Microstructure Analysis on Friction Stir Welding of Magnesium Alloys

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Abstract--- *Friction stir welding is an eco-friendly solid state welding technique employed particularly for joining the magnesium alloys since is a light weight metal which is difficult to join by conventional process. During the friction stir welding process the influence of tool rotational speed on the magnesium alloy are carried out at different speeds. Further microstructure analysis is performed on the welded joint, from this we find microstructure evolution, weld defects and properties of weld tool.*

Keywords--- *Friction Stir Welding, SS Tool, HSS Tool, Magnesium Alloy (AZ31B).*

I. INTRODUCTION

The use magnesium alloys has been increasing in day to day life in all the manufacturing industries like automotives, aerospace, shipbuilding industries etc. This is due to the lighter weight of magnesium alloys, when compared to other metal alloys it is 1/3 lighter than aluminum,3/4 lighter than zinc, 4/5 lighter than steel. Magnesium also has the highest strength-weight ratio of any of commonly used metals. More over magnesium has many advantages like good castability, recyclability, high die-casting rates, electromagnetic interface shielding properties, dimensional accuracy and excellent machinability which promote its utilization in manufacturing industries.

Conventional welding process for joining the magnesium alloys produces the defects like porosityand hot cracks which leads to the changes in mechanical properties. So to avoid such defects we have chosen friction stir welding. Friction stir welding is capable of joining the lightweightAZ31magnesium alloy without melting and it can eliminate the problems due to the solidification.

Friction stir welding does not require any filler materials like other welding process, metallurgical problems associated with it can also be eliminated, by this we can obtain the good quality of weld to the workpiece.

Further the influence of different ratios of different rotational speed on mechanical properties of different zones of friction stir welded AZ31 magnesium alloy was studied by performing the microstructure tests.

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II. LITERATURE SURVEY

S.NO	PAPER NAME/ AUTHOR NAME/YEAR	TOOL MATERIAL	MAJOR FINDING	JOURNAL PUBLISHER
1	Review on friction stir welding of magnesium alloys/ Kulwant Singh, Gurbhinder Singh, Harmeet Singh/ 2018	Tool steel, H13 tool steel, Mild Steel, Stainless Steel, High Carbon Steel, High Speed Steel, High carbon High chromium steel	In this paper the devolvement on FSW process and its factors are studied by examining various factors like microstructural evolution, residual stress, Hardness and the mechanical properties.	Elsevier B.V
2	Investigation of microstructure on friction stir welded AZ61 magnesium alloy joint/ Kulwant Singh, Gurbhinder Singh, Harmeet Singh/ 2018	H13 steel	Formation of finer grains during the FSW results in improving the hardness of the welded joint.	Elsevier B.V.
3	Friction stir welding of magnesium AM60 Alloy/ Naiyi Li, Tsung-Yu Pan/2014	H13 Tool steel	The investigation clearly states that FSW leads to increasing the welding strength & ductility while compare to other base materials.	Research gate
4	Paper on Friction stir welding of Magnesium Alloys-A Review/V. Prasanna/K. Sarath/2016	Tool steel, H13 tool steel,HSS,M35 HSS Tool, High Carbon High Chromium Steel,H13 Steel	Friction stir welding on various types of Magnesium Alloy grades has been studied, among various grades of Mg Alloy AZ31 grade has been used in major FSW process	IJIRST

III. EXPERIMENTAL WORK

Rolled plates of 5 mm thickness AZ31B magnesium alloy were cut to the required dimensions (240mmx60 mmx5mm) by wire cut Electric Discharge Machine. The schematic diagram of AZ31B Mg alloy plates used for FSW is shown in Fig.1.

