Mechanical Properties of FSW Joints in Magnesium Alloy at Different Rotational Speeds

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Abstract: Magnesium (Mg) has become a focus in the transportation industry due to its potential in reducing fuel consumption and gas emissions while improving recyclability. Mg alloys are also known for their low neutron absorption, good resistant of carbon dioxide as well as thermal conductivity which makes them suitable for use in industrial equipment for nuclear energy. there has been an increasing interest in the research and development of Mg alloys. These are the lightest of all metallic structural materials and are approximately 33% lighter than aluminium (Al) and 75% lighter than ferrous (Fe) alloys and have excellent specific mechanical properties. In this work, FSW of AZ31B Alloy was examined at the various rotational speeds of 900 -1440 rpm, with fixed welding speed of 40mm/min and 2° tool tilt angle using an HSS tool. The mechanical properties were compared for the different rotational speeds. The quality of FSW joints is dependent on input value of heat and material flow rate, which are prejudiced by process parameters., higher rotation speeds may cause abnormal stirring, resulting in a tunnel defect at the weld nugget due to increased strain rate and turbulence.

1. Introduction

Friction stir welding is a revolutionary manufacturing method that presents many benefits than traditional welding methods[1,2]. These benefits which include great mechanical

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properties, low residual stresses, and defects [3]. The tool rotation and translation together which leads to material movement from forward-facing to the back pin, which can be quite complex due to various geometrical features of the tool [4]. The tool applies substantial forging force to consolidate the plasticized metal behind it [5]. Insufficient axial pressure during the welding process can cause flash formation when the material escapes from the weld cavity [6]. different types of joints can be done on FSW such as butt [7], lap [8] , T-butt [9] and fillet joints etc [10]. K. Kumar et al [11] studied two distinct modes of material flow in friction stir welding are referred to as pin and shoulder flow. The geometric of pin-driven flow which combined with the vertical measure of material due to shoulder interaction, results in the formation of onion rings. Ugendera et al. [12] concluded that rotational speed of 1120 rpm formed superior mechanical properties compared with other speeds. To establish optimal parameters for friction stir welding AZ31B magnesium alloy. The five different tool pin profiles with 3 different tool shoulder sizes to produce the joints. [13]. Dhanesh G. et.al [14] explained the tool profile and orientation heat on the material during welding at various speeds. Malarvizhi et al [15] focused tool shoulder diameter, which is a key source of heat generation during the welding process of dissimilar AA6061 and AZ31-mg. the shoulder diameter of 21 mm which had been almost 4 times the thickness of sheet. B.Mansoor et al [16] analysed tool rotation speed /welding speed between Al and Mg alloys. The intermetallic phases that formed in the stirred zone and evaluated their influence on the microhardness and overall mechanical properties of the weld. The welding process can cause liquation, resulting in the formation of intermetallics at the joint interface [17]. Kulwant Singh et.al [18] provides a general overview of the basic principle of friction stir welding, along with a description of various aspects related to the welding of magnesium alloys. In this work , we analysed the FSW welding joint for AZ31B Alloy at Different Rotational Speeds along with mechanical testing

2. Materials and methodology

AZ31B is a type of magnesium alloy known for its excellent strength and ductility at room temperature. It also boasts impressive corrosion resistance and weldability, making it a popular choice in various applications. For instance, AZ31B is commonly used in the production of airplane fuselages, laptop and cell phone cases, speaker cones, and concrete tools. Moreover, the alloy can be subjected to super forming techniques at high temperatures to create intricate components for the automotive industry [19-23].For this study, we have selected AZ31B as our base metal. This type of metal belongs to the family of wrought magnesium alloys and has a general chemical composition that is presented in Table 1.

