A Study on Mechanical and Tribological Properties of Magnesium Alloy AZ31 Reinforced With SiC and Al2O3 Particulates

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Abstract— This work deals with fabricating or producing magnesium based metal matrix composite and then studying its mechanical and tribological properties such as microstructure, tensile strength, impact strength and wear behavior of produced test specimen. In the present study a modest attempt has been made to develop magnesium based MMCs with reinforcing material, with an objective to develop a conventional low cast method of producing MMCs and to obtain homogeneous dispersion of reinforced material. To achieve this objective stir casting technique has been adopted. An Alloy similar to commercially available composition of AZ31 and SiC, Al2O3 has been chosen as matrix and reinforcing material respectively. Experiment has been conducted by varying weight fraction of 3% SiC and 1% Al2O3 & 1% SiC and 3% Al2O3 in matrix metal. The result shown that tensile strength, impact strength, wear resistance is good in matrix metal as compared to used weight compositions of SiC and Al2O3 in the composites.

***Key words**:* Al2O3, matrix metal, SiC, Stirr casting, Pin-on-Disc tribometer

I. INTRODUCTION

Magnesium alloys exhibit the attractive combination of low densities (1.74 g/cm3 versus 2.7 g/cm3 for Al) and high strength per weight ratios (comparable or greater than that of precipitation strengthened Al alloys), along with good damping capacity, cast ability, weld ability, and mach inability [1,2]. Of the various commercial Mg alloys, those developed from the Al–Zn ternary system (i.e. the as-named AZalloys) have found the largest number of industrial applications. Major commercial grades of AZ alloys are AZ31, AZ61 and AZ91, which are produced either as cast products (e.g. die, sand and mold castings) or wrought products (e.g. extrusions, forgings, sheet and plates). In general, as Al content of the alloy increases, yield strength, ultimate tensile strength, corrosion resistance and oxidation resistance all increase, whereas cast ability and weld ability rapidly decrease.

Mg alloy based MMCs (metal matrix composites) among other MMCs are widely used in various applications in aerospace, automobiles, and sports equipments because of its low density and better mechanical properties [1]. Particulate reinforced Mg composites are becoming more popular, as compared to fiber reinforced Mg composites, due to their increased production rate, reduced reinforcement costs and easier fabrication processes. Micrometer-size SiC, Al_2O_3 particles are commonly chosen as reinforcement in Mg because of their low cost and easy availability [2]. The microstructure and mechanical properties were significantly improved with the micro size particulate reinforcements and it is reported by various authors that nano size reinforcement will further improve the properties if the nanoparticles are homogeneously reinforced into the matrix material. Few authors have tried with nano reinforcements like Al_2O_3, SiC, and TiO_2 and found reasonable improvement in the mechanical properties [3–5].Composites are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties that remain separate and distinct within the finished structure. The bulk material forms the continuous phase that is the matrix (e.g., metals, polymers) and the other acts as the discontinuous phase that is the reinforcements (e.g., ceramics, fibers, whiskers, particulates). While the reinforcing material usually carries the major amount of load, the matrix enables the load transfer by holding them together [3].

The objective of present work is to produce hybrid composites of AZ31-SiC-Aluminium oxide by stir casting method. And determine the effect of addition of different compositions of SiC and Aluminium oxide on mechanical and tribological properties of AZ31-SiC-Aluminium metal matrix composites.

II. MATERIALS AND METHODOLOGY

A. Materials

The materials used in this present investigation are an alloy similar to the commercially available composition of AZ31,SiC and Aluminium oxide. Chemical composition of magnesium alloy AZ31(i.e sample 1),AZ31+3%SiC+1%Al2O3(i.e sample 2) and AZ31+1%SiC+3%Al2O3(i.e sample 3) is shown in table 1.

