ELASTOHYDRODYNAMIC LUBRICATION FOR BIO-BASED LUBRICANTS IN RECTANGULAR CONJUNCTION

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To my late baby, my beloved son Muhammad Azizi Syalia and my family

ABSTRACT

Knowledge of tribology is very important for successful design of machine elements. The most effective mean of overcome failures in machine elements is by proper lubrication. With the presence bio-based lubrications in the industry, the tribology understanding will changed significantly and will directly affect the performance and reliability to the machine elements. In this study, involute spur gear is used and remodeled using computational fluid dynamic software to simulate speed and squeeze phenomena behaviours. The gear teeth load is treated in a simplified idealistic way according to the experimental gear load spectrum. This analysis will enable the study of elastohydrodynamic lubrication in rectangular conjunction with different type of bio-based lubricants. Emphasis of analysis is focused on the speed and dynamic pressure distribution along the pinion surface. For each type of lubricant, computations were carried out in sixteen different low speeds which are 1.00 m/s until 0.05 m/s and 0.01 m/s. The results show that computer modelling exercise have demonstrated CFD with standard k-epsilon model is suitable for modelling a rectangular conjunction.

ABSTRAK

Bidang tribologi adalah penting terutama dalam merekabentuk alatan-alatan mesin. Antara kaedah terbaik dalam menangani masalah ini adalah melalui penggunaan minyak pelincir. Kehadiran minyak pelincir berasaskan *bio-based* telah meningkatkan kefahaman dalam bidang tribologi dan seterusnya membaiki prestasi dan ketahanan terhadap alatan-alatan mesin. Dalam kajian ini, *gear* telah dimodel semula menggunakan perisian komputer untuk menganalisa sifat halaju dan kejadian kilasan yang terjadi. Gigi *gear* akan dianggap sebagai ideal berdasarkan kajian bebanan *gear*. Kajian ini juga membolehkan analisa *elastohydrodynamic* bentuk segi empat terhadap pelbagai jenis *bio-based* minyak pelincir dijalankan. Hasil kajian tertumpu kepada halaju dan tekanan dinamik yang dialami pada permukaan *pinion*. Sebanyak 16 halaju rendah yang berlainan dianalisa bagi setiap jenis *bio-based* minyak pelincir. Keputusan analisa menunjukkan penggunaan perisian komputer berasaskan model *k-epsilon standard* adalah sesuai dijalankan terhadap model berbentuk segi empat.

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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
$\bar{\gamma}$	Tangential load

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CHAPTER 1

INTRODUCTION

1.1 Background

The purpose of this paper is to review the development understanding of elastohydrodynamic lubrication (EHL) throughout twentieth century, to drawn attention to topics currently under investigation and finally to consider future direction. In 1886, Osborne Reynolds had established the foundations of fluid-flim lubrication theory, following earlier experimental work on railway axle bearing by Petrov and Tower in 1883. In subsequent years, plain bearing technology developed rapidly but attempts to explain the effective lubrication of highly stressed counter-formal conjunction in gears, on the basis of hydrodynamic principles alone remained ineffective throughout most of the first half of the twentieth century. It was recognize that very high pressures associated with such counter-formal conjunctions would enhance the lubricant viscosity and causes substantial local elastic deformation. Both effects might contribute to satisfactory film deformation. When such effects were individually incorporated into analysis by various investigators, both indeed resulted in predictions of enhanced film thickness, but, when considered alone, neither was found to lead to values sufficiently large to be consistent with the experimentally recognized performance of gears.

The quandary was resolved in the middle of the twentieth century for nominal line contacts when the interactive effect of pressure upon both the viscosity and local elastic deformation was found to result in spectacular increases in the predicted film thicknesses in many lubricated, highly stressed machine elements. The subject became known as ‘elastohydrodynamic lubrication’ and it has dominated advances in the field of fluid-film lubrication in the latter half of the twentieth century. In 1970, Barwell reflected this idea when he wrote the elucidation of the mechanism of elastohydrodynamic lubrication may be regarded as the major event in the development of lubrication science since Reynolds ‘own paper’.

Film thickness equations were thus available in the 1980s for the analysis and design of any highly stressed, lubricated machine element, presenting gear geometries. Emphasis was focused upon film thickness, since it was necessary to ensure adequate separation of the rolling/sliding machine elements if adequate durability was to be ensured. Most of the numerical solutions considered Newtonian fluids and isothermal conditions in those early years, with different simplifications, and the observed agreement between theoretical predictions and experimental measurements of film thickness were recorded and made further refinement unnecessary.

Squeeze is an oscillating motion in normal direction towards each other. It happened in fluid film from the fact that a viscous fluid cannot be instantaneously squeezed out from the interface with two surfaces that are approaching each other. When two surfaces move apart, the fluid is sucked in and fluid film can recover its thickness in time for the next application (Pinkus and Sternlicht, 1961; Fuller, 1984; Hamrock, 1994). The effect is efficient in oscillations with high frequencies in the kilohertz to megahertz rage at submillimeter amplitudes (Tam and Bhushan, 1987).

Continuum mechanics has served to illuminate the essential operating characteristics of many elastohydrodynamic conjunctions, but current consideration of nanometer rather than micrometer thick elastohydrodynamic films is increasingly leading to a consideration of molecular models of the interactions between the lubricant and the solid boundaries. Approaches based upon molecular dynamics and instruments like the atomic force microscope are now being linked to the conventional continuum mechanics analysis of the past half century.

1.2 Objective

The objective of this study is to determine the correlation between speed and squeeze phenomena in rectangular conjunction elastohydrodynamic lubrication.

1.3 **Scope of Study**

Numerical analysis will be used in determining speed and squeeze phenomena behaviors of spur gear. Boundary conditions will act as a guide to avoid too much complexity. The scopes for this study are:

(i) To analyze in two dimensional (2D) model by using numerical modeling
(ii) To use bio-based lubricants
(iii) Temperature is constant at 313K.