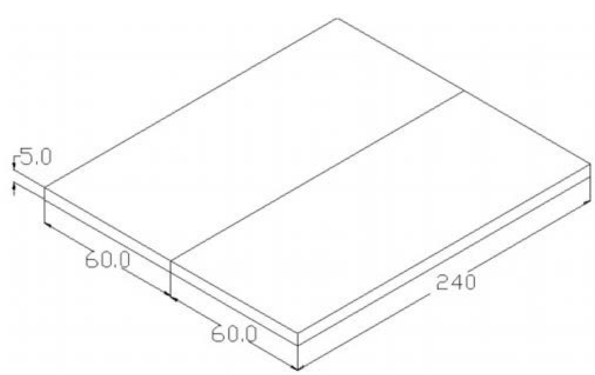

Figure 1: The Schematic Digarm of AZ31B Mg alloy Plates used for FSW

The initial joint configuration was obtained by securing the plates in position using mechanical clamps. The direction of welding is normal to the rolling direction and single pass FSW used to fabricate the joints. The diameter of the tool shoulder (D) is 18 mm and that of the insert pin diameter (d) and pin length (L) are 6 mm and 4.8 mm respectively. The schematic diagram of Tool geometry is shown in Fig.2.

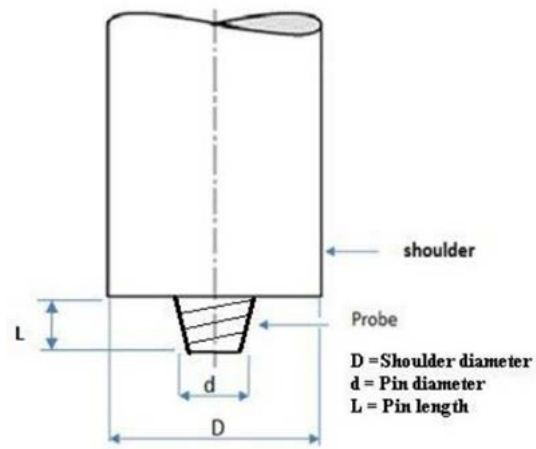

Figure 2: The Schematic Diagram of Tool Geometry

Table 2: FSW Process Parameters and Tool Nomenclature

Rotational speed(rpm)	900,1120,1400,1800
Welding speed(mm/min)	40
Pin length(mm)	4.8
Tool shoulder diameter(mm)	18
Axial force(KN)	5
Tilt angle	2.5^0
Pin diameter(mm)	6
Shoulder diameter(mm)	18
D/d Ratio of tool	3.0
Tool materials	Stainless Steel, High Speed Steel
Tool Profile	Taper with Threaded

The FSW parameters such as tool rotational speeds and travelling speed were 900 rpm, 1120 rpm, 1400rpm, and 1800 rpm with 40mm/min respectively. The tool onward tilted an angle of 2.50 and a vertical load of 5KN is applied. The FSW process parameters and tool nomenclature are presented in Table 2.The process is carried out on a vertical milling machine (VMM) (Make HMT FM-2, 10hp, 3000rpm). The macrographs of VMM and tool arbor are shown in Fig.3 and Fig.4 respectively. For various testing the required dimensions of the specimens were cut from the region under the tool shoulder (i.e. stir zone) by using wire EDM.

Figure 3: The Macrographs of Vertical Milling Machine

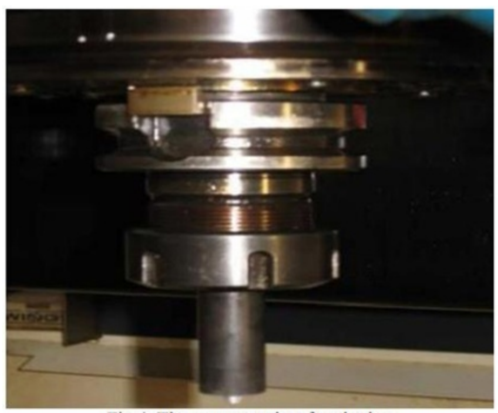

Figure 4: The Macrographs of Tool Arbor

The specimens for metallographic examination were sectioned to the required size and then polished using different grades of emery papers. A standard reagent made of 4.2 g picric acid, 10 ml acetic acid, 10 ml diluted water, and 70 ml ethanol was used to reveal the microstructure of the welded joints. Micro structural analysis was carried out using a light optical microscope (Maker: Metzer-M, Binocular Microscope; model: METZ-57) incorporated with an image analyzing at high magnification to estimate the weight percentage of elements.

