ELASTOHYDRODYNAMICS LUBRICATION FOR BIO-BASED LUBRICANTS IN ELLIPTICAL CONJUNCTION

NAZRI HUZAIMI BIN ZAKARIA

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To my late beloved Parents, my Siblings& friends

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ABSTRACT

The issue of elastohydrodynamic lubricants in industry has been investigated by many researchers. Whereby many machine elements, such as gear teeth, cams and followers and rolling-element bearings are working under spinning and rolling conditions. Thus, the function of lubricant is to prevent friction and wear which causes material failure between two surfaces. Bio-based lubricants are one of the possibilities that might be used as a substitute to the conventional lubricants in the industries. Therefore, in this research we focused on elastohydrodynamic lubrication flows at the elliptical conjunctions by using bio-based lubricants. The numerical approach is used in this study to determine the effect of elliptical conjunctions by using the Gambit and Fluent software. This software helps to verify the deformation of the pressure distribution at the conjunctions. We had obtained that at constant speed, the mineral oil has the highest value of dynamics pressure than bio-based lubricants along X and Y axis between two surfaces. So, the mineral oil will able to carry more load than bio-based lubricant. However, we obtain that the bio-based lubricant is the best lubricant to protect the surfaces from wear and damage than mineral oil because mineral oil has higher value of dynamics pressure than bio-based lubricant.

ABSTRAK

Ramai penyelidik telah mengkaji tentang isu pelincir *elastohydrodynamic* di dalam industri. Terdapat banyak bahagian pada mesin seperti gear, pengikut sesondol dan bearing yang bergerak dalam keadaan berpusing dan berputar. Oleh itu, pelincir ini bertindak untuk menghalang geseran dan kehausan yang akan menyebabkan kegagalan bahan pada dua permukaan yang bersentuhan. Pelincir *bio-based* adalah pelincir yang mempunyai potensi untuk menggantikan pelincir yang sedia ada di dalam industri kini. Oleh yang demikian, di dalam kajian ini, penekanan tertumpu kepada pelincir *elastohydrodynamic* yang melalui bentuk elips dengan menggunakan pelincir *bio based.* Di dalam kajian ini, pendekatan penggunaan perisian komputer seperti *Gambit* dan *Fluent* telah di guna pakai untuk mengenal pasti kesan ke atas bentuk elips. Perisian komputer ini membantu untuk mengesan pembentukan tekanan ke atas bentuk elips tersebut. Pada kadar kelajuan tetap, didapati pelincir mineral mempunyai nilai tekanan dinamik yang paling tinggi dari pelincir *bio-based* sepanjang paksi X dan Y di antara dua permukaan. Jadi, pelincir mineral boleh membawa lebih bebanan dari pelincir *bio-based.* Walau bagaimanapun, pelincir *bio-based* adalah pelincir yang terbaik bagi melindungi permukaan daripada haus dan rosak berbanding dengan pelincir mineral kerana pelincir mineral mempunyai nilai tekanan dinamik yang tinggi berbeza dengan pelincir *bio-based*.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

LIST OF SYMBOLS

τ	-	Shear stress
γ	-	Shear strain rate
η	-	Absolute viscosity
σ_x	-	Normal stress
p	-	Fluid pressure
μ	-	Coefficient of viscosity
u	-	Flow velocity
q_m	-	Mass flow rate
x_{cp}	-	Center of pressure
f'_a	-	Shear force per unit length
F	-	Force
dl	-	Changes of deformation
E	-	Modulus Young
$\overline{\gamma}$	-	Tangential load

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Elastohydrodynamic Lubrication

Many machine elements, lubricated by fluid film have surfaces that do not conform to each other, so small lubricated areas must then carry the load. The lubrication area of a nonconformal conjunction is typically three orders of magnitude less than that of a conformal conjunction. In general, the lubrication area between nonconformal surfaces enlarges considerably with increasing load, but it is still smaller than the lubrication area between conformal surfaces. Some examples of nonconformal surfaces are the concentrated load-supporting or load-transmitting contacts such as gear teeth, cams and followers, rolling-element bearings and others.

Gear tooth contacts have been recognized as one of the most complicated applications of tribology. There is no good substitute for practical experience in gear design. Among the many types, the most commonly used are spur, helical, bevel, and worm gears. The lubrication process and lubrication-related failures in these gears have a great deal in common because the loads on these gears are all transmitted through Hertzian lubricated contacts known as elastohydrodynamic (EHL) contacts. Film thicknesses in this regime range from 0.025 to 1.250 μm [1].

From the kinematic relations of gears, the rolling and sliding velocities can also be determined. With this input data, one can determine the lubrication performance of the gears using recent EHL theories. However, there are two primary concerns:

1) What is the location of the areas of very thin film thickness that can initiate surface distress and lead to contact fatigue, and what are the sizes of these films?
2) What is the location of the areas of very high surface contact temperatures that can initiate scuffing, and what are the magnitudes of these contact temperatures?

