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Wear Behavior on Magnesium Reinforced with Nano Alumina Particulates

V Sridhar, Ch Ratnam

Abstract: *The present study explores the wear properties of Mg composites with different amounts of nano- alumina particles (up to 1.4 vol. percent). Tests are carried out on wear device with a constant load of 10N, at sliding speeds range between 1 to 10 m/s compared to EN31 steel disks. Magnesium metal matrix composites reinforced by 1.4 volume percent of alumina particles (nano – sized) possess mechanical properties equivalent or even superior to alike composites of high level micron reinforcement. The outcomes reveals that the introduction of nano powder in various proportions influences the increment of wear performance of magnesium alloy and shows better wear performance at both the speeds by adding 1.4 volume % nano Al_2O_3 to the pure Mg and other Mg- Al_2O_3 composites. Due to the presence of Al_2O_3 as reinforcement for lower and higher sliding speeds, the improvement if found in wear property. The enhancement in wear property of the nano- composites is due to the increased hardness and strength with the nano- alumina particles presence in matrix. Initially there is increase in porosity by the addition of nano alumina to magnesium and later decreased gradually by inceasing the nano alumina percentage. Magnesium nano alumina composites can be considered as an excellent material because of better wear components are of major importance, mainly used in the aerospace and automotive engineering applications.*

Index Terms: *Mg – nano Al_2O_3, Powder metallurgy, Sintering Pin on Disc Tribometer, Wear Characteristics*

I. INTRODUCTION

Magnesium- based alloys have attracted a lot of responsiveness as light weighed materials, also as they have high specific strength, high damping capacity, good capacity and natural mineral obtainability. Currently the main focus is on development of the new and novel nano- composites that can display good combinations of properties. Researchers have recently shown that ductility and magnesium fracture work can be augmented by using reinforcement materials like Mo, Ti and CNTs. [1].Conventional reinforcements like SiC and Al_2O_3 in particulate form are normally utilized in alumina composites for magnesium matrix composites [2]

Accordingly, the purpose of this study is to synthesize Mg / Al_2O_3 composites with aid of a powder metallurgy route integrating furnace sintering resistance. Powder metallurgy is widely used in the manufacture of a variety of materials.

A typical composite material is an arrangement of materials composed of 2 or more microscopic materials. For attaining the desired form the matrix holds the reinforcement while the reinforcement enhances the complete mechanical characteristics of matrix. The newly combined materials exhibit better strength than the individual material when properly designed. [3]

1.1 Powder Metallurgy

It is a method of mixing finely powdered metals or alloys as the desired form or shape and followed by heat treatment of compressed material in an organized environment to bind the material [4], [5]. Extremely fine particles were made by guiding a stream of melted metal through a high temperature plasma flame, atomizing and mixing the materials simultaneously.

1.2 Nano Composites

A nano-composite, which is a solid multi-phase material that have one phase with 1, 2 or 3 dimensions below 100 (nm) or nano-scale structures that repeats the distances between the various material phases. In a broader sense, the same definition may consist of colloids, porous media, copolymers and gels, but is mostly referred to as the solid combination of a bulk matrix and nano-dimensional phases, which differ in characteristics because of structural as well as chemical variations. The mechanical, optical, electrical, electrochemical, thermal, catalytic nano-composite material properties are significantly different from those of the components. Limits have been proposed for these influences, < 5 nm for catalytic activity, < 50 nm for refractive index changes, < 20 nm for soft hard magnetic material and < 100 nm for super par magnetism, mechanical reinforcement or restriction of the motion of matrix dislocation [6], [7].

II. EXPERIMENTAL PROCEDURE

2.1 Powder Mixing Process

In this process powders are taken into a bowl and then dispersed in distilled dichloride methane (CH_2Cl_2) solution which is not aquiferous, Mg powder particles do not form either oxides or Mg $(OH)_2$ during wet mixing. Mg powders are then slowly transferred to the solution containing both CH_2Cl_2 and Al_2O_3 and wait for the solution to wet. The powders used in the present work are spherical shaped.

2.2 Grinding of Powder

The powder is further grinding is performed for reduction of the grain size with the aim that specimen to be compacted should possess high strength. Monolithic magnesium & nano-composites are produced with aid of the technique of powder metallurgy [8].In the synthesis process, 5 hours (300 minutes) of mixing pure Mg powder with nano- sized powder in an alloy namely mortar & pestle.

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*Correspondence Author(s)
V Sridhar, Department of Mechanical Engineering, V R Siddhartha Engineering College, Vijayawada, Andhra Pradesh, India.
Prof Ch Ratnam, Department of Mechanical Engineering, Andhra University College of Engineering, Andhra University, Visakhapatnam, Andhra Pradesh, India.

