TRIBOLOGICAL PERFORMANCE OF HYBRID COMPOSITES BASED ON PALM KERNEL ACTIVATED CARBON AND ALUMINA BLEND

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DECLARATION

I declare that this report entitled “Tribological Performance Of Hybrid Composites Based On Palm Kernel Activated Carbon And Alumina Blend” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : CHEN WEI WEI

Date : .....

APPROVAL

I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality for the award of degree of Bachelor of Mechanical Engineering.

Signature : .....

Supervisor Name : PROF. MADYA DR. MOHD FADZLI BIN ABDOLLAH

Date : .....

DEDICATION

Dedicated to my beloved father and mother,

my friends and family members

for their encouragement and supports throughout the research.

ABSTRACT

Nowadays, it is expected the demand of new composites with optimum tribological performance is growing in industry applications. Hybrid composites are finding increased applications because of the improved mechanical properties and wear resistance and hence are better substitutes for single reinforced composites. On the recent global green technology trend, innovative and sustainable raw materials are becoming a priority choice for manufacturer. Agricultural wastes may consider as potential sustainable materials such as carbon consisting wastes to be treated as new reinforcement substitutes in enhancing tribological properties. There are limited tribology studies regarding to reinforcement of agricultural wastes carbon with good wear properties metal. The objectives of this study were to determine optimal composition and tribological properties of blended hybrid composite sample of Palm Kernel Activated Carbon (PKAC) with Aluminium Oxide/ Alumina, AL_2O_3 and to compare its wear performance with conventional composites, SK2 carbon steel disc by conducting ball-on-disc tribometer dry sliding test. Basically, PKAC and AL_2O_3 were measured according to the set compositions and pressed into disc shaped with size of 74mm diameter using hot compaction technique. Some basic mechanical tests were done when the disc specimens were ready such as surface roughness and hardness tests. Then, specimens were tested through ball-on-disc tribometer test under unlubricated condition at room temperature and surface morphology of specimens were studied by using 3D Surface Profilometer. Collected data were analyzed through qualitative and quantitative approaches. This study has found that friction coefficient and wear rate are highly affected by composition percentages with respect to weight of samples due to the amount of content of PKAC, AL_2O_3 and epoxy. Through the comparison between two hybrid composites, PKAC+AL/E (60/40) exhibit lower friction coefficient than PKAC+AL/E (50/50) with difference of 0.057 while for specific wear rate, PKAC+AL/E (60/40) is slightly higher than PKAC+AL/E (50/50) with insignificant difference of 8.530×10^{-8} mm^3/Nmm. Hence, PKAC+AL/E (60/40) was suggested as optimal composition hybrid composites which exhibited better wear performance in this study.

ABSTRAK

Pada masa kini, permintaan komposit baru dengan prestasi tribologi optimum telah berkembang dalam aplikasi industri. Aplikasi komposit hibrid meningkat kerana sifat-sifat mekanikal dan rintangan haus yang lebih baik. Oleh itu hibrid dianggap sebagai pengganti yang baik berbanding dengan komposit bertetulang tunggal. Mengenai trend teknologi hijau global baru-baru ini, bahan mentah yang inovatif dan mampan menjadi pilihan utama bagi industri. Bahan buangan agrikultur boleh dipertimbangkan sebagai bahan berpotensi yang mampan terutamanya bahan buangan yang mengandungi karbon dianggap sebagai pengganti tetulang baru dalam meningkatkan sifat-sifat tribologi. Berdasarkan kajian-kajian sebelum ini, kajian tribologi masih terhad tentang pengukuhan antara bahan buangan agrikultur yang mengandungi karbon dengan logam yang mempunyai prestasi tribology yang baik. Objektif kajian ini adalah menentukan komposisi optimum dan sifat-sifat tribologi tentang campuran komposit hibrid antara kernel sawit diaktifkan karbon (PKAC) dengan aluminium oksida / alumina, AL_2O_3 serta membandingkan prestasi tribologinya dengan komposit konvensional, disk keluli karbon SK2 dengan menggunakan tribometer "ball-on-disc" dalam keadaan yang tiada pelinciran. Pada asasnya, PKAC dan AL_2O_3 diukur mengikut komposisi yang ditetapkan dan ditekan ke bentuk disk dengan diameter 74mm menggunakan teknik pemadatan panas. Beberapa ujian mekanikal asas telah dilakukan seperti ujian kekasaran permukaan dan ujian kekerasan. Kemudian, spesimen diuji melalui tribometer "ball-on-disc" di bawah keadaan tiada pelinciran pada suhu bilik dan morfologi permukaan spesimen telah dikaji dengan menggunakan 3D Surface Profilometer. Data yang dikumpulkan dianalisiskan melalui cara kualitatif dan kuantitatif. Kajian ini mendapati bahawa faktor yang mempengaruhi pekali geseran dan kadar haus ialah peratusan komposisi yang berdasarkan berat sampel, jumlah kandungan PKAC, AL_2O_3 dan epoksi. Melalui perbandingan antara dua komposit hibrid, PKAC + AL / E (60/40) mempunyai pekali geseran yang lebih rendah daripada PKAC + AL / E (50/50) dengan perbezaan 0.057 manakala untuk kadar haus spesifik, PKAC + AL / E (60 / 40) lebih tinggi daripada PKAC + AL / E (50/50) dengan perbezaan yang tidak signifikan 8.530×10^{-8} mm^3 / Nmm. Oleh itu, PKAC + AL / E (60/40) dicadangkan sebagai komposit hibrid yang mempunyai komposisi optimum dan memaparkan prestasi tribologi yang paling baik dalam kajian ini.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
Al	Aluminium
AL	Alumina
Al_2O_3	Alumina / Aluminium Oxide
AMC	Aluminum Matrix Composite
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
B_4C	Boron Carbide
CoF	Coefficient of Friction
DIN	Deutsches Institut für Normung (German Institute for Standardization)
E	epoxy
EFB	Empty Fruit Brunches
FIB	Focused Ion Beam
GDP	Gross Domestic Product
Gr	Graphite

