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Research Article

Friction Stir welding on ZE41 Magnesium Alloys

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ABSTRACT

Friction Stir Welding (FSW) is a solid state welding process in which the heat for welding is produced by the relative motion between the tool and the two interfaces being joined. This method relies on the direct conversion of mechanical energy into thermal energy to form the weld without the application of heat energy from any other source. The rotational speed of the tool, the axial pressure of the tool and the welding time are the principle variables that are controlled in order to provide the necessary combination of heat and pressure to form the weld. [2] These parameters are adjusted so that the interface is heated into the below recrystallizing temperature range where welding can take place. During the last stage of welding process, atomic diffusion occurs while the interfaces are in contact, allowing metallurgical bond to form between the two materials. The functional behavior of weldments is substantially determined by the nature of the weld strength characterized by the mechanical and metallurgical behavior.

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MECHANICAL RESEARCH ARTICLE

Friction Stir welding on ZE41 Magnesium Alloys

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ABSTRACT

Friction Stir Welding (FSW) is a solid state welding process in which the heat for welding is produced by the relative motion between the tool and the two interfaces being joined. This method relies on the direct conversion of mechanical energy into thermal energy to form the weld without the application of heat energy from any other source. The rotational speed of the tool, the axial pressure of the tool and the welding time are the principle variables that are controlled in order to provide the necessary combination of heat and pressure to form the weld.[2]These parameters are adjusted so that the interface is heated into the below recrystallizing temperature range where welding can take place. During the last stage of welding process, atomic diffusion occurs while the interfaces are in contact, allowing metallurgical bond to form between the two materials. The functional behavior of weldments is substantially determined by the nature of the weld strength characterized by the mechanical and metallurgical behavior.

1. INTRODUCTION

Magnesium is the lightest of all the engineering metals, having a density of 1.74 g/ cm^3. It is 35% lighter than aluminum (2.7 g/cm^3) and over four times lighter than steel (7.86 g/ cm^3). Magnesium is the eighth most common element. It has a good ductility, better noise and vibration dampening characteristics than aluminum and excellent cast ability.

ZE41 is a popular Mg-Zn-Re alloy and has moderate strength, creep resistance and rich weldments of ZE41 alloy. ZE41, which is a Mg–Zn–RE based alloy, is used for components such as aircraft gearbox and generator housings, particularly in military helicopters, which are exposed to corrosive environments during service [1] In present study attempt is made to determine and evaluate the influence of the process parameters of Friction stir Welding on the weldments. [1]The mechanical and metallurgical behavior is considered for investigation by varying tool feed and tool speed, maintain constant depth of penetration of weld. Experiments are conducted on ZE41 Magnesium Alloy in a Vertical axis CNC milling machine by programming for every experiment.

All the weldments are tested by optical microscope and microstructures are analyzed. Hardness and tensile strength for each weldments are measure by Vickers hardness test and Universal Testing Machine respectively.[1]The experimental results of hardness and ultimate tensile strength for Friction stir welding of ZE41 magnesium alloy obtained at various combinations of tool feed and tool speed are analyzed. The conclusion from the analysis is presented.

2. EXPERIMENTAL PROCEDURE

2.1 Raw Material – Magnesium ZE 41

Magnesium alloy developments have traditionally been driven by aerospace industry requirements for lightweight materials to operate under increasingly demanding condition

a) Raw Material Data

Raw Material ZE 41 Magnesium alloy

Zinc	Zirconium	Rare Earth elements	Remaining
Up to 5%	0.2- 0.5%	Max. 2%	Magnesium

Table 1.1: Standard chemical composition as per ASM

Zinc	Zirconium	Rare Earth elements	Remaining
4.3%	0.3	1.8%	Magnesium

Table 1.2: Experimental Chemical composition of the work piece

Alloy	Yield strength (MPa)	Ultimate Tensile strength (MPa)	% Elongation	Hardness
ZE 41 Magnesium alloy	134	193	5	60 HV

Table 1.3: Mechanical Properties

2.2. Mechanical and physical properties:

Tensile strength	Yield strength	Elongation	Hardness (VHN)	Elastic modulus	Density
1990 Mpa	1650 Mpa	9%	549 HV	190-210 Gpa	7.76 g/ cm^3

Table 1.4 Mechanical and physical properties of H13 tool steel

Fig 1.1 : H13 tool steel

2.3 Pin Design:

Friction stirring pins produce deformational and frictional heating to the joint surfaces. *Operation*. The length of the pin is reduced to 5.6 mm.

Type of tool	Shoulder diameter (mm)	Pin diameter (mm)	Pin length (mm)
Tapered with groove	16	2.6	5.6

Table 1.5: FSW tool dimensions used in experiments.