Table.1 Chemical composition % of the base metal (AZ31B)

Metal	Al	Zn	Si	Cu	Fe	Mn	Mg
Chemical composition	3.5	1	0.1	0.05	0.005	1	balanced

we examined rolled plates made of MgAZ31B alloy, with a thickness of 6mm. A square butt joint measuring 150mm x 60mm x 6mm was fabricated for the investigation. This joint was produced using the FSW welding technique.The setup of the machine for FSW process as shown in Fig.1

Fig.1 FSW Vertical milling machine

3. Materials testing

Tensile strength

To prepare the specimens for tensile testing, we cut the welded joints using milling cutters and machined them to the required dimensions [24-27] . The transverse tensile testing specimens were then fabricated following the ASTM E8/E8M11 standards, as shown in Fig.2.[28,29]

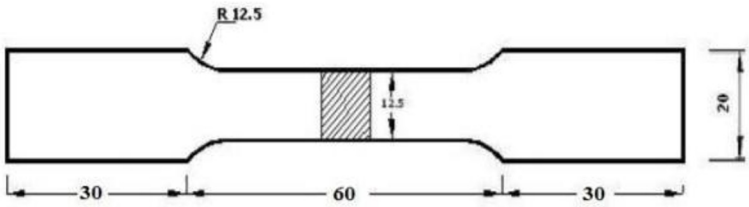

Fig.2 ASTM E8 Tensile Specimen

Micro hardness

We determined the hardness of the welded joint by measuring it with a Vickers hardness machine using a load of 100g at 20 seconds time[30,31]. The micro hardness was evaluated depends upon cross-section of the welded joint and the stir zone .

4. Result& discussion

Tensile properties

We evaluated several tensile properties of the fabricated welding, including tensile strength, micro hardness, density, % of elongation, and heat input. We prepared the tensile specimens according to the ASTM E8/E8M11 standards and conducted the tensile testing using a digital tensometer with a load capacity of 60KN. the result of the tensil as shown in the Table.2

The micro hardness of fabricated welded joint done at stir zone of welded joint, the micro hardness of metal is tested on the Vickers hardness tester and result of the hardness of welded as shown in the Table.2. We conducted the hardness test with a load of 100 grams and calculated the heat input.

Table.2 Observations for mechanical properties

Rotational speed (rpm)	Ultimate tensile strength (Mpa	Hardness(Hv)	%Elongation	Density (g/cm3)	Heat input Kj
900	106.85	87.57	8.1	1.87	0.38
1120	135.55	92.21	11.1	1.81	0.85
1440	134.9	96.53	11.43	1.82	0.91
Base metal	215	70		1.77	

It is perceived that the welded joint with a rotational speed of 1120 rpm and a welding speed of 40mm/min had high tensile strength and a better percentage of elongation. This joint also had moderate heat input and hardness. As a result, we conclude that the welded joint with a rotational speed of 1120 rpm is preferred for achieving high tensile properties in Fig.3. the highest elongation (11.43%) is observed at 1440 rpm in Fig.4.We also measured the density of the stir zone in the welded joint. The density of the base metal was determined to be 1.77g/cm3. We found that the welded joint with a rotational speed of 900rpm had a higher density of 1.87 g/cm3 which shown in Fig.5. the hardness value also increased at 1440 rpm which possess 96.53Hv illustrate in Fig.6.

