TRIBOLOGICAL STUDIES ON ULTRA HIGH MOLECULAR WEIGHT POLYETHYLENE WITH PALM KERNEL SHELL IN DRY CONDITION

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DECLARATION

I declared that this project entitled “Tribological Studies on Ultrahigh Molecular Weight Polyethylene with Palm Kernel Shell in Dry Condition” is the result of my own work except as cited in the references.

Signature	:	....
Name	:	....
Date	:	....

APPROVAL

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

Signature	:	....
Supervisor's Name	:	....
Date	:	....

DEDICATION

To my beloved mother and father, family members and friends who's been with me throughout an incredible journey of this 23 years of life.

ABSTRACT

Ultra high molecular weight polyethylene (UHMWPE) is self-lubricating polymers that widely used for reducing friction and wear in dry condition. Despite that, there are some aspects such as poses a low load bearing capacity and inferior thermal conductivity which can limit its application. Therefore, this study is conducted to develop a composite of UHMWPE reinforced with palm kernel shell (PKS) with varying compositions and investigate the tribological performance of the composite. All specimens were fabricated into 74 mm diameter disc of 4 mm height with different compositions (0, 5, 10, and 15 wt%) of PKS by undergo hot press process. Tribological test was run utilizing pin-on-disc tribometer. The outcomes demonstrated that the coefficient of friction (COF) and wear rate were steadily decreased as the composition of PKS is enhanced. The pure UHWMPE have the highest COF and wear rate of 0.086 and 6.24 x 10^{-6} mm^3/N.mm while the UHMWPE reinforced 15 wt% PKS have lowest COF and wear rate of 0.063 and 5.13 x 10^{-6} mm^3/N.mm. PKS is considered as one of the most potential reinforcement as carbonaceous fillers among the engineered and other agrarian waste based polymeric composite

ABSTRAK

Ultra high molecular weight polyethylene (UHMWPE) merupakan polimer pelincir diri yang digunakan secara meluas untuk mengurangkan geseran dan kehausan pada keadaan geser kering. Walau bagaimanapun, terdapat beberapa aspek seperti ianya mempunyai kapasiti galas bebanan yang rendah dan kekonduksian terma yang kurang baik yang boleh menghadkan penggunaannya. Oleh itu, kajian ini dijalankan adalah bertujuan untuk menghasilkan komposit UHMWPE yang diperkuat oleh cengkerang kelapa sawit (PKS) dengan komposisi yang berbeza serta mengkaji prestasi tribologi komposit tersebut. Semua spesimen telah difabrikasi yang berbentuk cakera mempunyai diameter 74 mm dan ketinggian 4 mm dengan komposisi PKS yang berbeza (0, 5, 10, dan 15 wt%) melalui proses 'hot press'. Ujian tribologis dijalankan menggunakan mesin pin-on-disc tribometer. Keputusan menunjukkan bahawa pekali geseran (COF) dan kadar kehausan semakin berkurang apabila komposisi PKS dipertingkatkan. UHWMPE tulen mempunyai COF dan kadar kehausan yang paling tinggi iaitu 0.086 dan 6.24 x 10-6 mm^3 / N.mm manakala UHMWPE yg diperkuat 15 wt% PKS mempunyai COF dan kadar kehausan yang paling rendah iaitu 0.063 dan 5.13 x 10-6 mm^3 / N.mm. PKS dianggap sebagai salah satu agen pengukuh paling berpotensi sebagai pengisi karbon di antara komposit polimer berasaskan buangan sintetik dan pertanian.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

UHMWPE	-	Ultra-High Molecular Weight Polyethylene
PKS	-	Palm Kernel Shell
COF	-	Coefficient of Friction
PTFE	-	Polytetrafluoroethylene
DLC	-	Diamond-Like Carbon
GNPs	-	Graphene Nanoplatelets
DSC	-	Differential Scanning Calorimetry
CF	-	Carbon Fibre
PKAC-E	-	Palm Kernel Shell Activated Carbon-Epoxy
ASTM	-	American Society for Testing and Material
SEM	-	Scanning Electron Microscopy
EDX	-	Energy-dispersive X-ray Spectroscopy