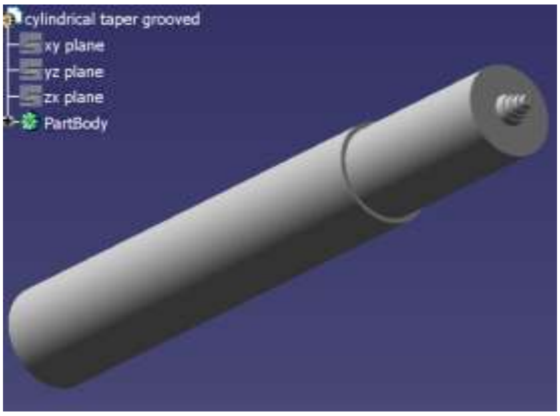


Fig 1.2: Tapered cylindrical grooved tool designed in CATIA

Tensile Specimen:

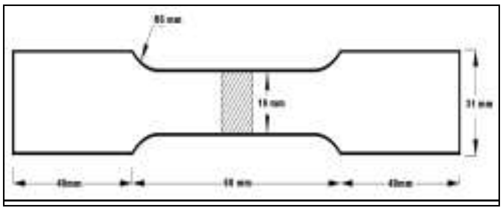


Fig 1.3: Standard specimen size

3. HARDNESS TEST RESULTS AND GRAPH

The Vickers Hardness Number of friction stir weldments of ZE41 Mg alloy at various tool Speeds and tool feed are tabulated in table and graphs are drawn.

Distance from the weld nugget	Vickers Hardness Number
-20	65.4
-15	77
-10	74.9
-5	76.4
0	84.5
5	90.4
10	84.2
15	74.3
20	58.3

Table 1.6: Weld Distance Vs Hardness (1000 rpm/40 mm/min)

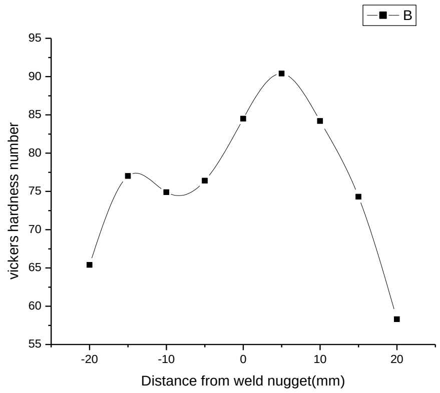


Figure 1.4: ZE41 magnesium alloy (1000rpm, 40mm)

Weld distance Vs Hardness

Distance from the weld nugget	Vickers Hardness Number
-20	58.8
-15	55.9
-10	57.4
-5	59.6
0	59.8
5	61
10	61.4
15	59.3
20	58.4

Table 1.7: Weld Distance Vs Hardness (1000 rpm/90 mm/min)

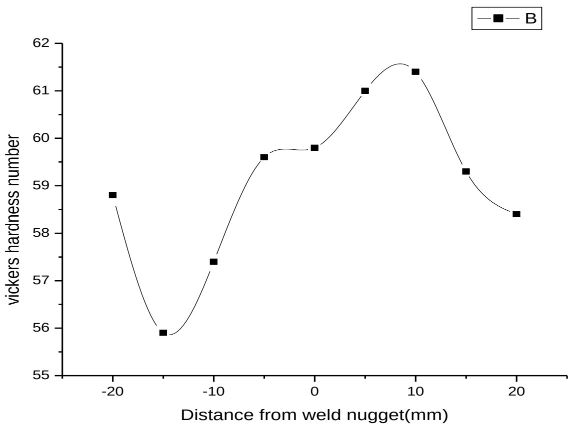


Figure 1.5: ZE41 magnesium alloy (1000rpm, 90mm/min)

3.1 MICROSTRUCTURE ANALYSIS

The first attempt at classifying microstructures was made by P L Thread gill (Bulletin, March 1997). The system divides the weld zone into distinct regions as follows:

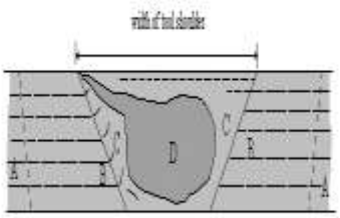
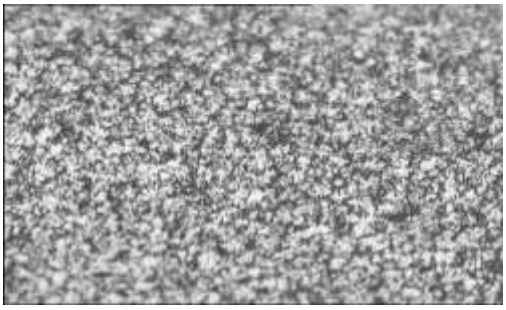


Fig 1.6: Different zones of FSW

A. Unaffected material (BM)
B. Heat affected zone (HAZ)
C. Thermo-mechanically affected zone (TMAZ)
D. Weld nugget (Part of thermo-mechanically

Microstructures analysis

The microstructures of friction stir weldments of ZE41 alloy at various combinations of tool rotational speed and tool travel speed are observed under optical microscope size 200x and the observation are presented below.



