EFFECT OF APPLIED LOAD AND THE SLIDING SPEED ON THE SUBSURFACE DEFORMATION OF WEAR ON HYBRID METAL MATRIX COMPOSITE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Manufacturing Engineering

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by

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Date : 22 June 2017

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Engineering Materials) (Hons).

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ABSTRACT

A recent study has focused on the surface and subsurface of a material that is subjected to wear. Subsurface deformation played an important role in wear mechanism which can cause considerable change in the microstructure of the material. These changes can lead to the change in material properties. Subsurface deformation of pure magnesium was tested while incorporating with 10 wt.% micro-sized silicon carbide (SiC) particles and 1 wt.% carbon nanotubes under four applied loads (5, 10, 20 and 40N) with two sliding speeds (0.5 and 1.5m/s). Microhardness testing was carried out to analyze the effect of different applied loads and the sliding speeds on the subsurface of a worn surface. It can be observed that the presence of hard reinforcements in a matrix increases the hardness of a material. As the addition, the extent of the subsurface deformation was also measured and the characterization of a worn surface was analyzed by using the optical microscope (OM) and scanning electron microscope (SEM). The extent of the deformation and banded structure in pure magnesium can be measured and seen clearly. This banded structure becomes larger as increasing in applied loads and sliding speed. Meanwhile, when silicon carbide (SiC) and carbon nanotube (CNT) were added, the banded structure was almost absent for each load and sliding speed. The finding of this study hope will lead to the benefits and aid the future researches as their guide for better understanding.

ABSTRAK

Kajian terdahulu telah menumpukan kepada permukaan dan sub-permukaan bahan yang tertakluk kepada haus. Sub-permukaan ubah bentuk memainkan peranan yang penting dalam mekanisme haus dimana ia boleh menyebabkan perubahan yang ketara di dalam mikrostruktur bahan. Perubahan ini boleh membawa kepada perubahan dalam sifat bahan. Ubah bentuk struktur di bawah magnesium tulen telah diuji manakala menggabungkan dengan 10 wt. % mikro saiz karbida silikon (SiC) dan 1 wt.% tiub nano karbon di bawah empat beban (5, 10, 20 dan 40N) digunakan dengan dua kelajuan gelongsor (0.5 dan 1.5 m/s). Ujian kekuatan mikro telah dijalankan untuk menganalisis kesan beban yang berbeza dan kelajuan gelongsor di bawah permukaan permukaan yang dipakai. Ia boleh diperhatikan bahawa kehadiran bala keras dalam matriks meningkatkan kekerasan bahan. Sebagai tambahan, takat ubah bentuk sub-permukaan juga diukur dan pencirian permukaan yang dipakai dianalisis dengan menggunakan mikroskop optik (OM) dan mikroskop elektron pengimbas (SEM). Sejauh mana perubahan bentuk dan struktur berkumpul dalam magnesium tulen boleh diukur dan dilihat dengan jelas. Struktur berbelang menjadi lebih besar kerana peningkatan dalam beban gunaan dan kelajuan gelongsor. Sementara itu, ketika karbida silikon (SiC) dan tiub nano karbon (CNT) telah ditambah, struktur berkumpul hampir tidak hadir untuk setiap beban dan kelajuan gelongsor. Dapatan kajian ini diharap dapat memberi manfaat dan membantu pengkaji akan datang sebagai panduan mereka untuk lebih memahami.

DEDICATION

I Humbly Dedicate to

My beloved father and mother,

Ahmad Mawardi Bin Mat Nooh and

Noor Liza Binti Mohd Sadali

For their understanding and courage

&

My supervisor,

Professor Dr. Qumrul Ahsan

For his infinite guidance and

support in completing this research

&

All my friends,

For their help in finishing this thesis

Thank you so much

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Finally, yet importantly, I would like to express my indebtedness thanks to my beloved parents for their blessings, love, courage, and understanding throughout finishing this project and also to all my friends for their help and support to me to carry on this project.

I failed to find the appropriate words that could properly describe my appreciation for their devotion, support, and faith in my ability to attain my goals. I ended it with a simple word, Thank you.