B. Methodology

The synthesis of metal matrix composite used in the study was carried out by stir casting method. A stir casting setup, Consisted of a Induction Furnace and a stainless Steel rod was used to synthesize the composite. The stirrer was made by cutting and shaping a Stainless Steel block to desired shape and size manually.

Graphite crucible of 2 Kg capacity was placed inside the furnace.Typical stir casting process is shown in below figure.

Magnesium alloy AZ31 was melted at 650c in induction furnace. Preheating of reinforcement (SiC and Al2O3) was done for one hour to remove moisture and gases from the surface of the particulates.In first trail pure magnesium alloy AZ31 specimens of length 130mm and dia 22mm was prepared by pouring molten magnesium alloy in to the die.In the second trail 3% SiC+1% Al2O3 were added to molten magnesium alloy AZ31 and poured in to the die.In the third trail 1% SiC+3% Al2O3 were added to molten magnesium alloy AZ31 and poured into the die. By this process three sets of specimens were prepared for each test.

III. FIGURES AND TABLE

Fig. 1: Reinforcement   Fig. 2: Inductio Furnace

A. Chemical Composition

Sample	Al	Zn	Mn	Cu	Fe	Si	Mg
1	3.34	.89	.01	.011	.002	.071	Rem
2	3.48	.80	.02	.01	.006	.063	Rem
3	3.42	.01	.02	.006	.001	.054	Rem

B. Results Of Tensile Test

Sample	Ultimate Load(KN)	Tensile strength(MPa)	Elongation(%)
1	10.860	140.238	5.6
2	9.6	113.2	4.6
3	9.18	113.4	4.7

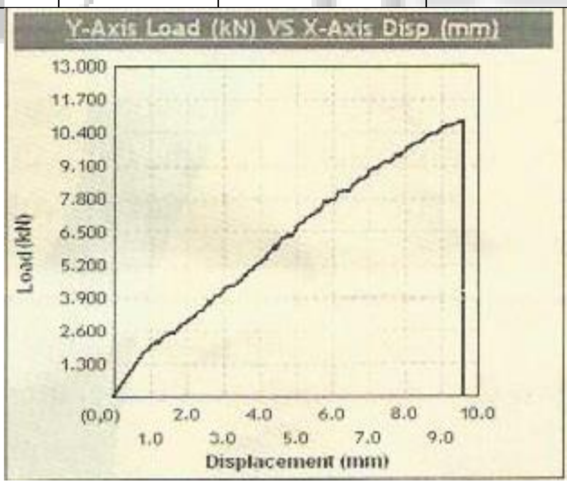

Fig. 3: Load vs Dislacement daigram for Mg alloy AZ31(sample 1)

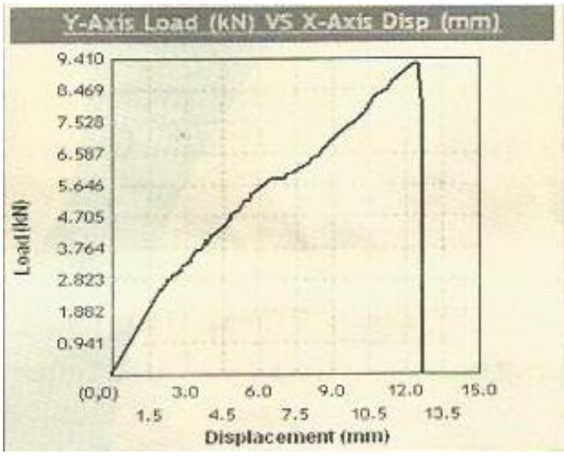

Fig. 4: Load vs Displacement diagram for AZ31+3%SiC+1%Al2O(sample 2)