LIST OF SYMBOLS

D	-	Distance of slide, m
r	-	Radius wear track, m
N	-	Sliding speed, rpm
t	-	Time, min & sec
F	-	Frictional force, N
W	-	Applied load, N
V_{loss}	-	Volume loss, mm^3
a	-	Wear scar radius, mm
h	-	Wear depth, mm
L	-	Sliding distance, mm

CHAPTER 1

INTRODUCTION

1.1 Background of study

Tribology is the study and application of principles of friction, wear and lubrication. As indicated by Oxford Dictionary ‘tribo-’ is gotten from the Greek word ‘*tribos*’, which means rubbing and friction. The phenomena of tribology have been discovered for decades ago. In 1996, it was published in the Jost Report (Lubrication (tribology) Education and Research, Department of Education and Science, HMSO, 1966) and was officially clarified as ‘The science and technology of contact surfaces in relative movement and the practices identified with that (Jin & Fisher, 2014). Since then, the word ‘tribology’ has been generally used and study on this field has been widely researched. Tribology is a branch of science and engineering that deals with the contact of surfaces in relative movement in man-made and artificial systems. These systems include mechanical components, transportation systems), biomedical devices, living bodies, manufacturing technologies, electrical contacts and others.

Wear and friction are the two fundamental sources of energy and material losses in tribological conjunctions of mechanical systems. Lubrication is the principal focus to enhance energy efficiency and mechanical durability. Previous studies on tribology have resulted some favourable techniques of controlling wear, for example, film coating, multi-stage alloying, and composite structuring (Mat Tahir et al., 2015). In dry sliding state, ultrahigh molecular weight polyethylene (UHMWPE) which is a self-lubricating polymer have been explored as the solution to minimize wear and friction (Aliyu et al., 2018). UHMWPE is a subset of the thermoplastic polyethylene that are widely used in industrial application such as unlubricated bearings, liners, gears, and seals due its attractive properties (Ahmad et al., 2013). According to (Aliyu et al., 2018), these include high abrasion resistance, good impact strength, low coefficient of friction (COF) and resist to wear better than other polymers. Despite of that good properties of UHMWPE, there are also some factors that affect its properties. Therefore, the incorporation of reinforcement like carbonaceous fillers can result a better tribological properties of UHMWPE.

Previous research discovered that carbon-based materials can act as a self-lubricating material when reinforced with various materials. Palm Kernel Shell (PKS) is a palm oil extraction waste material consisting of carbon characteristics which can be transformed into a self-lubricating material with a low COF and high resistance to wear (Mahmud et al., 2017). Malaysia produces around 4 million tons of PKS every year. (Itam et al., 2016) stated that both policy of "Zero Waste Concept" introduced by Malaysian Palm Oil Board (MPOB) and improving tribological properties at a low cost can be accomplished by utilizing carbon-based materials from agricultural waste materials to formulate a new polymer matrix composite. PKS is easy to conduct with no side effects, so that make it as environmentally friendly and renewable resources. PKS has good thermal insulation, low density, structurally adequate, lightweight and high in strength. (Dnoke, 2006) studied that the utilization of PKS in the development of structural lightweight concretes improved the mechanical strength, thus PKS is capable to be used as base material in friction composites, to resist the high impact and variable force. The coefficient of friction (COF) of PKS on metal surfaces is in the range of 0.37-0.52 (Mgbemena et al., 2014). Thus, PKS is likely a suitable substance to be reinforced with UHMWPE to improve the tribological properties.

1.2 Problem statement

Despite of the wide use of UHMWPE in mechanical component, transportation system and manufacturing technologies, the poor load bearing capacity of UHMWPE limit its utilization in tribological applications. Besides, its high viscosity cause complication in the fabrication process and also the restriction for high contact sliding speed application due to its poor thermal conductivity (Aliyu et al., 2018).

Researchers over the years have studied various method to overcome these hurdles, and one of the methods is by developing a matrix composite of UHMWPE reinforced with ceramic, metallic, carbon-based, and mineral fillers (Mohammed, 2018). However, the current commercial self-lubricating filler materials such as graphite, layered silicate and etc, are relatively expensive in the global market (Mat Tahir et al., 2016). Thus, it required high cost in order to produce a new polymer matrix composite.

Lastly, the utilization of PKS, which produce in large quantities per year as reinforcement in the fabrication of polymer matrix composite have potential to achieve zero waste strategy with economical budget. The physical properties of PKS, which its biodegradability ensures the environmental friendliness when the product wears debris decomposes. Therefore, the tribological studies on UHMWPE with PKS in dry condition will be investigated in this study.