IV. Results & Discussion

The optical micrographs taken at stir zone of FSW of all the joints are displayed in Fig.5 (A-I).From the micrographs, it is understood that there is in appreciable variation in average grain diameter of weld region in AZ31B Magnesium alloy. Due to FSW, the coarse grains of base metal are changed in to fine grains in the stir zone.

The joints fabricated with a rotational speed of 1120 rpm with a constant welding speed of 40 mm/min and SS tool contain finer grains in the weld region compared to other joints. This is one of the reasons for higher tensile properties of these joints compared to other joints. From the micrographs, it is inferred that there is an appreciable variation in grain size across the welds; this is because of in sufficient plastic flow and thermal exposure, It has been observed during this work that the total impact energy increased in the friction stir welding of (medium strength) AZ31B Mg alloy for both temper conditions especially at 1120 rpm and 40 mm/min with respect to the base metal while rotation and transverse speed have little effect on the impact value of (high strength) results were very close to each other. Finally it is important to mention that the relation between rotation speed, transverse speed and input heat which effect on the impact value seems to be compound and depend on the material properties being welded, Grains are relatively smaller in the retreading side of SZ compared to the advancing side, and this is caused by the greater straining in this location. The similar observation was made in friction stir welding of AZ31B Magnesium alloy. This may be another reason for failure along the SZ region on the advancing side.

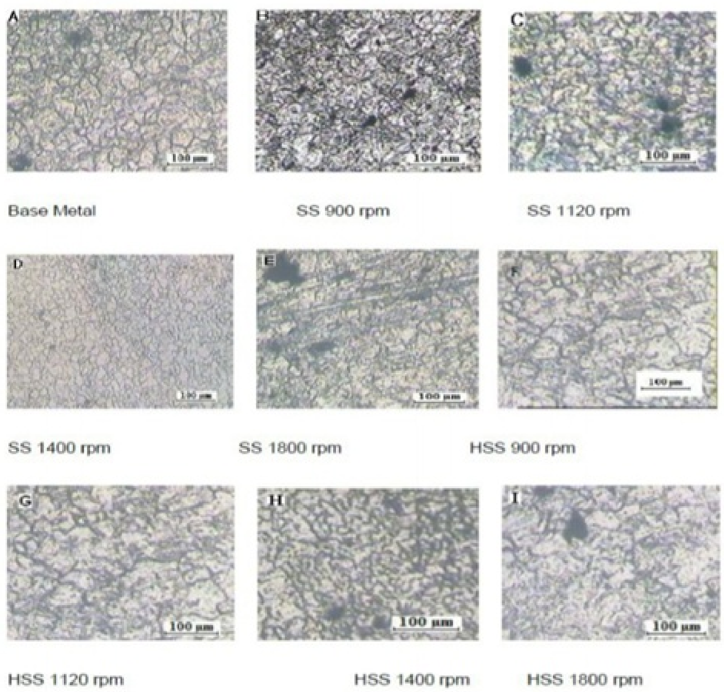

Fig.5: (A-1) Effect of tool material on stir zone Microstructure with SS tool & HSS tool

The heat input and material flow behavior decides the quality (defect free) of FSW joints. The heat input and material flow behavior are predominantly influenced by the FSW process parameters such as tool rotation speed, welding speed and axial force. The heat input increases with increase in rotation speed. At lower rotation speed, the heat input is not sufficient and also improper stirring causes a tunnel defect at the middle of the retreating side. Higher rotation speeds could raise the strain rate and turbulence (abnormal stirring) in the material flow caused a tunnel defect at the weld nugget. As the rotation speed increases, the strained region widens, and the location of the maximum strain finally moves to the retreating side from the advancing side of the joint. This implies that the fracture location of the joint is also affected by the rotation speed.

V. CONCLUSION

The tool material and rotational speed have been identified as the important parameters that affect the stir zone microstructure and properties of FSW process. The following conclusions can be obtained. SS tool material provided fine grained microstructures and better mechanical properties as compared to HSS.

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