TRIBOLOGICAL STUDIES OF BIO-LUBRICANTS ON PLASTICS

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DECLARATION

"I hereby declare that the work in this in my own except for summaries and quotations which have been duly acknowledged"

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SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure-Materials)"

Signature : ……………………..……….

Supervisor : ……………………...…….

Date : …………………………..….

DEDICATION

Special thanks to my beloved parents who always support me; my hero, Abdul Kadir Bin Attan and my lovely mom Norani Binti Ariffin. Then, I would like to thanks my siblings who are always give moral support from the beginning until this study is complete. Lastly, to my fellow friends who are always helping me during the experiment set up, thank you so much.

ABSTRACT

17th Century BC: lubrication dates back at least as far as this period in ancient Egypt. According to archaeological discoveries, olive oil is used as a lubricant to move large stones and other heavy objects. After that, the lubricants evolve rapidly and a lot of lubricants produces based on animal fats, vegetable oils and etc. A lubricant is a substance proposes to reduce friction between surfaces in mutual contact. Lubricant becomes important substance and widely used in industrial application, medical, cooking and other purposes. This study investigates experimentally the effect of Banana Peel oil lubricant on the coefficient of friction and wear behavior of polymer materials against stainless steel disc plate. The Banana Peel lubricants were prepared in four different percentage; **5% BP + 95% NCO**, **20% BP + 80% NCO**, **50% BP + 50% NCO** and **100% NCO**. Each lubricant contains with the different concentration of Banana Peel oil. The lubricants were test by using Pin-on-disc method. Experiments were carried out under load 156.96 N, rotation speed of 800rpm and fixed temperature 25±2°C. Results show that the friction coefficient of polymer decreases with the increasing of Banana Peel oil percentage in lubricant. **50% BP + 50% NCO** lubricant provide a lot of changes in friction coefficient and wear behaviour to PVC and PMMA polymer. The lowest value of friction coefficient is shown by PVC which is 0.0351. It is also found that the wear rate decrease with the increase of percentage of Banana Peel oil in lubricants. Table 4-7, 4-8 and 4-9 shows the microscopic image of polymer's wear behavior.

ABSTRAK

Abad ke-17 SM; medium pelinciran wujud sekurang-kurangnya sejauh tempoh ini di Mesir purba. Menurut penemuan arkeologi, minyak zaitun digunakan sebagai minyak pelincir untuk menggerakkan batu besar dan objek berat yang lain. Selepas itu, pelincir berkembang dengan pesat dan banyak pelincir dihasilkan berdasarkan lemak haiwan, minyak sayur-sayuran dan lain-lain. Minyak pelincir adalah bahan yang diperkenalkan untuk mengurangkan geseran antara dua permukaan yang bersentuh. Pelincir menjadi bahan penting dan digunakan secara meluas dalam aplikasi industri, perubatan, memasak dan tujuan lain. Kajian ini mengenal pasti kesan pelincir yang berasaskan kulit pisang terhadap daya geseran dan kadar haus bahan polimer yang dikenakan terhadap keluli tahan karat secara kaedah eksperimen. Pelincir dari kulit pisang telah disediakan sebanyak empat jenis peratusan; ***5% BP + 95% NCO****,* ***20% BP + 80% NCO****,* ***50% BP + 50% NCO*** *dan* ***100% NCO****. Setiap pelincir mengandungi kandungan minyak kulit pisang yang berbeza. Pelincir diuji menggunakan kaedah pin terhadap cakera. Kajian ini telah dijalankan di bawah beban 156.96 N, kelajuan putaran 800rpm dan suhu tetap 25 ± 2 ° C. Hasil kajian menunjukkan bahawa daya geseran polimer berkurangan dengan peningkatan peratusan minyak kulit pisang dalam pelincir. Pelincir* ***50% BP + 50% NCO*** *memberikan banyak perubahan terhadap daya geseran dan kadar haus polimer PVC dan PMMA. Nilai daya geseran yang terendah telah ditunjukkan oleh PVC dengan nilai sebanyak 0.0351. Ia juga mendapati bahawa penurunan kadar haus dengan meningkatnya peratusan minyak kulit pisang dalam bahan pelincir. Rajah 4-7, 4-8 dan 4-9 menunjukkan gambar mikroskopik kadar haus bagi polimer.*

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

POM	Polyoxymethylene
PVC	Polyvinyl chloride
PMMA	Polymethyl methacrylate
BP	Banana Peel oil
NCO	Natural cooking oil

LIST OF SYMBOLS

μ	Coefficient of friction
L	Sliding distance
N	Angular sliding speed
W	Applied load
r	Wear track radius
t	Sliding time
K	Specific wear rate
V_{loss}	Volume loss
F	Frictional force

CHAPTER 1

INTRODUCTION

1.1 Background

In the phase of static friction or pre-sliding, the shear stress applied to two contacting surfaces in order to cause relative sliding is not high enough to break the interface linkages. It has been revealed that the behaviour during stiction phase which would induce difficulties in the case of high-precision positioning, is the result of non-linear behaviour in dynamic systems (Hsieh C,2000). Numerous studies on the variety of the dynamic friction force with relative slip velocity during sliding motion have been accounted for in the literature. A number of theories based on different hypothesis and observations resulting from experimental data have been proposed to explain the variations of the friction force under different conditions of the interface (Habib S. Benabdallah et al.,2006).

