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FRICTION STIR WELDING JOINTS MADE OF AZ31 Mg ALLOY AND ITS MECHANICAL PROPERTIES

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ABSTRACT: Magnesium is a metal which is widely used because of its light weight and high specific strength. But there are some problems associated with magnesium and its alloys when they are welded using traditional welding techniques like oxidation, distortion etc. So, Friction Stir welding (FSW) is being applied to weld magnesium and its alloys. Astudy is being carried out to join magnesium alloy AZ31 using FSW on the vertical milling machine. High carbon steel cylindrical tool was used to make butt joints of thin plates of magnesium alloy. FSW parameters such as speed of tool and welding speed were varied to see their impact on ultimate strength and yield strength of the welded joints. Hardness testing was done using charpy test.

KEY WORDS: Friction Stir Welding (FSW), Welding Speed, Tensile Strength, Yield Strength, Hardness

I. INTRODUCTION

At the Welding Institute Friction Stir Welding was evolved by Wayne Thomas and his colleagues [1]. FSW is a very simple process in which material is joined with the help of frictional heat produced due to rotating tool and fixed work piece. This results in plastic deformation of material due to which it gets softened and tool starts moving along the weld interface causing stirred material to fill the weld. The shoulder of the tool presses the material to give solid state joint. There is metal to metal contact in FSW joints, so it is also called solid state welding. FSW working is presented in Fig. 1.
FSW was initially applied for aluminium but slowly it is being extended to weld aluminium alloys as well as other materials such as magnesium, steel, copper, titanium etc. Now days, lot of research is going on to weld magnesium alloys using this process because of its advantages. Magnesium is light and have good specific strength so is widely used in manufacturing of automobiles, airplanes, electronic items etc. Magnesium can form intermetallic compounds easily with other elements such as aluminium, titanium, zinc, copper etc., so it is widely used for joining with other materials [3]. There are also some advantages to weld magnesium alloys using FSW than using fusion welding techniques. There is improvement in mechanical properties of the joints like strength, hardness etc. [4] as compared to properties of base material using FSW. There is also improvement in the microstructure obtained after FSW along with some environmental benefits.
There are different process parameters of FSW which critically impact mechanical properties of the joints during the process. These are tool speed, welding speed, tool material, tool shape, welding forces etc. Tool speed and welding speed are most important parameters as heat generation and quality of joints are directly dependent upon them. Plastic deformation of material depends upon these parameters. Increase of tool speed and reduction of welding speed increases the heat input. Tool material should be hard as compared to material that is to be welded. It should have sufficient strength and must not undergo much wear and tear during the process. Specially designed tool is used for the FSW process and it generally comprises of pin and shoulder. Different shapes of pin and shoulder can be used to weld the materials to see the effect on mechanical properties. Different types of forces also acts during the process and they should be reduced for the proper joints.

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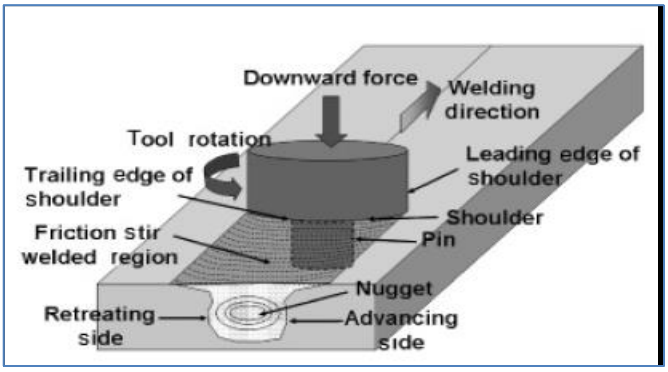

Fig. 1. FSW Working [2]

II. LITERATURE REVIEW RELATED TO FSW OF MAGNESIUM ALLOYS

FSW is widely used for aluminium and its alloys but due to number of applications of magnesium, lot of research is being carried out to join magnesium and its alloys.

