HIGH AMPLITUDE WAVE LINER EFFECTS ON JOURNAL BEARING PERFORMANCE

ASRAL

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DEDICATION

To Sukmawati, Suci, and Farabbi for all their love and understanding

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ABSTRACT

Modification on the liner bearing was one of the ways to achieve sufficient lubricant on a journal bearing system. Efforts had shown that the ability to retain some lubricant by introducing wave like grooves on the liner has improved the performance of the bearings. However, the database for the modifications is still lacking. This study aims to establish and correlate modifications of the liner with the performance of the journal bearing. Numerical and experimental work were done to compare and relate several geometries of liner bearing modifications based on previous studies as well as new ones. The previously studied sine wave liner bearing involved investigations with the square and semi circular liners. Plain liner bearing was used as reference. All cases were investigated experimentally by a test rig under low operating loads of 30 N to 450 N with high speed conditions of 1200 RPM to 2800 RPM. Some of the parameters were validated in order to compare the numerical and experimental data. Case studies also included engine oil and palm olein as the lubricants. The performance of the bearings was analyzed by examining the side flow rates, lubricant temperature change, eccentricity ratio, and pressure distributions. The results show that, modifying the shape liner bearing under all operating conditions could increase the lubricant flow rate which was approximately 1.5 times than the plain liner bearing and reduce the lubricant temperature change by about 35%. The bearings with the wave shape liner led to the eccentricity ratio increase but within the acceptable range of 0.6 to 0.9. Majority of the results showed lower a maximum pressure than the plain liner bearing with the exception of the bearing with the square wave shape liner.

ABSTRAK

Pengubahsuaian ke atas pelapik galas adalah salah satu cara untuk mencapai pelincir yang mencukupi pada sistem galas jurnal. Usaha telah menunjukkan bahawa keupayaan untuk mengekalkan beberapa pelincir dengan memperkenalkan alur seperti gelombang pada pelapik telah meningkatkan prestasi galas. Walau bagaimanapun, pangkalan data untuk pengubahsuaian masih kurang. Kajian ini bertujuan untuk mewujudkan dan menghubungkaitkan pengubahsuaian pelapik dengan prestasi galas jurnal. Kaedah berangka dan eksperimen dilakukan untuk membandingkan dan mengaitkan beberapa geometri pengubahsuaian pelapik galas berdasarkan kajian terdahulu dan yang baru. Kajian sebelum ini meliputi galas dengan pelapik gelombang sinus, disiasat bersama-sama dengan pelapik bentuk gelombang persegi dan bulatan separa. Pelapik galas biasa telah digunakan sebagai rujukan. Semua kes-kes telah disiasat secara eksperimen di bawah beban operasi yang rendah sebanyak 30 N hingga 450 N dengan keadaan kelajuan tinggi sebanyak 1200 RPM hingga 2800 RPM. Beberapa parameter telah disahkan dalam usaha untuk membandingkan data berangka dan uji kaji. Kajian kes juga merangkumi minyak enjin dan minyak sawit sebagai minyak pelincir. Prestasi galas dianalisis dengan memeriksa kadar aliran sisi, kenaikan suhu minyak pelincir, kesipian dan agihan tekanan. Keputusan menunjukkan bahawa, mengubahsuai bentuk pelapik galas di bawah semua keadaan operasi, boleh meningkatkan kadar aliran minyak pelincir sebanyak lebih kurang 1.5 kali daripada pelapik galas biasa dan mengurangkan perubahan suhu minyak pelincir sehingga 35%. Galas dengan pelapik bentuk gelombang membawa kepada kenaikan nisbah kesipian tetapi dalam julat yang boleh diterima iaitu 0.6 hingga 0.9. Majoriti keputusan menunjukkan tekanan maksimum lebih rendah daripada galas pelapik biasa dengan pengecualian kepada galas dengan pelapik bentuk gelombang persegi.

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LIST OF SYMBOLS

A	-	Wave amplitude (m)
c	-	Diametrical clearance of journal bearing
D	-	Diameter of bearing (m)
F_i	-	External body forces (N)
h	-	Fluid film thickness (m)
k	-	Consistency index
L	-	Length of bearing (m)
N	-	Shaft rotational speed (RPM)
n	-	Power law index
P	-	Static pressure (Pa)
R	-	Radius of circle to draw a wave circle (m)
Re	-	Reynolds number
S	-	Sommerfeld number
S_m	-	Mass added to the continuous phase
T_o	-	Reference temperature (K)
U	-	Velocity of shaft surface (m/s)
v	-	Kinematics viscosity of lubricant (m^2/s)
W	-	Load (N)
L_G	-	Length of a half wave (m)
n_V	-	Sum of wave valley
n_C	-	Sum of wave crest
Q_x	-	Lubricant flow rate (m^3/s)
Q_{SC}	-	Lubricant flow rate for semi circular wave liner (m^3/s)
Q_{SQ}	-	Lubricant flow rate for square wave liner (m^3/s)
Q_{Sin}	-	Lubricant flow rate for sinusoidal wave liner (m^3/s)

Qinlet	-	Sum of total oil enter the bearing (m^3/s)
Qoutlet	-	Sum of total oil out the bearing (m^3/s)
Qends	-	Sum of oil collected from both of the ends of bearing (m^3/s)
Qloses	-	Sum of lubricant fluid uncollected (m^3/s)
R_b	-	Radius of bearing (m)
r_j	-	Radius of shaft (m)
¯	-	Angle of radius to draw a wave circle (º)
e	-	Eccentricity (m)
£	-	Eccentricity ratio, e/c
¥	-	Shear rate (1/s)
μ	-	Absolute viscosity (N.s/ m^2)

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CHAPTER 1

INTRODUCTION

In this study, current journal bearings designed are proposed to be improved by modifications of the inner side of the bearing at the usual location of the shaft slide. Performance of journal bearing has been reported to be greatly affected by changes in the profile of inner side surface (liner). This change has great effect on pressure distribution, lubricant temperature reduction, and side flow rate increment. All mentioned performance measurements are analyzed and compared to normal journal bearings.

1.1 Background of the Problem

Hydrodynamic lubrication is a condition where journal bearings operate in thick film creating sufficient hydrodynamic pressure to support the load (Bhusan, 2002). When fluid film is thick enough then the hydrodynamic lubrication condition can ensure solid contact does not occur. In many years, efforts deliver lubricant into the bearing has been considered. The aim is to ensure sufficient lubricant is always present in the journal bearing. In an attempt to meets this aspect, geometries of liner

bearings has been modified. Flack *et al.* (1980) introduced four lobes journal bearing and show that the maximum pressure occurred at middle area, circumferentially. