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Significance of tool rotational speed and impact of tool pin profile on the tribological properties of friction stir welded AZ80A Mg alloy

P. Sevvel[1,*], V. Jaiganesh[2]

[1)] Department of Mechanical Engineering, Magna College of Engineering, Magaral, Chennai, 600055, Tamilnadu, India.
[2)] Department of Mechanical Engineering, S.A. Engineering College, Thiruverkadu, Chennai, 600077, Tamilnadu, India.

[*]Corresponding e-mail: sevvel_ready@yahoo.co.in

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ABSTRACT – An investigation was conducted to find out the impact of the rotational speed and tool pin profile on the tribological properties of the friction stir welded AZ80A magnesium alloy joints. A series of FSW joints were fabricated using three different tool pin profiles at various tool rotational speeds. The tensile fracture surfaces are subjected to microstructural investigations. Additionally, detailed experimental measurements are also done on hardness & wear losses of the joints. The joints fabricated at 1000 rpm using the taper cylindrical pin profiled tool exhibited sound joints with better tensile strength, higher microhardness values and minimum wear losses.

1. INTRODUCTION

Since being one of the lightest material under the metallic category, Mg alloys in practical usage, provide an extensive potential for weight saving in the automotive industries. Mg sheets can be used in the fabrication of automobile body parts including semi structural and non-structural applications [1]. Conventional welding processes are not suitable for joining magnesium alloys because of their strong cracking susceptibility, large energy requirement and high corrosion of with respect to copper electrode. Friction Stir Welding (FSW), a ingenious welding technology formulated by TWI (The Welding Institute), can present higher potential for magnesium alloys [2]. Because, it utilizes a non-consumable rotating tool for producing heat from friction, facilitating plastic deformation at nugget zone [3]. It had also been observed that the aluminium lap joints using FSW are found to be stronger than the comparable resistance spot welded and riveted lap joints [4]. High quality of welds, cheaper price, ability to weld various types of hard–to–weld metals & non-metals is yet another reason for choosing FSW to join AZ80A Mg alloys.

2. METHODOLOGY

Magnesium alloy is taken as the base material in this present investigation. AZ80A Mg alloy were obtained in the required dimensions (150 mm X 50 mm X 5 mm) by machining the rolled plates of AZ80A Mg alloy. The chemical compositions and mechanical properties of AZ80A wrought magnesium alloy are listed in Table 1.

Table 1 Chemical compositions & mechanical properties of AZ80A Mg alloy.

Alloy	Composition Wt %				Mechanical Properties	
	Al	Zn	Mn	Mg	Tensile Strength	Yield Strength
AZ80A Mg alloy	7.8	0.7	0.3	Bal	290 Mpa	193 MPa

A semi-automatic FSW machine (10kW; 1500 rpm; 5 Ton) was used in this investigation. The FSW of the Mg alloys were performed by firmly securing the flat plates with the help of specially designed fixtures as illustrated in Figure 1.

Figure 1 Arrangement of AZ80A Mg Alloy plates along with the with taper cylindrical pin profiled tool.

2.1 *Tool Material and Design*

The tool pin profile design has a direct impact on the plastic flow thereby influencing uniformity of the FSW welded joints [5]. Figure 2 illustrates the photographic view of the 3 different HSS tool pin profiles used in this investigation.

Figure 2 HSS tools with straight square, straight cylindrical & taper cylindrical pin profiles.

3. RESULTS AND DISCUSSION

AZ80A Mg flat plates are successfully joined by means of FSW process using three different pin profiled HSS tools at various tool rotational speeds by applying a constant axial force at uniform feed rate. Photographs of the series of FSW joints fabricated under above mentioned conditions are shown in Figure 3.

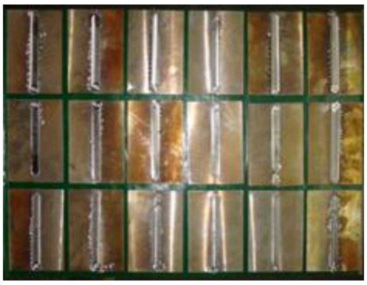

Figure 3 Photographs of the part of the joint specimens fabricated by FSW using the three different tool profile and various rotational speeds.

3.1 *Tensile Strength*

By analyzing the macro and microstructures of the joint surfaces fabricated in this investigation, it was observed that the geometry of the tool pin profile and axial force value had played a significant role in determining the quality of the weld and defect free sound weld joints were obtained during the use of tool with taper cylindrical pin profile at 1500 rpm.

Procedures prescribed by the ASTM standard guidelines were adopted during the preparation of the specimens for carrying out the tensile tests. The joints produced using taper cylindrical pin profiled tool geometry at a tool rotational speed of 1000 rpm exhibited better tensile properties compared to joints fabricated under other conditions.

By carefully examining the microstructural images of the base metal and defect free joint shown in figure 4, it can be visualized that the coarse unevenly distributed grain structure of the base metal have been transformed into an uniformly distributed fine grain structure at the nugget centre region in the fabricated joints.

Figure 4 Micrographs of the AZ80A Mg alloy base metal & nugget zone of defect free joint specimen.

3.2 *Distribution of Microhardness*

The values of micro hardness of the welded specimens fabricated using the taper cylindrical pin profile at various tool rotational speeds are graphically demonstrated in the Figure 5. By producing very fine grain sizes in the nugget zone compared with that of the base metal, higher values of hardness was achieved in the nugget zone of these joints.

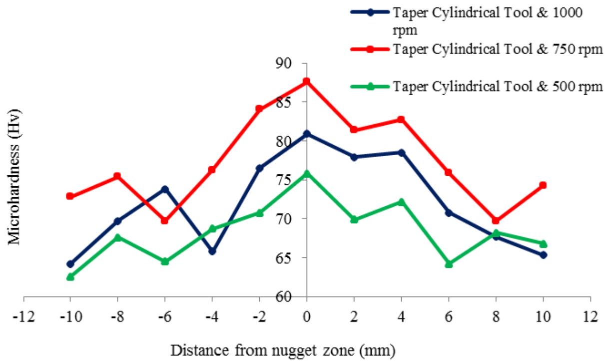

Figure 5 Graphical representation of micro hardness values under different conditions.

3.3 *Losses Due To Wear*

Further, it can be seen that the refined fine grain size and uniform distribution grain in the nugget zone leads to minimum wear losses compared with the coarse & large grain structures. Finally, it was evident that the taper cylindrical pin profiled tool produces minimum wear losses at 1000 rpm.

4. CONCLUSIONS

The results produced in the present investigation allow us to draw the following conclusions:

a) The joints welded using the taper cylindrical pin profiled tool at 1000 rpm exhibited higher tensile strength of 234 MPa, yield strength of 156 MPa, elongation of 7.1%.

b) Materials having smaller sizes of grains are found to possess higher values of hardness or greater strength.

c) It was experimentally observed that the wear losses are minimum at the highest tensile strength values. And the minimum wear losses were experienced in the specimens fabricated using taper cylindrical pin profiled tool at 1000 rpm.

5. REFERENCES

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