2.3 Compacting

The mixture grinded is now utilized for making of billets using 100 tons of the cold compaction process on the universal test machine [9]. The EN24 steel circular die is having 2 slots of $46\times7\times4$ mm^3 parallel to one another. A 30 tons load is progressively enforced in 15 seconds UTM [10] [11] [12]. The billets so formed are weighed over the weighing machine and further calculations are done.

Fig 1 Specimens

2.4 Sintering Process

It is a thermal treatment process that is applied for compacted powder to give strength and also integrity at the same time. The sintering temperature is lower than the melting point of the main component of the powder metallurgical material [13].After compaction, cold welds hold neighboring powder particles together, giving the compact enough green strength to handle.

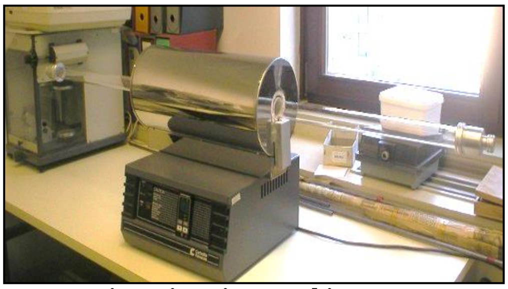

Fig 2 Sintering Machine

Sintering furnaces are availed which enables the application of cooling rate acceleration in cooling area and material grades that could be converted to martensite microstructures at such rates of cooling have been developed. [14] This method, together with a consequent treatment for tempering, is called as sinter hardening, a process that has emerged, in recent years, has a leading means to enhance sintered strength [15]. Magnesium material maximum melting point is 630oC; the experiment is carried out with an Argon gas flow rate of 15L / min up to 610oC.The bonding area in relation to the particle size is the determining factor for properties such as strength and conductivity. The temperature and the initial grain size are the variables that can be controlled for any given material because the vapor pressure depends on the temperature. [16]

2.5 Void Fraction

Void fraction or Porosity is the measurement of voids in any material and is also a volume fraction of voids over the material total volume. Porosity is affected by three major microstructural parameters namely grain size, packing of grains, particle shapes and the grain sizes distribution. There are many methods for measuring porosity, among those one of the best methods is Direct Measurement Method. Through this method porosity values are calculated in this present work.

2.6 Wear Test

The tribometer is the instrument that measures the frictional force, coefficient of friction, and wear volume, between two contacting surfaces. Sliding wear tests are performed under 10N loading conditions on pin-on-disk wear test device at 160 rpm and 320 rpm sliding speeds against EN31 steel disks. The pin samples are 47 x 7 x 4 mm^3 dimensions. The disk is made of steel. The wear test is carried out with 10N load. The surface of the steel disk is cleaned and washed with ethanol at the end of each stage.

Fig 3 Pin on disc Tribometer

2.7 Pin on disc Tribometer

Pin-on-disk wear test was an approach of illustrating coefficient of friction, metal frictional force and wear rates among materials. Pin sample surfaces are made as flat without small fins using emery paper before the test to ensure effective contact with the steel disk [18].The load is applied to the specimen at a track radius of 60 mm have intimate contact with the rotating disks. The pin is set to slide contrary to the steel disk EN 31 in dry lubrication conditions for about 300 secs. Parameters such as sliding speed, sliding time are fed manually to the pin in a disk tribometer setup. Graphs are plotted consisting of wear vs. data points on digital computer connected to the pin on the tribometer device. The corresponding wear of the pin Vs the time is plotted on graphs.

Fig 4 Tribometer

III. RESULTS AND DISCUSSIONS

3.1 Porosity

Experimental density values of the samples are determined by using Archimedes principle. Three randomly chosen polished samples are employed for evaluation of the density and their weighs which are obtained from experimentation are recorded firstly in the air and further in distilled water with aid of high accuracy electronic balance.

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Densities and porosity values of the samples are also calculated theoretically by the rule of mixture method [16].

Porosity=100 (1- r1/ρ2)

r1 = Green density value of the sample

ρ2 = Sintered density value of the sample

Table1. Porosity values for varying compositions and speeds

Material (%)	Green Density (gm/cm3) (a)	Sintered Density (gm/cm3) (b)	Porosity 100(1-a/b)
Sample A	1.748	1.90	0.92
Sample B	1.803	1.85	0.9745
Sample C	1.759	1.84	0.9560
Sample D	1.766	1.85	0.9545

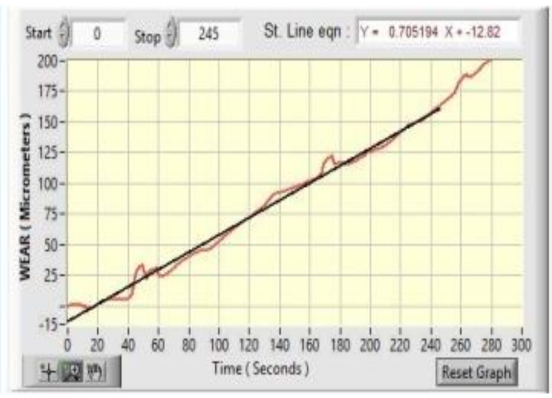
3.2. Wear Behavior Analysis

3.2.1. Wear graph at 160 rpm

The wear of magnesium and nano alumina reinforced composites is plotted with respect to the time and wear in micrometers. It is obvious that there is sudden decrease in wear with the introduction of nano alumina into pure magnesium and with increment in amounts of nano alumina wear decreased.

