ABSTRACT (ENGLISH)

Full Name : SYED ZABIULLAH

Thesis Title : WEAR BEHAVIOR OF MAGNESIUM BASED NANOCOMPOSITES

Major Field : MECHANICAL ENGINEERING

Date of Degree : December 2012

In the present work, wear behavior of magnesium based nanocomposites reinforced with different nanoparticles were investigated by using pin-on-disc configuration under dry sliding conditions.

In the first group of materials, dry sliding wear behavior of AZ31 magnesium alloy and its nanocomposites reinforced with 1.5 vol.% Al_2O_3 and 1 vol.% CNT were studied within a load range of 5-20 N at sliding speeds of 1, 2 and 5 m/s for sliding distance up to 2500 m. The test results showed that the wear rates of the magnesium alloy increases with the addition of reinforcement. Scanning electron microscopy (SEM) identified abrasion, oxidation, delamination, adhesion and thermal softening as the dominant wear mechanisms. The high wear rates in the nanocomposites were attributed to higher ductility, porosity and mismatch of thermal expansion coefficients between the reinforcement and matrix alloy.

In the second group of materials, dry sliding wear behavior of Mg/Y_2O_3 nanocomposites reinforced with varying amounts of nickel from 0.3-1.0 vol.% were studied within a load range of 5-30 N at a constant sliding speed 0.5 m/s for sliding distance up to 1000 m. The test results showed that the wear rates of the Mg/Y_2O_3

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In the third group of materials, dry sliding wear behavior of Mg/Y_2O_3 nanocomposites reinforced with varying amounts of copper from 0.3-1.0 vol.% were studied within a load range of 5-30 N at a constant sliding speed 1 m/s for sliding distance up to 1000 m. The test results showed slight improvement in the wear resistance of Mg/Y_2O_3 nanocomposite with 1.0 vol.% Cu. The improvement in wear resistance of the nanocomposites was attributed to the improved hardness of the material with increase in Cu content. Scanning electron microscopy (SEM) identified abrasion, oxidation, adhesion and mild delamination as the dominant wear mechanisms.

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WEAR BEHAVIOR OF MAGNESIUM BASED NANOCOMPOSITES

BY

SYED ZABIULLAH

A Thesis Presented to the
DEANSHIP OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

MECHANICAL ENGINEERING

December 2012

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
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DEANSHIP OF GRADUATE STUDIES

This thesis, written by **SYED ZABIULLAH** under the direction of his thesis advisor and approved by his thesis committee, has been presented to and accepted by the Dean of Graduate Studies, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN MECHANICAL ENGINEERING**.

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Dr. Salam A. Zummo
Dean of Graduate Studies

19/5/13

Date

بسم الله الرحمن الرحيم

This Work is dedicated

to

My Family for their dua, constant support and encouragement throughout my life

ACKNOWLEDGEMENTS

All praise belongs to Almighty ALLAH (S.W.T.) for bestowing me with health, knowledge and patience to carry out this work and complete my M.S. successfully at King Fahd University of Petroleum and Minerals, Dhahran.

Acknowledgement is due to King Fahd University of Petroleum and Minerals for providing me financial support and good academic environment during the course of my study. Special thanks to the Deanship of Scientific Research (DSR) for funding this work.

My deep gratitude and appreciation goes to my thesis advisor Dr. Syed Fida Hassan for his constant help, guidance and motivation during the course of my study. His priceless suggestions made this work interesting and challenging for me. I also wish to express my deep appreciation to Dr. Amro Al-Qutub for his constant help, guidance and encouragement during my study. I am greatly indebted to Dr. Amro Al-Qutub for the valuable time he spent throughout my thesis work and also for always being supportive and helping me during difficult times. Sincere thanks to Dr. Tahar Laoui for his interest and cooperation. I would also like to acknowledge all the Mechanical Engineering faculty members with whom I took courses during my master's program. Special thanks to Mr. Murtuza, Lateef Hashmi for helping me carry out the experimental work.

I would like to thank all my family members and friends for their strong encouragement at times of difficulty and for their patience and moral support which made this work possible and made me achieve one of the important goals of my life.

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CHAPTER 1

INTRODUCTION

The development of metal matrix composites (MMCs) has been one of the major innovations in materials which are rapidly replacing conventional materials in various applications such as automotive, aerospace, defense, sports, appliance and other industries. When compared to monolithic metallic materials, MMCs offer better physical, mechanical, thermal and tribological properties such as low density, high specific strength, high specific modulus, better fatigue resistance, improved wear resistance etc [1-3]. Generally, MMCs are defined as matrix materials (either metals or metallic alloys) that are reinforced with metals, ceramics, refractory metal, inter-metallic or semiconductor to combine the properties of reinforcing material with that of the matrix materials such that the resultant properties of the composite material are better than the properties of unreinforced materials. These MMCs are further divided into three main categories based on the shape of their reinforcement such as particles, fibers or whiskers. Among these three types of MMCs, particulate reinforced composites are of significant interest because (a) they exhibit isotropic properties, (b) can be successfully fabricated by using conventional metallurgical process, (c) can be machined using conventional methods and (d) low cost. The most commonly used particulate reinforcement for MMCs are ceramics such as silicon carbide and alumina because of their high strength, hardness and low cost. Depending upon the application, the end properties of these materials can be tailored based on some key factors such as type of processing, matrix constitution, type, size, amount, morphology, distribution and orientation of reinforcement, nature of matrix-reinforcement interface and heat treatment procedure. Among all these factors, compatibility of reinforcement with that of metallic matrix is of greater importance in realizing the best properties from the resultant composite [4-6].