Polymeric materials are widely used in household and machinery applications including toothbrushes, shower doors, mobile phones, bearings, casing, bolts and nuts. It is very hard to imagine our daily life without using any single thing of polymeric based materials. If the products include sliding interfaces, friction becomes an important role in comfort design. The understanding on friction and wear mechanism of polymeric materials is quite important (Cho Dae-Hyun et al., 1996). Friction is governed by the surface interaction in moving contact, while the wear is defined by the break down or exhaust of specimen by relentless pressure or resistance.

Interfacial properties which affect friction can vary during sliding dependent upon contact conditions. Typically, a change in surface roughness, formation of tribo-film , and wear debris are ascribed to the change in interfacial properties (Bhushan B et al.,1996). Hence, the contact conditions such as sliding speed and dwell time as well as applied normal load are important. Shooter and Tabor reported that the friction of polytetrafluoroethylene, polymethyl methacrylate, polyvinylchloride, polyethylene, and nylon sliding at the load range from 10 to 100 N changes with sliding distance (Shooter K et al.,1952). Friction can also depend on applied load and speed (Smith RH et al.,2008).

The static friction coefficient is related to many factors including materials properties, topography, applied load and environmental conditions including temperature, humidity and lubrications. On the other hand, the increase of temperature was found to cause reduction of stiction for mechanically textured media due to change of lubricant properties (Habib S. Benabdallah et al.,2006). Lubrication can also describes as the phenomenon such reduction of wear occurs without human disurbance. There are useful lubricants that can give best protection to the reducing wear and friction generated from sliding between two contact surface.

In this study, the polymeric-based materials are tested by using pin-on-disc method. The sample will be test in wet sliding condition. The concentration of lubricants, various load and speeds are the variable factors condition will be conduct in this studies.

1.2 Problem Statement

Engine lubrication is the process or technique to reduce wear of one or both surfaces in close proximity and it moving relative to each other by interposing a substance called lubricant between the surfaces to carry the load. It is mean by the pressure generated between the opposing surfaces. In the most common cases the applied load is cause by pressure generated within the fluid due to the frictional viscous resistance to motion of the lubricating fluid between surfaces. At the point when lubricants begin to break, metal or different parts can rub dangerously over one another bringing on ruinous harm, heat and failure. There are useful lubricants that can give best protection to the engine and reducing wear and generated from sliding between two points in contact surfaces (Mohd Azman Abdullah et al., 2013). In this project, the coefficient of friction and wear mechanism of plastic are being studies when different concentration of lubricants and various loads is test on it.

1.3 Objective

The objectives of this project are as follows:

1. To prepare the bio-based lubricants by using banana peel (epicarp).
2. To investigate the effects of percentage of Banana Peel oil in lubricants towards the friction and wear on plastics.
3. To study the wear behaviour of plastic towards the bio-lubricants.

1.4 Scope Of Project

The scopes of this project are:

1. The bio-based lubricants are prepared in different concentrations..
2. Conduct pin-on-disc test by using different loads and concentration of lubricants.
3. Analyse the coefficient of friction and wear behavior of plastic.

CHAPTER 2

LITERATURE REVIEW

2.1 Friction and Wear

2.1.1 Friction and wear mechanism fundamental

The study of friction, wear, and lubrication is of enormous practical importance because the functioning of many mechanical, electromechanical, and biological systems depends on the appropriate friction and wear values.

Friction and wear characteristics can best be explained using the adhesion theory of friction (Bowden, 1950). The theory of friction is based on strong adhesive forces between contacting asperities. As the load is applied the asperities come into metallic contact, with resulting high stresses at the true contact area. The true area of contact is so small that following elastic deformation. The stress was immediately come to the yield stress of one of the two materials. Hence, the plastic flow occurs and a cleaning action is obtained at the contact area (some of the surface contaminants are forced out).

The adhesion theory of friction states that the friction force is equal to the sum of two terms; shear and ploughing or roughness term. The shear term is that force required to shear at the welded junction. The ploughing term is that force which results from displacement of the softer of the two metals by an asperity of the hard metal. The ploughing or roughness term is negligible in comparison with the shear term (E. Bisson et al., 1968).

Friction:

$$F = S + P \tag{2.1}$$

where:

F = friction

S = Shear

P = Ploughing

Contact area:

$$A = \frac{\text{Load}}{\text{Flow Pressure}} \tag{2.2}$$

Friction coefficient :

$$f = \frac{\text{Friction}}{\text{Load}} \tag{2.3}$$

When the ploughing term is negligible:

$$f = \frac{s}{p} = \frac{\text{Shear strength}}{\text{Flow pressure}} \tag{2.4}$$

While the science of friction had been given so much attention from physicists and engineers alike, wear is just viewed as an engineer's problem. It is an undesirable consequence of friction and many other phenomena that occur on the surface. High friction leads to wear was account by the high shear stress on the surfaces. The softer of the two connecting surface will begin wearing out. Frictional heating is also a strong reasons to the surface weakening (softening, oxidation , and melting) of the surfaces. **Figure 2.1** below shows the simple mechanism of friction and wear.

