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Wear Characteristics And Mechanical Properties Of Az91 Magnesium Alloy Surface Hybrid Composite Of (Sic+Al_2o_3) Fabricated By Friction Stir Process

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Abstract: Magnesium (Mg) and its alloys are now becoming the promising choice for various structural applications due to their low density and high specific strength compared with other light metals such as aluminium and its alloys. Among all Mg alloys, AZ (aluminium and zinc) series is the most widely used alloy system for various structural applications. In this study, a Magnesium based alloy namely AZ91 based hybrid nano composite was fabricated using (Sic+Al_2O_3) by Friction Stir Processing (FSP). Distribution of nano (Sic+Al_2O_3) particles in the Mg matrix was studied using Scanning Electron Microscopy. Grain size analysis of the as-cast and FSP AZ91/(Sic+Al_2O_3) composite were done using Scanning Electron microscopy. The performance of the fabricated nanocomposite was investigated wear test using pin on disc operator at different loads. The tensile strengths and micro hardness values of specimens were measured. The results showed that friction stir processing modified the size of grains noticeably and improved the mechanical properties.
Keywords: Friction stir processing, AZ91 magnesium alloy, Surface composite, SiC/Al_2O_3 particles.

1. INTRODUCTION

Magnesium is a very promising light metal for the universal use in Aerospace, vehicles & so on. Traditional materials like steel and cast iron or even also Al can be replaced with it in automotive parts. Mg alloys have by 33% lower density in comparison to Al and by 77% compared to steel. On the other hand, the wear resistance and stiffness of Mg is not sufficient for many applications. In order to improve the technical performance of magnesium based machine part the material has to be reinforced while requirement of low weight can be also fulfilled. The application of lightweight construction of magnesium based hybrid material parts has been extended in the last few years. Since recently the friction stir processing technologies made possible to improve the mechanical properties of the materials. Magnesium– aluminum-silicon (Mg–AlSi hybrid) are used more and more. Promising application in automotive industry [2] is the Mg-based hybrid engine block. Despite the potential of Mg MMCs, their study has been relatively limited when compared to abundance of Al MMC investigations over the last two decades. Research on the tribological properties of these materials is even scarcer. Among the earliest was a study by Li et al. [5], which examined wear behavior of SiC and Al_2O_3-reinforced magnesium & Mg-9Al-1Zn composite sliding tests. They noted that presence SiC does not appear to be beneficial in reducing wear rates. The hybrid material is advantageous due to its low weight combined with high strength, good wear characteristics and heat resistance. Structural parts exposed to heavy loads are produced of wear or heat resistant, high strength materials like AlSi. These embedded parts improve the relative poor mechanical strength of magnesium alloy while the high volumetric proportion of magnesium ensures low weight for the whole structure. The advantages of composites are only realized if a reasonable cost performance ratio is achievable on production of the component. In this respect it is important for economic and ecological reasons to recycle crap components, production waste, etc.

1.1 Composites

Composite materials (also called composition materials or shortened to composites) are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components.

1.2 Hybrid Materials

Composites consisting of two constituents at the nanometer or molecular level. Commonly one of these compounds is inorganic and the other one organic in nature. Thus, they differ from traditional composites where the constituents are at the macroscopic (micrometer to millimeter) level. Mixing at the microscopic scale leads to a more homogeneous material that either shows characteristics in between the two original phases or even new properties.

1.3 Reinforcement

A material in which a continuous metallic phase (the matrix) is combined with another phase (the reinforcement) to strengthen the metal and increase high-temperature stability. The reinforcement is typically a ceramic in the form of particulates, platelets, whiskers, or fibers. The metals are typically alloys of aluminium, magnesium, or titanium. In this work silicon carbide (Sic) & Aluminium oxide (Al_2O_3) particulates are used as the reinforcing metal in Mg-9Al-1Zn composites.

2. MATERIALS AND METHODS

2.1 Experimental Details

AZ91 Mg alloy sheets (Exclusive Magnesium, Hyderabad) of chemical composition 2.75% Al, 0.91% Zn, 0.001% Fe, 0.01% Mn and remaining being Mg with dimensions of 100×50×8 mm3size. Friction stir processing (FSP) was carried out using an automated universal milling machine (Sri Venkateswara Industry, balanager, Hyderabad, India). FSP tool made of H13 tool steel was used to process the samples. FSP tool has a shoulder of diameter 18 mm and a tapered pin with root diameter of 3 mm, end diameter of 1 mm and a length of 3.6 mm. Initially, trial experiments were conducted to optimize the process parameters to get defect free stir zone. Then the FSP was carried out with a tool travel speed of 24 mm/min at a tool rotational speed of 1100 rpm and tool tilt angle of 20. The penetration depth (3.6 mm) was given such a way that the tool shoulder touches the work piece surface. The processed AZ91 was coded as FSPedAZ91.