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LIST OF ABBREVIATIONS

Ag	-	Silver
Al	-	Aluminum
Al_2O_3	-	Alumina
ASTM	-	American society for testing material
Au	-	Gold
BCC	-	Body-centered Cubic
Cu	-	Copper
CMC	-	Ceramic Matrix Composite
CNT	-	Carbon Nanotube
EDX	-	Energy Dispersive X-ray
Fe	-	Iron
FCC	-	Face-centered Cubic
HCP	-	Hexagonal Closed Pack
Mg	-	Magnesium
MMC	-	Metal Matrix Composite
MML	-	Mechanically Mixed Layer
MoS_2	-	Molybdenum Disulfide
MWCNT	-	Multi-walled Carbon Nanotube
OM	-	Optical Microscopy
Pb	-	Lead
PM	-	Powder Metallurgy
PMC	-	Polymer Matrix Composite
PPE	-	Personal Protective Equipment
PSA	-	Particle Size Analyzer
SEM	-	Scanning Electron Microscopy
SiC	-	Silicon Carbide
SWCNT	-	Single-walled Carbon Nanotube

Ti	-	Titanium
TiC	-	Titanium Carbide
Zn	-	Zinc

LIST OF SYMBOLS

g/cm^3	-	Gram per centimeter cube
^{o}C	-	Degree Celsius
MPa	-	Mega Pascal
α – quartz	-	alpha quartz
GPa	-	Giga Pascal
TPa	-	Tera Pascal
%	-	Percentage
μ	-	Micron
F	-	Friction force
N	-	Normal force
V	-	Wear volume
k	-	Wear coefficient
P	-	Applied load
H	-	Hardness
L	-	Sliding Distance

CHAPTER 1

INTRODUCTION

1.1 Background Study

Metal matrix composite (MMC) is a combination of at least two constituents, which are metal and the other material may be a different metal or another material like ceramic or organic compound. Meanwhile, the hybrid composite is usually multilayer composites with mixed fibers. There are a few metal-based composite systems such as aluminum (Al), copper (Cu), titanium (Ti), magnesium (Mg) etc. Magnesium alloys have been used in this project and due to its lightweight with a density of 1.74 g/m^3 which is two-thirds of aluminum, one-quarter of zinc and one fifth of iron; Mg-MMC shows many benefits over monolithic magnesium or magnesium alloys as it is the lightest metal structure material. Apart from that, Mg-MMC also has shown other advantages, for example, high elastic modulus, high strength and good wear resistances at elevated temperatures. Nevertheless, due to the low ductility of Mg, it limits its widespread application (Dey & Pandey, 2015).

In this research, SiC has been used as the reinforcement. On the bright side, the addition of SiC improve the hardness of pure Mg but it also causes the increasing in wear rates which causes can lead to the high coefficient of friction. The presence of wear in a material can cause a substantial change in the structure of the subsurface to a point where it becomes somewhat different from bulk materials which adjustment can lead to a reduction in resistance to fatigue and creep (Basavarajappa et al., 2007).

To reduce the effect of wear in the material, nanofiller composite resins will be added. The reduction size of the reinforcement to the nano-scale may improve the mechanical properties of the MMC (Casati & Vedani, 2014). Carbon Nanotubes (CNT) as the nanofiller will significantly improve the tribological properties of the whole system under the sliding wear conditions where it may stabilize the wear as the amount of the nanofiller is increased.

1.2 Problem Statement

Magnesium and its alloy have gained a lot of attention in a scientific study as energy conservation and performance demands are increasing because of their low density and high specific strength as compared to other structural metals. However, the application of magnesium alloys is restricted clearly due to their poor creep resistance at high temperatures, low strength, low modulus and wear resistance (Dey & Pandey, 2015). This lack in properties can be reduced by adding reinforcement which helps to improve the properties of the base metal. Subsurface deformation also played a vital role in wear mechanism. This subsurface deformation is controlled by the filler inside the composite. Furthermore, the reinforcement such as SiC, Al_2O_3, TiC etc. may increase the ultimate tensile strength, hardness, ductility and wear resistance of Mg but only at a lower load (Dey & Pandey, 2015). A few studies have been carried out to characterize the subsurface deformation with the presence of nanofiller. The addition of CNTs in a matrix will increase the wear resistance of composite, but the mechanical properties decline beyond the critical loading of CNTs. Hybrid MMC was introduced for further intensifying the tribological properties and mechanical properties of the materials. Subsurface deformation will be tested while incorporating with Mg, Mg/SiC, and Mg/SiC/CNT. Published literature have shown no evidence of study on subsurface deformation of wear on the hybrid MMC with SiC and CNT.

1.3 Objective

The objectives of this research are as follows:

i. To analyze the effect of different applied loads and the sliding speeds on the hardness behavior of the subsurface of the worn surface by using microhardness testing.

ii. To determine the extent of subsurface deformation and characterization of the worn surface by an optical microscope (OM) and scanning electron microscopy (SEM).

1.4 Scope

This project will focus primarily on the experimental work on the effect of applied load and the sliding speed on the subsurface deformation of wear on hybrid metal matrix composite. There are several variables that need to be analyzed such as the effect of subsurface deformation on the wear mechanism and the extent of the subsurface deformation based on applied loads or varying the sliding speed. This report will carry out the microhardness testing on the deformation band of wear surface. Lastly, the specimen will be prepared for morphological study then evaluates the subsurface microstructure of the specimen by using Optical Microscope (OM) and Scanning Electron Microscope (SEM).