From past few decades, MMCs with lightweight matrix materials are showing considerable interest because of their superior mechanical and tribological properties in many engineering applications [7-8]. As shown by many researchers, use of ceramic particulates such as SiC, Al_2O_3 as reinforcement reduced wear and friction of aluminum based MMCs both at room and elevated temperatures making them strong candidate material for a number of tribological applications such as piston, cylinder liners, engine blocks, brakes, power transfer system elements etc., in automobile industry [9-11]. However, continuous attempt by aerospace and automobile industries to push performance limits, constantly presents the crucial issue of weight reduction. In this connection, magnesium is 35% lighter than aluminum and is attracting more attention as the lightest structural material because of its low density and high specific strength and stiffness, which make them strongest applicant and an alternative to aluminum in many tribological applications in near future. However, pure magnesium cannot be directly used for tribological applications due to their low thermal stability and poor resistance to wear. To overcome these difficulties significant research work has been done over the last few decades to improve the performance of magnesium beyond traditional alloying using discontinuous reinforcement. Recently, magnesium based composites with nano-sized particulate reinforcements are receiving high attention due to their improved mechanical properties [12-14]. However, the study on the tribological properties of magnesium based MMCs with nano-particles as reinforcement are very less in the open literature.

Accordingly, the primary aim of the present study was to investigate the tribological behavior of magnesium based nanocomposites containing nano-size Al_2O_3, CNT, (Y_2O_3 + Cu) and (Y_2O_3 + Ni) particulate reinforcements. The effects of load, sliding speed and particulate content on the wear performance are investigated using a laboratory pin-on-disc wear tester designed and fabricated in Mechanical Engineering Department at KFUPM.

In the present work, Chapter 2 discusses the magnesium based metal matrix composites and their tribological behavior, and Chapter 3 describes experimental procedure used in the present study. Wear data obtained from the wear testing are presented in Chapter 4. And the wear mechanisms as identified by SEM and EDX analysis and their comparison with the obtained results are discussed in Chapter 5. Finally, the thesis ends with the main conclusions and recommendations for future work in chapter 6.

CHAPTER 2

LITERATURE REVIEW

The main motivation behind the development of composites is the utilization of advantageous properties of constituent materials to meet specific demands in many applications. The term "composite" is defined as the combination of two or more materials in which one of the material is termed as the reinforcing phase, which is in the form of fibers, whiskers, or particles, and is embedded in the other material termed as matrix phase (present in greater quantity in the composite) [15]. Typically, these materials have the ability to combine the properties of reinforcing phase with that of the matrix such that the resultant properties of the composite materials are better than the properties of monolithic counterparts. As a result of this, composite materials have the capability to serve a wide spectrum of applications [5, 16]. Composites can be broadly classified into three categories based on their matrix material namely: Metal Matrix Composites (MMCs), Polymer Matrix Composites (PMCs), and Ceramic Matrix Composites (CMCs). Among these three different types of composites, MMCs are one of the promising candidates for use in applications which require high strength and stiffness, particularly at elevated temperatures and for wear resistance applications [17].

2.1 Metal Matrix Composites and Nanocomposites

Metal matrix composite materials have been subject of scientific investigation and applied research from past few decades in the field of material science. These MMCs consists of two or more components namely: Matrix material (metal or metallic alloy) and Reinforcement (ceramics, metallic or refractory metal). Generally, the matrix is a "soft" phase (with excellent ductility, formability and thermal conductivity) in which "hard" reinforcements (with high stiffness and low thermal expansion) are embedded to improve its mechanical properties [6, 16, 18-20]. Previous studies on MMCs suggest particulate based reinforcement with size 1 to 100 microns as the most commonly used reinforcement due to their availability at competitive cost, well-developed cost effective fabrication process, ability to be machined using conventional methods and due to their isotropic nature [19]. Recently, more research in the field of production of nanocomposites is going on to explore the properties of MMCs when reinforced with nanoparticles (< 100 nm) instead of micron-sized particles. The challenge in developing these nanocomposites is to find different ways to create macroscopic components that benefit from the unique physical and mechanical properties of nanoparticles within them. The creation of these nanocomposites using nanoparticles as reinforcement has been investigated from past few years, and the development of these materials have shown comparable or greater strength and stiffness when compared to its micron sized MMCs [12-14, 22-23].

Today, increasing demand for the reduction of fuel consumption and environmental problems has led to intensive research efforts into design and development of lightweight

العنوان:	Wear Behavior of Magnesium Based Nanocomposites
المؤلف الرئيسي:	Zaboullah, Syed
مؤلفين آخرين:	Hassan, Syed Fida(Super)
التاريخ الميلادي:	2012
موقع:	الظهران، السعودية
الصفحات:	1 - 119
رقم MD:	621018
نوع المحتوى:	رسائل جامعية
اللغة:	English
الدرجة العلمية:	رسالة ماجستير
الجامعة:	جامعة الملك فهد للبترول والمعادن
الكلية:	عمادة الدراسات العليا
الدولة:	السعودية
قواعد المعلومات:	Dissertations
مواضيع:	الهندسة الميكانيكية، المغانسيوم، سلوك المغنيسيوم
رابط:	https://search.mandumah.com/Record/621018

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