Ideally, a most desirable gear lubrication analysis should include the following features:

- Transient effects due to variable load, contact radius, and rolling and sliding velocities;
- A coupled temperature and film thickness analysis to determine the variable bulk surface temperature distribution of both gears;
- Surface roughness effects on the lubrication; and
- Accurate friction models for fluid film and asperity contacts.

Elastohydrodynamic lubrication (EHL) is defined as the type of hydrodynamic lubrication where the pressure between contact surfaces is very high thus the contact surfaces deform elastically to an amount comparable to the film thickness. Unlike hydrodynamic lubrication where the expression for the film thickness can be determined a priori, in EHL problems the pressure distribution and the film thickness must be determined simultaneously. Although, there are generally two types of problems in EHL like line contact problems and point contact problems. In line contact EHL, the contact elements are assumed to be infinitely long in one direction and the contact takes place in an infinitely long strip. Meanwhile in point contact EHL; the contact takes place within a finite elliptical region [1].

According to the operating conditions under which the EHL contact takes place, EHL problems can be classified as either steady-state or unsteady (transient) problems. For steady-state problems, all variables involved in prescribing the contact are time independent. Hence, the pressure distribution and film thickness profile are functions of coordinates only.

During typical operations, often the load, the entraining speed and the contact curvature radius for machine elements such as gears and rolling element bearings change constantly in time. In these cases, the pressure and the film thickness within EHL conjunctions are functions of both space and time; in that case the EHL contact is referred to as unsteady or transient EHL.

The purpose of lubrication is to separate surfaces in relative motion by interposing a third body that has a low resistance to shear so that the two surfaces do not sustain serious damage or wear. This third body can be a variety of different materials, including adsorbed gases, reaction films, and liquid or solid lubricants. The formation of lubricating films is governed by the chemistry of film fluid and the gears surfaces. The effectiveness of these films in minimizing wear is determined by physical properties that include shear strength, surface adhesion, melting point or decomposing temperature and others [1].

In the elastohydrodynamic regime of lubrication, the rheology of the liquid lubricant is a key to the generation of a protective film and the transfer of shear across concentrated contacts. A complete solution of the EHL problem, however, requires a thorough knowledge of the lubricant constitutive behavior and the attending properties as functions of temperature and pressure. The Newtonian fluid assumption alone is often inadequate. In earlier non-Newtonian elastohydrodynamic lubrication studies, the pressure field was usually obtained by assuming Hertzian pressure; only the shear field was obtained using some non-Newtonian model.

1.2 Bio – based Lubrication

The need for lubrication cannot be over-emphasized as far as its role in engineering is concerned. With the technological advancement, man in his guest to improve his standard of living continues to invent and produce new machines. When two metal parts are in contact, the amount of asperities and interaction within the contact area increases thereby causing; frictions which insist motion wear of the metal parts and generation of excessive heat. These friction, wear and excessive heat caused by the interaction between the surfaces of the moving parts of the machine has to be controlled by lubrication whose function is to reduce friction and wear, prevent oxidation and corrosion while acting as a coolant facilitating heat dissipation from the engine. A lubricant may be in gaseous, liquid, semi-solid (grease) or solid form. Lubrication is achieved when the surfaces in contact are separated by a continuous lubricant film.

The lubricant is expected to have lower shear strength than that of the materials of the contact surfaces and also be able to withstand the loading of the parts in contact. The improved quality of today's synthetic lubricants has enabled the design of machines with higher stresses, load and operating temperature than before. Consequently, automobile engines capable of high rotational speed and higher specific power have been produced [2,3]. Liquid lubricants have the highest application because they headily provide the separation of surfaces when correctly applied. Because of the importance and wide application of lubrication, coupled with the ever increasing world energy crisis, there is need to source out lubricants other than the computational ones obtained from mineral oils [4,5].

So, we must consider one alternative of producing a lubricant from bio-based material. The environmental awareness is leading to a growing interest in biodegradable low-toxicity lubricants. Biodegradability is reached by using a suitable biodegradable base fluid, but low- toxicity requires an additivation that is environmentally friendly [2], too. However, the key aspects for any industrial application are technical performance and technical advantages proved in dedicated tests.

Lubricant performance (friction, wear, lifetime, load bearing, efficiency, etc.) has a major impact on its overall environmental compatibility, since premature wear or high energy needs are as well harmful to the environment. The technical performance of gear oils must be demonstrated in power loss, scuffing and micro pitting gear tests.

Therefore, in this project, a study about the bio-based lubrication will be used in analysis for the elliptical conjunction. Bio-based lubricant will be replace the conventional lubricants oil produced from mineral oil to analyze the effect of deformation on pressure distribution behavior in elastohydrodynamics lubrication.

1.3 Objective

The objective of this project is to determine the effect of bio-based lubricant on the elasto-hydrodynamic problem for elliptical conjunction.

1.4 Scope of Study

This project is done due to the certain boundary of conditions. This boundary can act as a guide to avoid too much complexity. The scopes of this project are;

a) To analyze in two dimensional (2D) model by using numerical modeling
b) To use bio-based lubricants and the suggested lubricants is biodegradable ester lubricants
c) To compare with the mineral oil