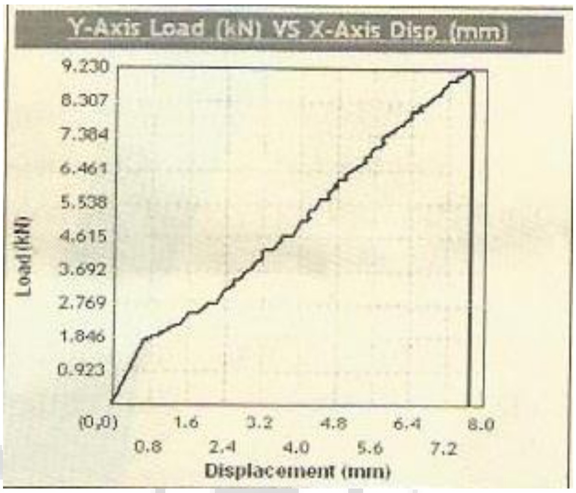

Fig. 5: Load vs Displacement diagram for AZ31+1%SiC+3%Al2O3(sample 3)

C. Results of Impact Test

Sample	Energy Obsorbed In Joules
1	14.67
2	6.67
3	6.00

D. Wear Testing and Results of Wear Test

Below result shows wear rate, frictional force and coefficient of friction by keeping 3kg load, 500rpm, 60mm wear track diameter and 5min time.

Dry sliding wear tests were conducted using pin-on-disc tester. Pin specimens of diameter 8mm & length 22-24mm were machined.

All the experiments were conducted in air with temperature and humidity maintained between 19-25 0c and 55-67% respectively. Normal load 3kg is applied using dead weights while disc speed, wear track diameter were selected. For each sliding condition, a total of 5min test is carried out. Volumetric wear rates, frictional force and coefficient friction calculated.

Fig. 6: Pin On Disc Tribometer (TR-20)

Specifications of pin on disc Tribometer (TR-20)

- Makers: Ducom Ltd, Bangalore.
- Pin Size: 3 to 12 mm diagonal.
- Disc Size: 160 mm dia. X 8 mm thick.
- Wear Track Diameter (Mean): 10 mm to 140 mm.
- Sliding Speed Range: 0.26 m/sec. to 10 m/sec.
- Disc Rotation Speed: 100-2000 RPM.
- Normal Load: 200 N Maximum.
- Friction Force: 0-200 N, digital readout, recorder output.
- Wear Measurement Range: 4 mm, digital readout, and recorder output.
- Power: 230 V, 15A, 1 Phase, 50 Hz.

Sample	Wear micrmeter	Frictional Force N	Coefficient of Friction
1	340	6.5	0.220
2	400	8	0.280
3	550	8	0.280