Study of FSW joints between aluminum and magnesium alloys was done and found that dissimilar joints of aluminium and magnesium have good strength due to mechanical interlocking of the metallic phases [5]. Study of impact of tool speed on mechanical and microstructure properties of FSW joints of magnesium alloy was done and it was found that tool rotation improves the tensile strength of the welded joints [6]. Study of microstructure & mechanical properties was done by taking into account the pin shape of the tool used for friction stir welding of AZ31B and found that taper and cylindrical pins with threads resulting in joints which were defect free [7].Study of properties of FSW joints of magnesium alloy was done and found that FSW can be used to join the magnesium alloy AZ31 [8].

So from the literature survey related to FSW of magnesium and its alloys, it is concluded that FSW parameters affects the properties and quality of joints. Further analysis can be done to see the impact of different FSW parameters on the mechanical properties of FSW joints of magnesium alloys [9].

III. METHODOLOGY

AZ31 magnesium alloy was selected for experimentation because of its wider applications. The composition of the AZ31 magnesium alloy was calculated in the laboratory usingspectra analysis. It was found that AZ31 contains more than 95 percent of magnesium and rests of the elements were aluminium, zinc and manganese. Mechanical properties of the base material were evaluated using various mechanical tests according to standards. It was found that tensile strength and yield strength of AZ31 magnesium alloy was 82 N/mm^2 and 73 N/mm^2 respectively. The butt joints of plates 6 mm thick were prepared on thevertical milling machine using fixture on the bed of the machine. The fixture is shown in Fig. 2. High carbon steel material was used to make cylindrical tool having dimensions i.e. length of pin 5.8 mm, diameter of shoulder 20 mm and its length 60 mm. Tool speeds selected to prepare joints were 600, 900 and 1200 rpm and welding speeds were kept at 20, 25 and 35 mm/min based upon the preliminary tests, literature survey and availability of machine.

Fig. 2. Fixture used for Experimentation

The experiments were performed at decided tool speeds and welding speeds to formulate the joints. The mechanical testing of the joints to evaluate their ultimate strength and yield strength was done on the universal testing machine. Standard specimens were formulated from the welded joints to measure their strength. The results are given in Table 1. The results mentioned is the average of three readings of samples taken at particular tool speed and welding speed. Hardness tests were done on Vickers hardness machine using pyramid shaped indenter and responses were noted.

Table 1. Mechanical Testing Results

Sr. No.	Tool Speed (rpm)	Welding Speed (mm/min)	UltimateStrength (MPa)	Yield Strength (MPa)	Hardness (HV)
1	600	20	95	79	60
2	600	25	110	90	66
3	600	35	105	87	65
4	900	20	117	96	75
5	900	25	112	90	72
6	900	35	110	88	71
7	1200	20	126	100	90
8	1200	25	122	98	87
9	1200	35	120	98	85

IV. DISCUSSION ON MECHANICAL TESTING RESULTS

Variation of ultimate tensile strength and hardness with respect to tool speeds and welding speeds taken for experimentation are shown in Fig. 3 and Fig. 4 respectively.