Material: ZE41 Magnesium alloy

Microstructure: Base Material

Microscope Focal Length: 200X

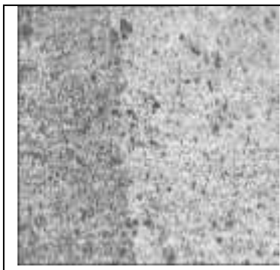
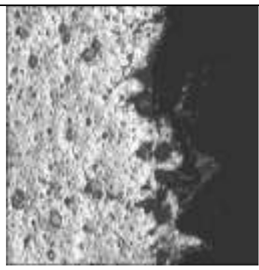
	
Tool Traverse Speed: 15 mm/min Tool Rotational Speed: 1000 rpm Microstructure: Weld Transition Zone Microscope Focal Length: 200X	Tool Traverse Speed: 15 mm/min Tool Rotational Speed: 1400 rpm Microstructure: Un bonded Weld Zone Microscope Focal Length: 200X

Fig 1.7: Microstructures analysis

3.2 Tensile Strength results and graph:

Fig 1.6: Tensile test specimen before test

Fig 1.7: Tensile test specimen after test

S.No.	Welding Speed (Tool travel Speed mm/min)	UTS (N/mm²)	UYS (N/mm²)
1	15	97.8	84.1
2	25	94.3	76.3
3	40	86.00	69.41
4	60	79.84	63.1
3	90	76.39	54.7
6	120	71.6	51.8
7	180	68.12	47.6
8	250	62.53	42.00

Table 1.8: Tensile Strength For 1000rpm Vs Various feeds (mm/min)

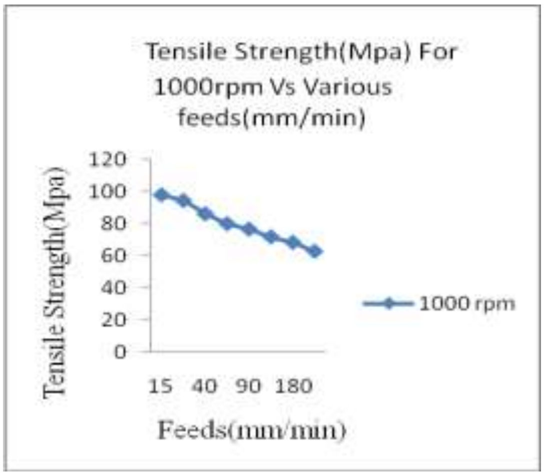


Fig 1.8: Tensile Strength For 1000rpm Vs Various feeds (mm/min)

4. CONCLUSIONS

From experimental investigation the following conclusions are given.

1. The variation of the hardness across the weld was found to be uniform and homogeneous in nature due to the distribution of the interfaced strengthening of the newly formed grains in the magnesium matrix during the process with 1000 rpm tool rotational speed as substantiated by the microstructures with smooth metal flow and good bonding between the plates.

2. The variation of the hardness across the weld was found to be non-uniform and inhomogeneous in nature for 1400 rpm tool rotational speed because of high tool rotational speed leading weak bond formation with a number of FSW defects being observed.

3. The hardness increase with increase of rotational speed .This is because of heat input (generated by the friction between tool shoulder and base metal) increase with increase in tool rotational speed.

4. The tensile strength is found to increase with reduced tool translational speed with a constant tool rotational speed; this is due to the reason that with increase in feed rate the frictional heat developed during the welding gradually reduces. The reduction in heat generation leads to a drop in plastic flow of the material and thus the metallurgical bond formed has a lesser strength.

5. Analysis on the mechanical and metallurgical properties of the ZE41 magnesium alloy welded joints indicates that the mechanical stirring is the major metal flow mechanism in metallurgical bond formation.

6. Complete mix of Base metal in weld nugget is observed in tool rotational speed of 1000rpm and tool travel speed of 40mm/min. Therefore, optimum mechanical properties are obtained at this process parameter.

7. Comparison of the mechanical and metallurgical properties of the joints which shows that the joint properties and the bond strength depend on mechanical stirring and the newly formed grains. The newly formed grains are strongly influenced by the tool rotational speed during welding.

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