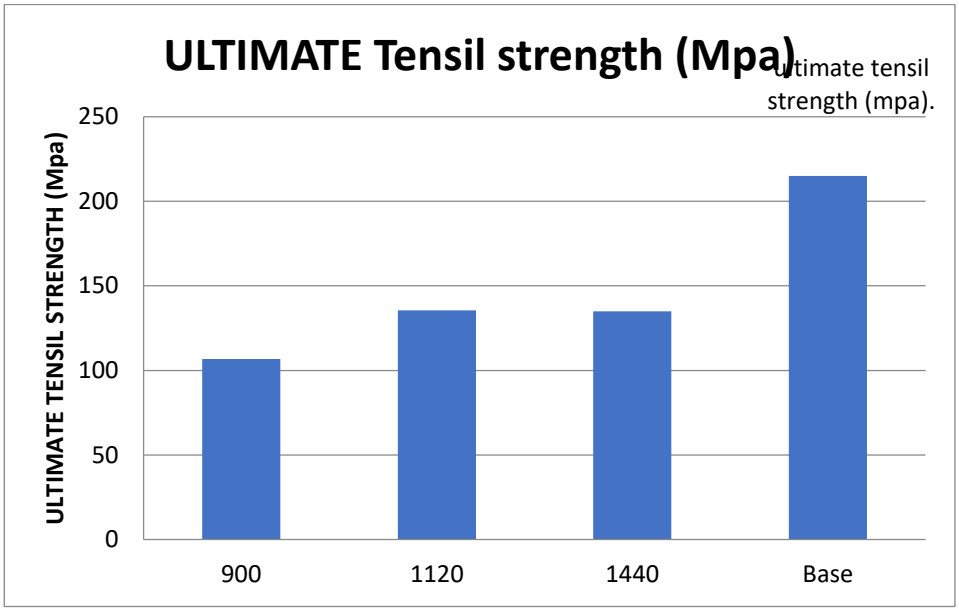

Fig.3 Tool Rotational speed vs Ultimate tensile strength

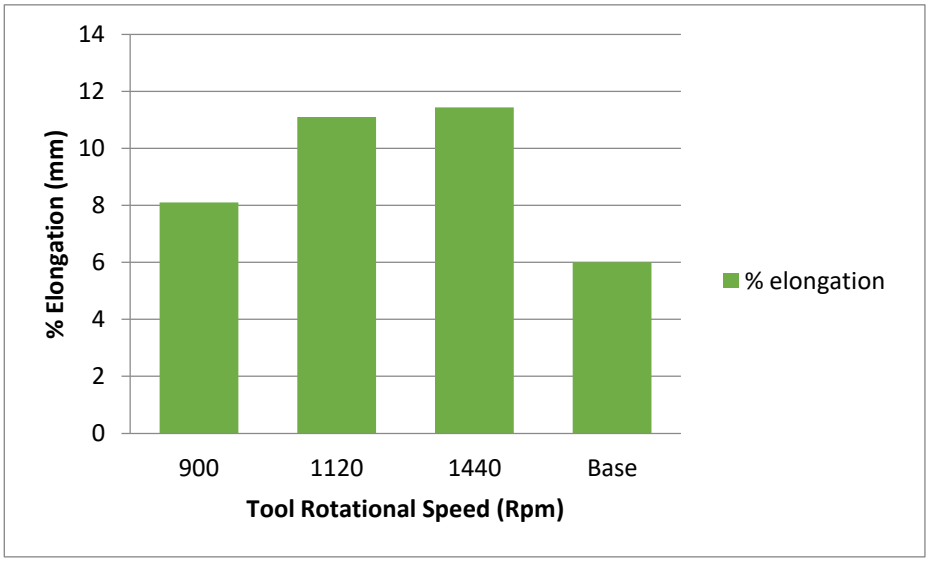

Fig.4 Tool Rotational speed vs % elongation

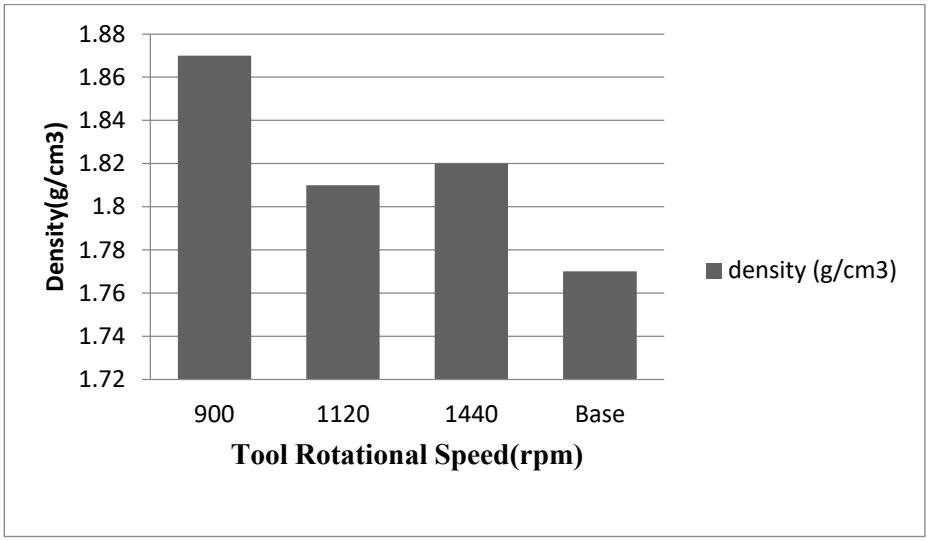

Fig.5 Tool Rotational speed vs Density

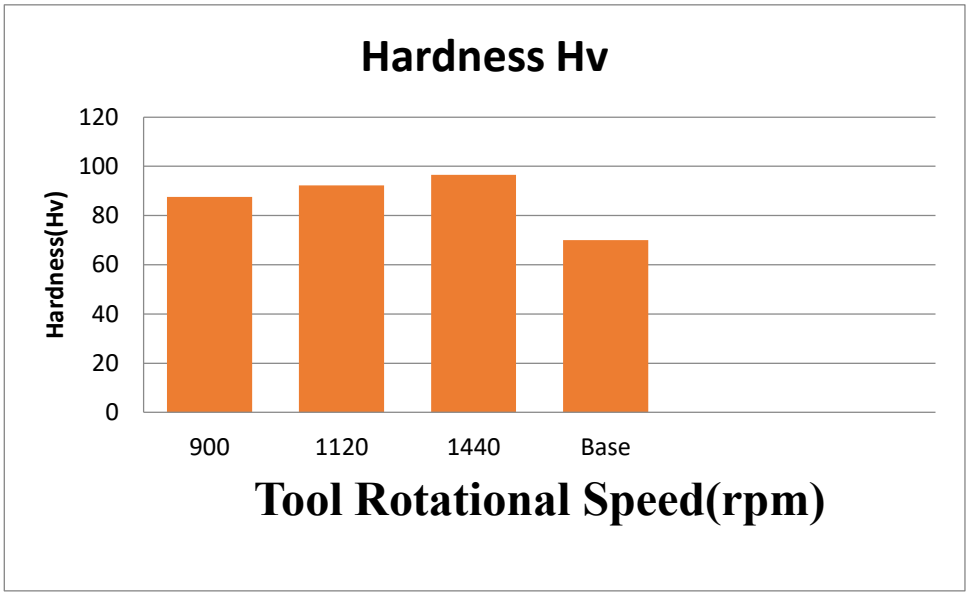

Fig.6 Tool Rotational speed Vs Hardness

5. Conclusion

Tool material and rotational speed have been identified as significant factors affecting the stir zone of AZ31B Alloy. The following conclusions can be drawn below

- lower rotational speed leads to a higher stirred zone microhardness than the base material, and there is an optimal combination of tool material and rotational speed to achieve high strength properties in the stir zone

- The ultimate tensile strength of the fabricated joint at a rotational speed of 1120 rpm is higher than those at 900 and 1140 rpm
- The fabricated joint at a rotational speed of 1440 rpm shows higher hardness compared to other joints at 900 and 1120 rpm.
- The density of the stir zone of the 900 rpm joint is lower than that of the other joints

the joint fabricated at 1120 rpm with a welding speed of 40 mm/min exhibits superior tensile strength and moderate hardness and % elongation, making it the most feasible option for FSW of the metal.

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