1.3 Objective

The objective of this study is to study the effect of different composition of PKS reinforcement to the tribological performance of UHMWPE.

1.4 Scope

The study covers the development of specimen of UHMWPE reinforced with PKS with different compositions. Hardness, surface roughness, friction and wear test were directed and the characterization of mechanical and tribological properties was observed. The test conducted also to determine the optimum composition. The analysis of the composites will be done by using scanning electron microscopy (SEM) in order to investigate the tribological properties of the composites.

1.5 General Methodology

The descriptions and details of methodology to achieve the objective will be explained in Chapter 3. Generally, the flow in order to accomplish this project are as follows;

a) **Literature review**

Collecting data of previous studies from journal, article, book, website and any related material about the project.

b) **Experiment setups**

The specimen of UHMWPE reinforced with PKS will be prepared with varying compositions of 0.5, 0.10 and 0.15 wt% through the ball milling process to ensure the materials are homogeneously dispersed. Hot pressing will be used to consolidate the prepared powder.

c) **Experiment and analysis**

The experiment will focus on friction and wear test by using a pin on disc test. The test will be conducted for pure UHMWPE and composites with varying compositions. The tribological properties will be collected and analysed to investigate the tribological performance.

d) Thesis writing

A complete thesis will be written which include all the data and analysis from the experiment.

The general methodology of this study is simplified in the flow chart as shown in Figure 1.1.

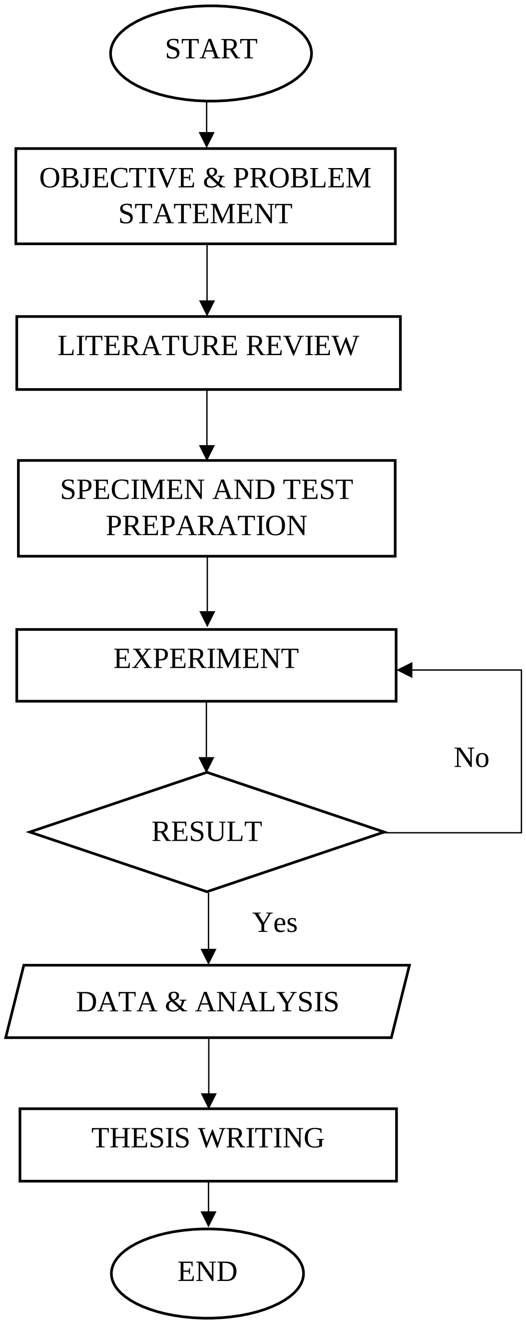

Figure 1.1: Flow chart of general methodology

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews previous research and sources obtained from journals, articles, reports, books and web sites to find the information related to this study. The aim of this chapter is to create a guideline from previous knowledge and ideas in order to complete this project. The information is selected based on the objectives of this study. For instance, the information about tribological studies, UHMWPE, PKS and pin-on-disc test are acquired to achieve the objectives.