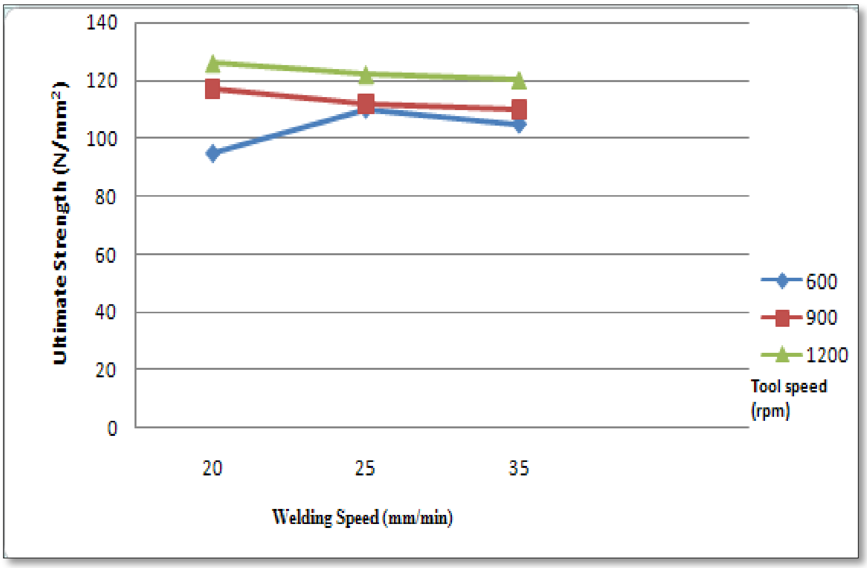

Fig. 3. Variation of Ultimate Strength

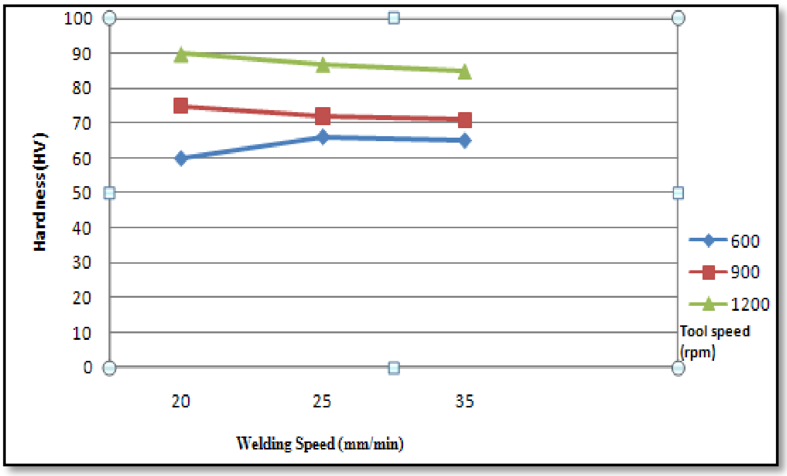

Fig.4. Variation of Hardness

From the above figures, it can be seen that at the speed of 600 rpm, the ultimate tensile strength first increases from 95 N/mm^2 to 110 N/mm^2 at welding speeds of 20 and 25 mm/min respectively and then decreases to 105 N/mm^2 at welding speed of 35 mm/min. Same trend can also be seen for yield strength at tool speed of 600 rpm. It can also be seen that at both tool speeds i.e. 900 and 1200 rpm, there is continuous reduction in ultimate tensile strength and yield strength as welding speeds increases from 20 to 35 mm/min. Maximum ultimate tensile strength at 900 rpm is found to be 117 N/mm^2 at welding speed of 20 mm/min and maximum ultimate tensile strength at 1200 rpm is 126 N/mm^2 at welding speed of 20 mm/min. Same results can also be seen for yield strength at tool speeds of 900 and 1200 rpm. The increase in strength at higher speeds and low welding speeds is may be due to the sufficient heat generation due to high speed and enough time for plastic deformation at lower feed rates as compared to higher welding speeds. Also, no cracks were seen on the surface of the welds at low welding speeds due to which quality joints were obtained.
Hardness results of the weld region also showed the similar trend. Maximum hardness obtained is 90 HV at tool speed of 1200 pm at welding speed of 20 mm/min and minimum hardness obtained is 60 HV at 600 rpm at welding speed of 20 mm/min. Hardness enhancement is may be due to refinement of grains at higher tool speeds and low welding speeds due to high temperature.

V. CONCLUSIONS

The following observations are obtained from the FSW of AZ31 magnesium alloy at different tool speeds and welding speeds:

- Good quality joints of AZ31 Mg alloy thin plates can be fabricated using FSW process.
- Welding at reduced welding speeds at high tool speeds results in improved mechanical properties i.e. strength and hardness of the welded joints.
- Higher tool speed results in heat generation and lower welding speed provides sufficient time for plastic deformation of metal. This also allows better bonding of material at the interface of joints which results in defect free joints.

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