LST	Low Surface Temperature
OPF	Oil Palm Fronds
OPMF	oil palm mesocarp fibre
OPS	oil palm shell
OPT	Oil Palm Trunks
PKAC	Palm Kernel Activated Carbon
PKS	Palm Kernel Shells
POME	Palm Oil Mill Effluent
PPF	Palm Pressed Fibers
PSAC	Palm Shell Activated Carbon
PSM	Projek Sarjana Muda
RHA	Rice Husk Ash
SiC	Silicon Carbide

LIST OF SYMBOLS

F	=Frictional Force
H	=Hardness of Rubbed Surface
K	=Wear coefficient
k	=Specific Wear Rate
L	=Sliding Distance
Ma	=Mass after sliding test
Mb	=Mass before sliding test
M_{loss}	=Loss of Mass
r	=Radius of Disc Sample
t	=Thickness of Disc Sample
t	= Time
t_S	=Time to reach steady state
V	=Wear Volume
V_{loss}	=Loss of Volume
W	=Applied Load
ρ	=Density

CHAPTER 1

INTRODUCTION

1.1 Background of Study

During the previous decade, the need for the new wear resistant material for high performance tribological applications has been one of the major driving forces for the tribological development. Importance of tribological properties influenced many researchers to study friction and wear behavior of lubricant materials and at the same time to identify the best composition of composites for various industrial applications (Kathiresan and Sonarkumar, 2010). This is due to the rapid growth of automotive, aerospace and biomedical fields which cause the growing demand of generating improved composites with optimum wear performance for certain harsh industrial applications (Jost and Peter, 1966). Previous tribology studies have introduced a few methods to enhance wear properties such as coating, alloying and composites reinforcement. In this study, the method used to test and enhance the wear properties of hybrid composites is composites reinforcement. Hybrid composites are finding increased applications because of the improved mechanical and wear resistance and hence are better substitutes for single reinforced composites (Slobodan et al., 2011). Hybrid materials are 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. The hybrid composites used in this study consist of palm kernel activated carbon-epoxy (PKAC-E) and alumina (with the chemical formula of Al_2O_3) which are the organic and inorganic compound respectively. Nowadays, activated carbon started emerged in

tribological applications due to its high porosity which provide large surface area. By referring to Yusoff et al. (2010), graphite and porous carbon such as palm shell activated carbon exhibited its potential to act as a self-lubricating material when reinforced in aluminum alloy, which significantly improved wear resistance by increasing palm shell activated carbon (PSAC) content up to 10 wt.% (Yusoff et al., 2010). Due to the potential of PSAC, PKAC has become an interesting research material in tribology field. Based on the previous studies, researchers stated a hypothesis that the excellent performance shown by the materials (PSAC) were obtained through residual oil from the palm fruit. Hence, the hypothesis supported the possibility of PKAC may also carry the residual oil from palm oil fruit (Tahir et al., 2017). Zamri (2012) found the content of reinforcement (PSAC and slag) had significant effect on wear resistance of aluminum matrix composite. The results showed the wear resistance of hybrid composite is better than un-hybrid composite due to the good bonding of slag particles in aluminum matrix causing improved the ability in supporting load. Prasad and Shoba (2014) have studied the dry sliding wear behavior of unreinforced alloy and hybrid composites through pin-on-disk wear test and the result showed the hybrid composite (aluminium, Al/ rice husk ash, RHA/ silicon carbide, SiC) exhibit higher wear resistance than the unreinforced alloy. Thus, a few of these previous studies proved that there are possibilities and potentials exhibited for activated carbon (PSAC/PKAC) and aluminum as one of the major research materials in tribological applications development. Last but not least, the global awareness of promoting the sustainable and environmental friendly products had influenced the increasing of demand in replacing synthetic composites materials with natural-based or secondary source of materials such as wastes or biomass products. Hence, this is one of the motivations for researchers to investigate the new reinforcement substitutes from agriculture wastes in order to be used in fabrication of composites which able to be classified as one of the effective self-lubricating materials.