This chapter is organized as follows. The second section which is Section 2.2 describes on tribological studies. Section 2.3 continues with the discussion of the UHMWPE studies while Section 2.4 explains about previous study on PKS, which will be reinforced with UHMWPE to be investigated in this study.

2.2 Tribological study

Tribology is characterized as the investigation of science and technology of contact surfaces in relative motion. Friction, wear and lubrication are the main components in tribological study. In 1966, Peter Jost introduced the word tribology which comes from the Greek, meaning 'the study of things that rub' and it was officially published in Jost Report. Leonardo da Vinci was the first to discover the two-fundamental law of frictions back in 1943, however, his discovery remains unpublished. In the beginning of the twentieth century, the extensive growth in industrialization led to the needed for a better understanding of tribology. Since then, the knowledge in all fields of tribology has enlarged widely. (Kapsa, 2011) stated that the mechanism of tribology needs to be studied in order to understand this field and improves the technology. The mechanisms are consisting of machine components, for example, gears, bearings, clutches, cables and all the way to human joints. The mechanisms are operators which require forces, speeds, etc., act on the moving object and form the output of friction force, wear and temperature.

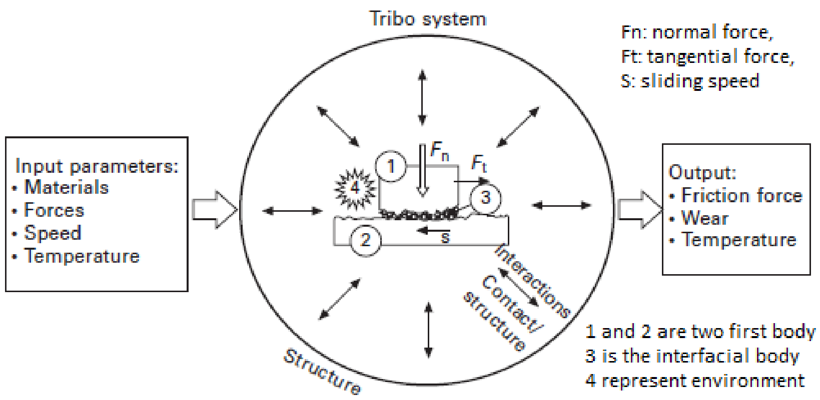

Figure 2.1: The various components of the tribo system (Kapsa, 2011)

2.2.1 Tribology in automobile engine

In the automotive sector, the utilization of tribological principles is important for the reliability of motor vehicle and has the prompted broad development in the tribology field. Engine durability improvement and lower vehicles maintenance cost are the most crucial challenges for the automotive industry. Energy lost in vehicles is mainly from the engine which approximately 62% of the lost. The high percentage of energy lost increase the amount of the fuel consumption, thus, result to the lower fuel efficiency. Nevertheless, in the past few years, the industry has gained extraordinary ground in improving energy utilization by limiting rubbing in vehicles. The turbocharged, direct-injection spark ignition engine with scaling back is one of the elective ways that have been utilized in the market (Wong & Tung, 2016).

Significant results on the fuel economy and the environment in a long term can be accomplished even with the littlest enhancements in the effectiveness of engine, emission quantity and durability. The energy from the fuel combustion process will be diffused in an engine and powertrain system. For medium size passenger car, just 12% of the energy has been accessible to drive the wheels while some 15% being dematerialized as energy lost mostly frictional losses. Previous fuel utilization information shows that, a decrease of 1.5% in fuel utilization was occurring due to 10% reduction in mechanical losses (Tung & McMillan 2004).