2.2 Material Characterization

Specimens were cut for testing as per required dimensions across the FSP ed zone and metallographic polishing was done using different graded emery papers. The specimens were then polished using diamond paste of 3 µm size using a disc polishing machine. After each step, the samples were cleaned in distilled water, wiped with cotton and soaked in ethanol to remove any water remaining on their surface. The polished samples were etched in the solution for 20 seconds and then cleaned in distilled water followed by cleaning in ethanol. The microstructure observations were carried out using a scanning electron microscope (SEM) at different areas of interest on the surface and cross sections of FSP ed regions.

2.3 Vickers Micro Hardness

Micro hardness measurements (Raghavendra spectro metallurgical laboratory, India) were carried out on polished specimens by applying 500 g load with 5 sec dwell period. The measurement was obtained at different places on each peace. The indents were placed across the FSPed regions at the surface and cross sections. Micro hardness was measured over a distance across the stir zone such a way that the base material hardness was also measured.

2.4 Wear Testing

Dry & wet sliding wear tests were conducted using pin-on-disc tester. Pin specimens of 8×8×20mm were cut using EDM. All experiments were conducted in normal atmospheric conditions with applied normal loads of 10N and 30N using dead weights, with constant sliding speed. For each loading condition tests, time of 3mins, speed of 500RPM, & a wear track diameter 60mm were selected.

2.5 Tensile Test

The Tensile properties of friction stir processed samples with different NanoSic and Al_2O_3 volume fraction were tested using computer controlled universal testing machine. The longitudinal tensile specimens were prepared on the middle of friction stir processed stir zone as per ASTME8 Standards. Wire cut EDM is used to cut the specimens as per the dimensions.

3. RESULTS AND DISCUSSIONS

3.1 Micro Vickers Hardness

The Micro Vickers Hardness of MMC with Magnesium AZ91 alloy as matrix material and Nano Sic and Al_2O_3 as reinforcement particles by Micro Vickers hardness test. A load of 0.5 kgf is applied at a dell period of 5 seconds.

S. NO	VOLUME %	NO PASSES	HARDNESS [HV0.5]
1	0	-	82.2
2	5	1	99.4
3	5	2	97.4
4	10	1	96.8
5	10	2	96.6

Table 1: Hardness Values for different Volume Fractions

From the above results we absorbed that, the Micro hardness increased around by 20% as compared to base material due to presence and pining effect of hard SiC and Al_2O_3 particles.

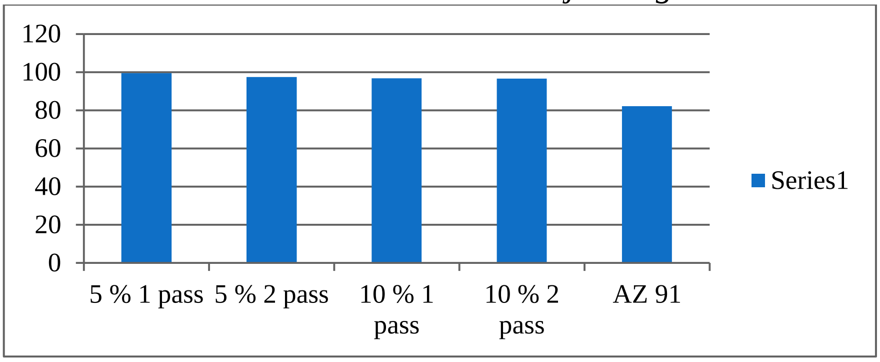

Fig.1 Graph representing the Hardness values for different passes

3.2 Tensile Strength

The ASTM standards known as the American Society for Testing and Materials is an international standards organization that develops and publishes voluntary consensus technical standards for wide range of materials products systems and services.