1.2 Problem Statement

The global impact of friction and wear on energy consumption, economic expenditure, and carbon dioxide emissions are still considerable (Jost and Peter, 1966). Based on "Influence of tribology on global energy consumption, costs and emissions" which published by Holmberg and Erdemir (2017), they considered four main energy consuming sectors which are transportation, manufacturing, power generation and residential. In these four sectors, 23% of the world total energy consumption originates from tribological contacts. Of that 20% is used to overcome friction and 3% is used to remanufacture worn parts and spare equipment due to wear and wear-related failures. Lubrication technologies for reduction of friction and wear in automation and machinery can reduce energy losses by 40 % in 15 years and by 18% in 8years. These savings would amount to 1.4% of GDP (Gross Domestic Product) per year and 8.7% of the long term total energy consumption on a global scale (Holmberg and Erdemir, 2017). Although there were many researches about tribological studies, few of them focused on friction and lubricants of hybrid composites. A clear understanding of effect of the composites' compositions on wear behavior is very essential for maximized the work efficiency. Therefore, a basic awareness of tribology in wear is important to increase the work performance efficiency of machinery without wasting valuable resources, reduce the cost of maintenance and avoid common manufacturing issues.

Previously, there are several studies on wear behavior of hybrid composites which undergoes hard reinforcement by using silicon carbide or soft reinforcement by using carbon. However, the studies and information available recently for natural-based material reinforcement such as PKAC is limited. Yusoff (2012) has done a similar research on physical and wear properties of hybrid biomass by-product particulates reinforced aluminum matrix composite (AMC) which the reinforcement is using PSAC and slag. His study's result showed that hybrid composite (undergoes PSAC and slag reinforcement) has better wear

resistance than un-hybrid composite. Hence, PKAC similar with PSAC as one of the palm oil extraction wastes is chosen in this study because it may be a potential self- lubricating material as well.

Malaysia palm oil production is the world's second- largest producer of the commodity after Indonesia. The biomass produced by Malaysia oil palm industries has created severe disposal problems. The solid wastes produced are empty fruit brunches (EFB), oil palm trunks (OPT), oil palm fronds (OPF) palm pressed fibers (PPF) and palm kernel shells (PKS) and palm oil mill effluent (POME). POME digestion gas which consists of methane will cause the ozone depletion and reduce the air quality. Incineration of EFB can be used for power generation and PKS is potential to be used as self-lubricating materials by transforming it into activated carbon. However, current practice is actually wasting the potential renewable energy resources. Moreover, by looking into the conventional hybrid composites recently, there is limited creation of the renewable sources-based hybrid composites which able to turn the biomass wastes residues into wealth.

In conclude that maximizing the usage of secondary resources and renewable energy is desirable for both economic and environmental reasons. In this study, an attempt is made in developing a new reinforced hybrid composite as one of the alternative self-lubricating material which is sustainable, effective and environmental friendly.

1.3 Objectives

Objectives of this study are:

a) To determine the optimal composition of the hybrid composites based on palm kernel activated carbon and alumina blend;
b) To investigate the tribological properties of the hybrid composite samples under dry sliding conditions;
c) To compare the tribological performance of the hybrid composites with the conventional composites, SK2 carbon steel disc;

1.4 Scope

Scope of this study:

1. Materials	: Palm Kernel Activated Carbon, Alumina and Epoxy
2. Samples compositions	: Shown in Table 1.1 below
3. Machine	: Ball-on-disc Tribometer
4. Load	: 49.05N (5kg)
5. Sliding Speed	: 400rpm
6. Sliding Distance	: 3000m
7. Surrounding Temperature	: Room temperature
8. Sliding Test Standards	: ASTM G99-95a

Table 1.1: Composition percentages of testing composites

Sample	Palm Kernel Activated Carbon (PKAC), %	Alumina (Al_2O_3), %	Epoxy, %
PKAC+AL/E	25	25	50
PKAC/E	50	-	50
AL/E	-	50	50
PKAC+AL/E	30	30	40
PKAC/E	60	-	40
AL/E	-	60	40
PKAC+AL/E	35	35	30
PKAC/E	70	-	30
AL/E	-	70	30

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

There is an increasing worldwide need for high wear performance materials such as hybrid composites. Recently, many researches have been conducted in the development of materials to investigate suitable materials with broad spectrum of properties combinations which to fulfill the demand of wide range engineering applications. For example, those combinations are high specific strength, low coefficient thermal expansion and high thermal resistance, good damping capacities, superior wear resistance, high specific stiffness and satisfactory levels of corrosion resistance (Ravindran et al., 2012). Previous studies have found that the hybridization of two reinforcements able to improve wear resistance, to reduce wear loss and have a lower friction coefficient which are the major topics in tribology (Bodunrin et al., 2015; Guo and Tsao, 1999; Ravindran et al., 2012).