1.5 Project Significance

The finding of this study will lead to the benefits and help the future researcher as their guide to achieve the objectives of the project as mention before. Previous published literature have not covered much about the study on the deformation of wear surfaces on the hybrid MMC with SiC and CNT. Therefore, by completing this research, it may aid the future researchers and students to have a better understanding regarding this topic.

1.6 Dissertation Outline

The content of this project can be organized in five chapters, such as introduction, literature review, methodology, results and discussion and conclusion and recommendation as shown in the figure below:

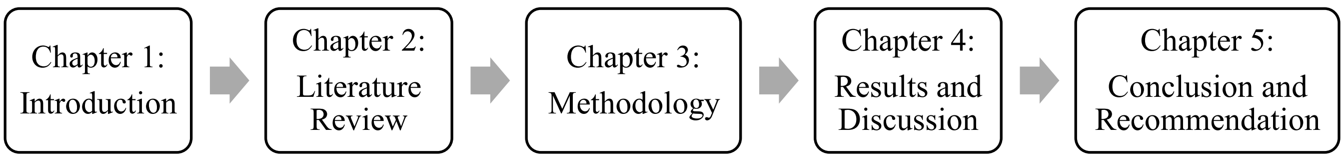

Figure 1.1: Structure of the dissertation

Based on figure 1.1, Chapter 1 will describe the introduction of this research which includes background studies of metal matrix composites (MMC) and its application. Besides that, problem statement, objective and scope will also be explained in this chapter. In chapter 2, it will summarize and organized published literature which includes the background of composite materials, types of metal matrix composites, selection of metal matrix composite, types of reinforcements used, details of fabrication methods for magnesium based composites. This fabrication method will focus more on powder metallurgy method. Furthermore, chapter 3 will present the experimental methodology and technique used in the research, including raw materials, equipment used, processing techniques and characterization techniques that carried out to analyze the hardening effect on the wear subsurface and the extent of the subsurface deformation and characterization of the worn surface. All the testing data will be compiled in chapter 4 and the discussion of the results. Finally, is a conclusion and recommendation that required for future researchers works in this scope will be concluded in chapter 5.

CHAPTER 2
LITERATURE REVIEW

2.1 Composite

The composite can be described as a product which is formed by the close combination of two or more discrete physical phases, usually a solid matrix and reinforcement (Matthew & Rawlings, 1999). However, this definition must fulfill another three criteria before a material can be called as composite, which is both constituents must be present in reasonable proportions, next is only when the constituent phase has different properties and lastly is a man-made composite which generally composed by mixing and combining the constituent by various metal. Most of the composites contain a bulk material and a reinforcement that added basically to boost the strength and the stiffness of the matrix.

The composite can be categorized into three types of the matrix material, which are Polymer Matrix Composite (PMC), Metal Matrix Composite (MMC) and Ceramic Matrix Composite (CMC). Generally, PMC has low strength and Young's Modulus, while CMC are strong, stiff and more brittle and MMC have intermediate strengths with good ductility. Another constituent is reinforcement. Reinforcement can be recognized as being fibrous or particulate. Particulate reinforcements have dimensions that equal in all directions. The shape of the reinforcing particles may be any regular or random geometry. While fibrous reinforcement is characterized by its length which is bigger than its cross-sectional dimension (Matthew & Rawlings, 1999).

2.2 Metal Matrix Composite (MMC)

Metal Matrix Composite (MMC) is a combination of metals and alloys which are generally produced and shaped in bulk form but can also be combined with another material to increase their performance. The density of most non-ferrous MMCs which is one-third of steels are resulting in high specific strength, stiffness, high specific modulus, good properties at elevated temperature and better wear resistance (Matthew & Rawlings, 1999; Seeman et al., 2010). However, their toughness is less to monolithic metals and quite expensive. Physically MMC also have high electrical and thermal conductivities, non-inflammability and resistance to most radiations.

2.3 Matrix Materials for MMC

Matrix materials for MMC can be classified into two types, which is ferrous and non-ferrous metal. Ferrous metals usually contain iron with small amounts of other metals or elements added which include iron and steel. While non-ferrous metals do not contain iron, for example, Cu, Al, Zn, Ag, Pb, Au etc. Aluminum, titanium, and magnesium are the most used matrix material compared to other.

2.3.1 Aluminum

Aluminum (Al) is the most commonly used and famous matrix material in a metal matrix composite. It is a silvery-white metal with an atomic number of 13 is a chemical element that is arranged in a face-centered cubic (FCC) structure with a density of 2.70 g/cm^3 (Lall et al., 2015). Because of its softness, pure aluminum strength can be increased through alloying and reinforcements. Aluminum is popular among researcher because it is easy to process and has about one-third the density and stiffness of steel.