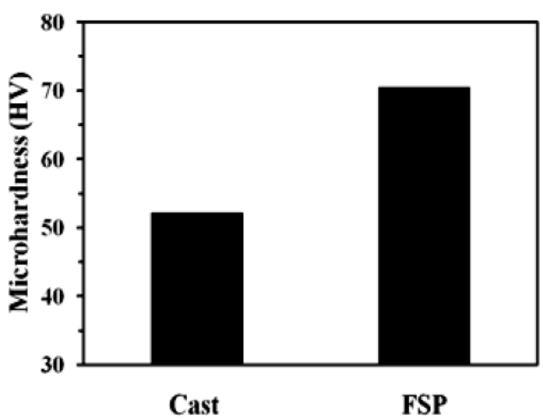

Fig-7 Microhardness of Stirred Zone

The grain boundaries are a source of dislocations in a polycrystalline material. As the grain size is refined during the first FSP pass, higher grain boundary area is available during the second pass. Therefore, the total number of dislocation sources available during the second pass only is much greater.

Exp No.	Tool Rotational Speed [RPM]	Tool Travel Speed [mm/min]	Hardness [HV]
01	900	30	61
02	1000	30	64
03	1100	30	68
04	1200	30	70

CONCLUSION

Microstructure, hardness and chemical composition were examined in an FSP AZ31B Mg alloy. The resulting microstructure and micro-hardness from these processes hold a key to the mechanical properties of the alloy. And compare those results with the unprocessed sheet. This analysis would help to understand and evaluate the specific aspects of grain size and micro-hardness that influence the fatigue life of a component.

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