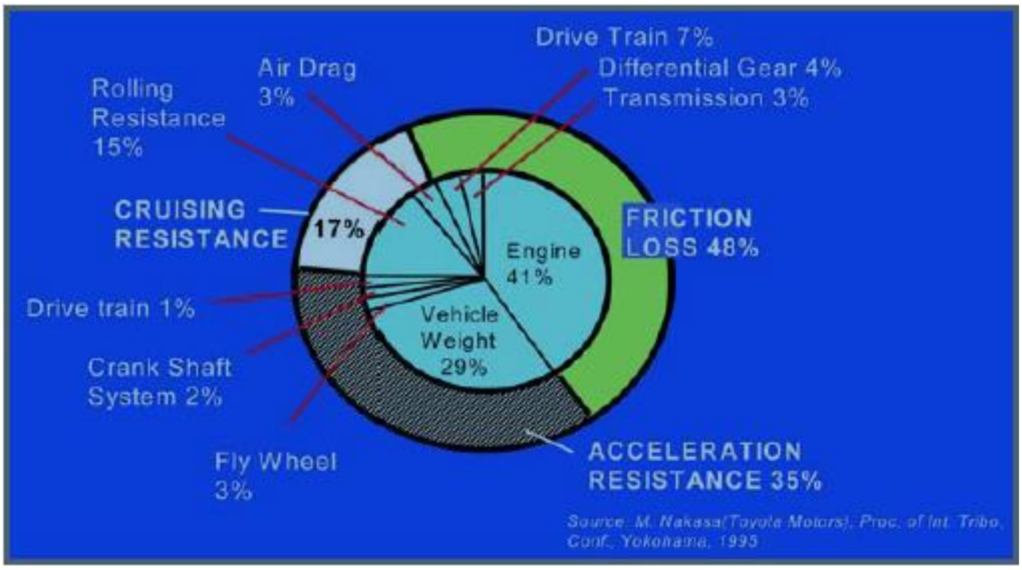

Figure 2.2: Energy utilization develop in an engine (Tung & McMillan, 2004).

Figure 2.2 shows that the crucial part of the energy utilization develops in an engine is friction loss (48%) followed by the second significant portion, acceleration resistance (35%) and the other portion is cruising resistance (17%).

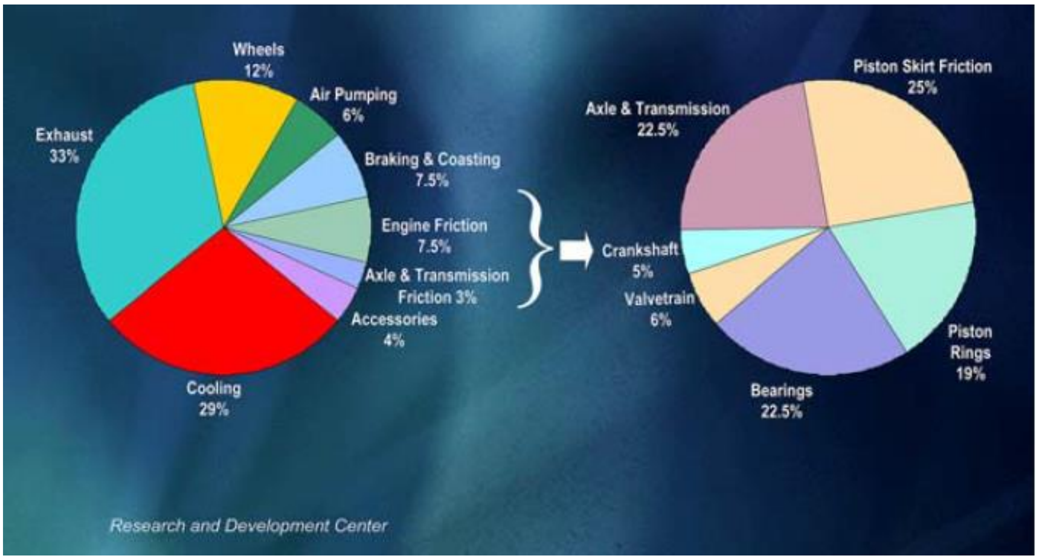

Figure 2.3: Distribution of energy consumption in a light-duty vehicle
(Tung & McMillan, 2004)

Based on the overall friction loss portion as shown in the Figure 2.3 combining the piston skirt friction, piston rings, and the bearing is 66% of the overall friction loss and the total of the valve train, crankshaft, transmission and axle are about 34%. Focusing only on powertrain friction, piston skirt friction and piston rings are the enormous contributions to friction in a powertrain system followed by rotating engine bearing, valve train and the aide like an oil pump, water pump, and alternator.

Tribological performance can be improved in three ways; by enhancing the tribological properties of the material used for the mechanical parts, coating surface and developing lubricants that improve tribological behaviour. The improvement of tribological performance can reduce fuel and oil consumption, increased power outputs, decline discharges of fumes, enhanced durability, reliability and engine life.

Lubrication includes the smoothing of the rubbing action between interacting surfaces. A direct solid-to-solid contact can be prevented by the formation of lubricant film between the contact surfaces. The applied mechanical forces, relative velocity, surface