Test parameter	Observed values				
	sample 1	sample 2	sample 3	sample 4	sample 5
gauge length (mm)	25	25	25	25	25
Original cross sectional area mm2	42.67	41.77	41.99	42.67	42.11
Ultimate tensile load (KN)	7.58	6.54	7.13	7.48	3.37
Ultimate tensile strength N/mm2	156.675	177.627	169.788	175.297	80.023

Table 2: Tensile strength values obtained for different samples

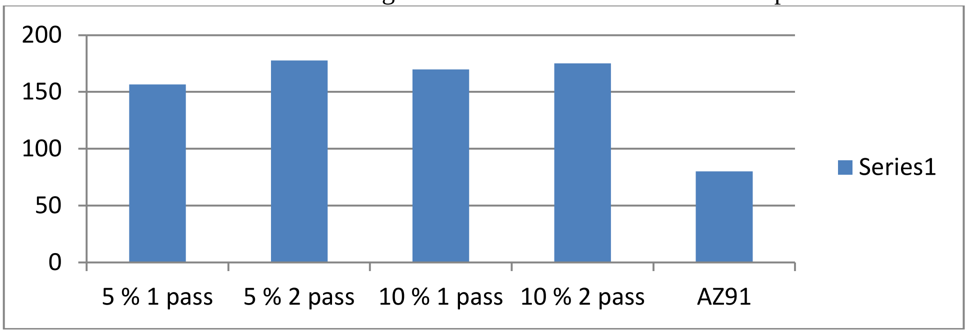

Fig.2 Graph representing the tensile stress for different passes

From the above results we absorbed that, tensile strength is increased by two times as compared to the base material due to the presence of reinforcement particles.

3.3 Wear Test Result

Pin on disc wet & dry sliding wear tests of Mg-9Al-1Zn composite reinforced with Al_2O_{3p}&SiC_p pins against a steel counter face were carried out under loads of 10N and 30 N. Wear rates observed in above all tests as compared to C.Y.H. Lim et al. [5]. Low wear rate was exhibited in the Mg–SiC/Al_2O_3 surface hybrid composite due to mechanically mixed layer generated between the composite pin and steel disk surfaces which contained fractured SiC and Al_2O_3. The presence of SiC particles serves as load bearing elements and Al_2O_3 particles acted as solid lubricant, Less accurate or less précised surfaces of the pin with un-uniformity may lead to random wear results.

Specimen	Normal load	Wear rate	Sliding distance	Sliding velocity	Co-efficient of friction
5% wt& 1 pass	10	0.0006197	471	2.61799	0.261733
5% wt& 1 pass	30	0.0002173	471	2.61799	0.215777
5% wt& 2 passes	10	0.0005262	471	2.61799	0.239613
5% wt& 2 passes	30	0.000176	471	2.61799	0.220747

10% wt& 1 pass	10	0.0006396	471	2.61799	0.242809
10% wt& 1 pass	30	0.0002294	471	2.61799	0.222815
10% wt& 2 passes	10	0.0006195	471	2.61799	0.244348
10% wt& 2 passes	30	0.0002314	471	2.61799	0.224536
0 wt& 0 pass	10	0.0005365	471	2.61799	0.250907
0 wt& 0 pass	30	0.0001878	471	2.61799	0.222615

Table.3 Wear test results for different Volume Fractions and Passes

3.4 SEM Studies

Here we are using a Scanning Electron microscope of magnification ranges from 0.1k to 50k. We obtain the images of specimen as follows. The below images shows the dispersion of Nano Sic and Al_2O_3 particles in the Magnesium matrix alloy. From the images it is clear that the Nano-sized Sic and Al_2O_3 particles(from 0% to 10% volume fraction in steps of 5% and different number of passes) were well dispersed in the Magnesium AZ91 matrix as shown. Tiny scratches due to polishing are displayed. Tool profile and processing parameters affects the distribution of reinforcement material in the stir zone.