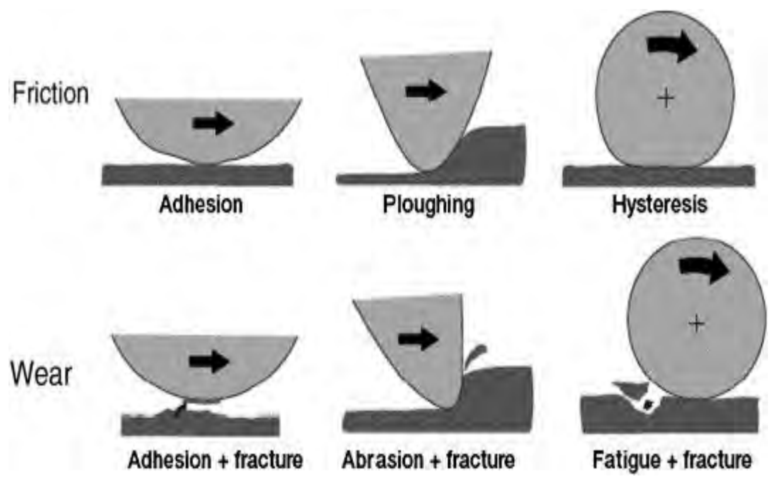

Figure 2.1 : Typical friction and wear mechanism (Hartford et al. ,2015).

Adhesion due to high surface energies can also lead to material removal effects. Thus, based on the causes of wear, there are many of the wear mechanisms proposed such as abrasive wear, surface fatigue wear, adhesive wear, chemical wear, oxidative wear, corrosive wear, and erosive wear .

2.1.2 Thermoplastic friction

Sliding machine elements made of plastics co-operate mostly with metallic material and are subject to different processes involced with friction and wear. During the friction of polymer materials on steel, several processes like mechanical and adhesion interactions, tribo-chemical and tribo-electrical reactions etc. are present (Bushan B et al., 2001). A share of these interactions in the process of friction is dependent upon the loading of the friction pair with the normal force, sliding velocity, surface roughness and waviness of the co-operating metal element, mechanical properties of the rubbing materials, adhesion characteristic of the sliding pair and other operating conditions. The process of creation of the polymer film on the surface of the co-operating element as well as the film stability and its ability to regenerate is also of great importance (W. Wieleba, 2007).

Surfaces of mechanical components, even those machined to the most noteworthy evaluation of completion are never preferably smooth. Their geometric elements are characterized by the surface harshness, waviness, deviation fit as a fiddle, and introduction of inconsistencies. The contact of two genuine surfaces subject to rubbing is done on the inconsistency severities. Many historical theories (Amontons, Coulomb) assumed that friction results from mechanical interactions of the contacting surfaces irregularities. In the so-called Coulomb model, the action of the wedge-shaped asperities causes the two surfaces to move apart as they slide from one position to another and then come close again. Work is done in raising the asperities from one position to another and most of the potential energy stored in this phase of the motion is recovered as surfaces move back (W. Wieleba, 2007).

It was confirmed that the greater the surface energy of polymer, the stronger sticks the polymer layer to the counter-specimen. Particles of fillers may build the attachment of the polymer layer to the surface of the counter example by making extra bonds. The thicker is the polymer film, the better assurance of the polymer material against severities of the counter-component surface (Polak A., 2000). At the same time the strongly bonded polymer film protects the surface against the detrimental action of hard particles trapped in the friction zone. Materials featuring a high value of the surface energy form a film featuring higher coherency of particles or layers. Such layers are more wear resistant. At the same time, however, strong adhesion interactions cause that polymer particles are more easily removed from the surface of the polymer material (Polak A., 2000).

The process of tribological wear of polymer materials is caused by the abrasion, cracking and spalling of material particles, surface adhesion of the co-operating elements and by tribo-chemical reactions present at the surface of contact (Belyj V. A et al., 1972). Many modes or wear characteristic for metallic materials, polymer materials are subject to abrasion, adhesion, and fatigue wears. On the other hand, creep wear, thermal wear and asperities melting are the wear processes inherently involved with polymers only (Myshkin N.K et al., 2005).

In the present study, polypropylene (PP), polyethylene terephthalate (PET), and high-density polyethylene (HDPE) samples were prepared because they are ordinarily utilized polymeric materials. Also, various contact conditions including load, speed, and dwell time were applied before measuring friction in order to stimulate the contact history of household applications (Bharat Bhushan et al., 2015). Static and kinetic friction of sliding pairs of PP on PET, PP on HDPE, and PP on PP were measured using a macroscale tribometer. The nanoindentration technique was employed to measure hardness and elastic modulus in order to elucidate frictional behaviour (Bharat Bhushan, 2011).

The wear mechanism was investigated by observing worn surfaces with an optical microscope and measurement of the change in surface roughness. Creep tests were carried out both on macro/nanoscale using a macroscale tribometer and nanoindentation in order to