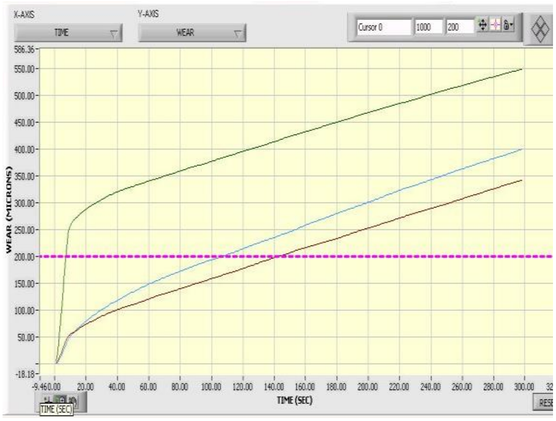

Fig. 7: Time vs Wear For Sample 1,2 &3

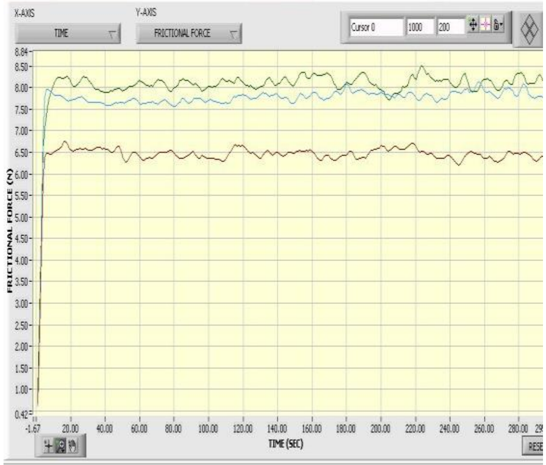

Fig. 8: Time vs Frictional Force For Sample 1,2&3

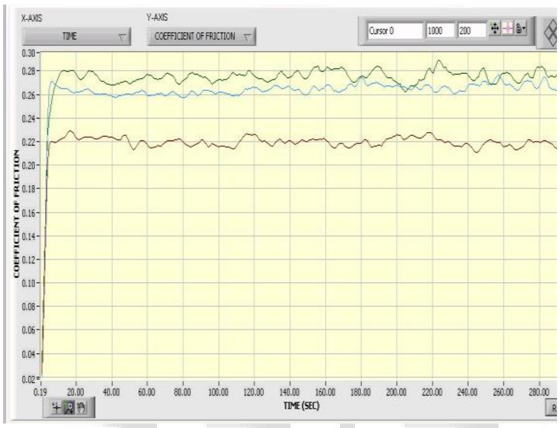

Fig. 9: Time Vs Coefficient of Friction For Sample 1, 2 & 3

E. Microstructure analysis

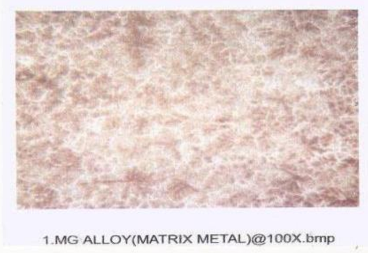

Fig. 9: Sample 1

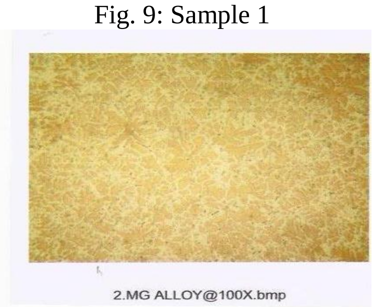

Fig. 10: Sample 2

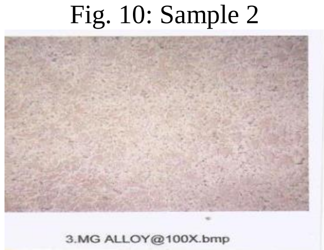

Fig. 11: Sample 3

Above figures represent the microphotographs of pure sample 1, sample 2 and sample 3 respectively. From the figure it can be observed that, the distribution of reinforcements SiC and Al2O3 in the respective matrix is fairly uniform. Further these figures reveal the homogeneity of cast composites.

IV. CONCLUSION

The conclusions drawn from the present investigations are as follows:

(1) Magnesium metal matrix composites has been successfully fabricated by stirr castin technique with fairly uniform distribution of SiC and Al2O3 particles.
(2) The results confirm that stirr formed magnesium alloy AZ31 without reinforcement of SiC and Al2O3 is clearly superior in tensile strength, impact strength and wear behavior in comparison magnesium alloy AZ31 with reinforcement of different weight fractions of Sic and Al2O3.
(3) It is found that elongation tend to decrease with different particle weight percentage, which confirm that silicon carbide and aluminium oxide increases brittleness.
(4) It appears from this study that UTS and UL tend start to decrease with different weight percenetage of SiC and Al2O3 in the matrix.
(5) Impact strength starts to decrease with the addition of SiC and Al2O3 particles in the matrix.
(6) Microstructure study shows that matrix cosist of fine grains of Mg,Al,Zn .
(7) Wear rate is low in matrix metal as compared to matrix metal with reinforcement of different compositions of SiC and Al2O3 this indicates material is strong but poor mach inability characteristics.
(8) Stir casting process, stirr speed and time, particle preheating tempreture, particle reinforcement rate are the important process of parameters.

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