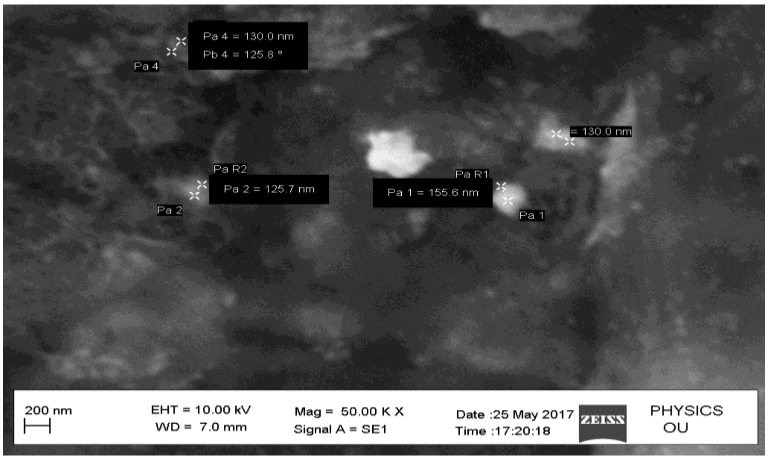

Fig.1 50k xmagnification of 5% wt of SiC & Al_2O_3, 1 pass

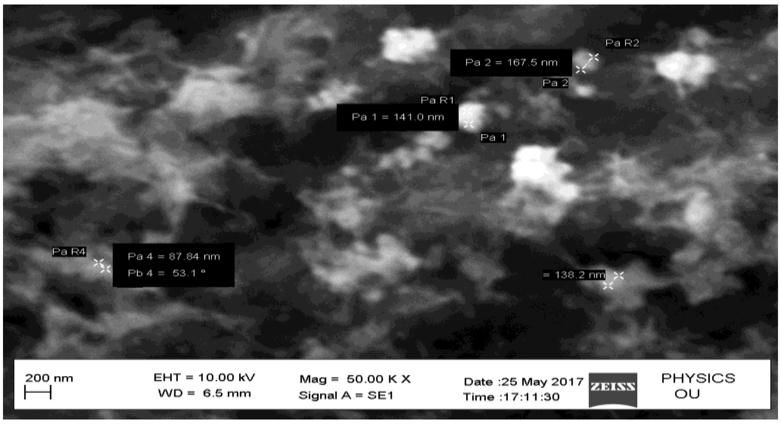

Fig.2 50k x magnification of 5% wt of SiC & Al_2O_3, 2 pass

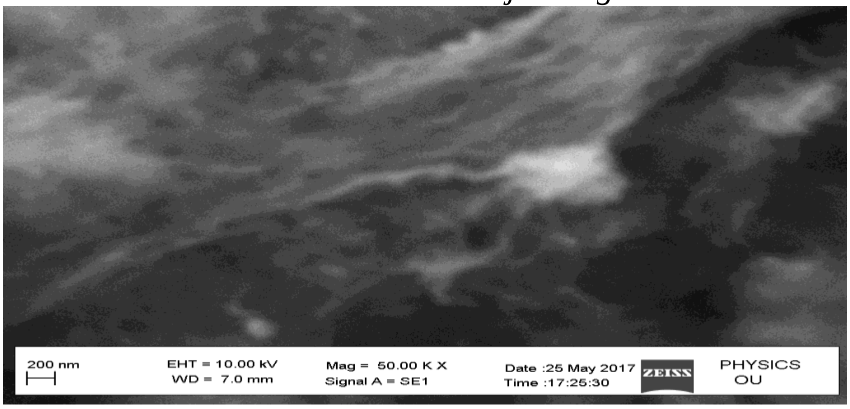

Fig. 3 50k x magnification of 10% wt of SiC & Al_2O_3, 1 pass

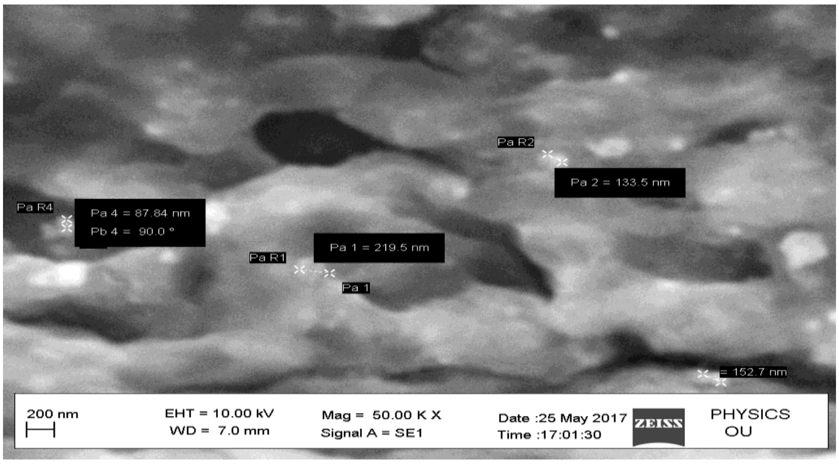

Fig. 5.13 50k x magnification of 10% wt of SiC & Al_2O_3, 2 pass

4. CONCLUSION

- The wear and mechanical properties of magnesium alloy AZ 91 surface hybrid composites fabricated via friction stir processing were investigated and the following conclusions were obtained.
- Micro hardness increased by 20% as compared to base material due to presence and pining effect of hard SiC and Al_2O_3 particles.
- Tensile properties are increased by two times as compared to the base material due to the presence of reinforcement particles.
- Low wear rate was exhibited in the Mg–SiC/Al_2O_3 surface hybrid composite due to mechanically mixed layer generated between the composite pin and steel disk surfaces which contained fractured SiC and Al_2O_3. The presence of SiC particles serves as load bearing elements and Al_2O_3 particles acted as solid lubricant.

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