Graph 1: Sample D (Mg + 1.4 % Al_2O_3)

The wear of magnesium and nano alumina reinforced composites is plotted with respect to the time and wear in micrometers. It is obvious that with increase in amounts of nano alumina wear increased and suddenly decreased on adding 1.4%. Al_2O_3 to pure magnesium.



Graph 2: Sample D (Mg + 1.4 % Al_2O_3)

Table 2. Wear Results for varying compositions and speeds

Chemical composition [%]	Time (secs)	Wear (micrometers) 160 rpm	Wear (micrometers) 320 rpm
Pure Mg	300	410	700
Mg+0.35%Al_2O_3	300	90	1400
Mg+ 0.7% Al_2O_3	300	95	2000
Mg+ 1.4% Al_2O_3	300	12.5	160

The results observed by the sliding wear examination performed on magnesium, reinforced with different proportions of nano alumina, are shown in Table 1.

It is revealed that the reinforcement with a combination of 1.4 % of nano alumina to magnesium provides good wear performance at both the speeds. The sliding wear test is carried out using the selected testing machine with different samples, under constant load of 10N and 60mm sliding distance at different speeds. The wear is calculated in µm. Four samples are tested with different compositions of Al_2O_3 and sliding velocity between 1m/s and 10m/s. The variation of wear in µm with time in seconds is plotted as shown in the graphs 1 & 2 respectively for different speeds. From the graphs, at 160 rpm, it is observed that there is decrease in wear on addition of 0.35% Al_2O_3 to pure magnesium and wear increased with increase of Al_2O_3 by 0.7% and suddenly decreased by adding 1.4% Al_2O_3 to pure magnesium. Whereas at 320 rpm the wear increased with the increase of percentage of Al_2O_3 and suddenly decreased on adding 1.4% Al_2O_3 to pure magnesium. It is obvious that there is a steady decrease in wear with increment in amount of reinforcement at lower speeds. This resembles the enhancement of strength and hardness values of the composite with respective reinforcement level and comes to agreement with Archard's equation that a material wear rate is inversely proportional to its hardness [18]. The results of previous study by C.Y.H. Lim et al [18] have presented that nano-sized alumina particulates of 1.11 volume % only are capable to attain noticeable improvement (up to 1.8 times) in pure magnesium wear resistance, particularly under high sliding speeds. At higher volume fraction (1.4% Al_2O_3) reinforcement to pure magnesium utilized presently is significant as in these studies we incurred that wear is optimum at a particular particulate size and sliding condition. Alumina particulate reinforcement exhibits an advantageous influence on the wear of magnesium at higher speed and improved reinforcement of particulates due to the formation of transfer layer which protects surface from abrasive wear [19]. Hence we can make use of these materials with this reinforcement which are better in the aerospace and automotive engineering applications.

IV. CONCLUSIONS

In the present study we conclude the following Initially there is increase in porosity by the addition of nano alumina to magnesium and later decreased gradually by increasing the nano alumina percentage.

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From wear behavior we conclude the following

1. The wear of the magnesium decreased with the increase of nano-alumina (0.35%) and increased on addition of 0.7 vol % of Al_2O_3 and again decreased by adding 1.4 vol % of nano alumina to pure magnesium at 160 rpm.

2. The wear of the magnesium increased with the increase of nano-alumina (0.35% and 0.7%) of Al_2O_3 composition and again decreased by adding 1.4% of nano alumina to pure magnesium at 320 rpm.

3. The composition of 98.6%Mg + 1.4% nano Al_2O_3 shows better wear performance compared to other compositions at both the speeds.

With an increase in nano-alumina composition at higher speeds, the wear of the graded composite material reduced. The present work shows that the wear properties of MMC's depend very much on the tribo system and type of metal matrix composite. The influences of a high loads over present composites go on as an objective for future work.

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AUTHORS PROFILE

V SRIDHAR completed his masters from JNTU college of Engineering Kakinada**.** Pursuing Ph.D from A U College of Engineering, Visakhapatnam. Areas of research are Nano Materials and FEM related problems. Presently working as an Assistant Professor in Department of Mechanical Engineering
V.R. Siddhartha Engineering College, Vijayawada, Andhra Pradesh, India.

Prof Ch Ratnam, working as Professor in Department of Mechanical Engineering, AU College of engineering, Visakhapatnam. Ph.D from IIT Madres. Areas of interest are vibrations, machine design and materials.

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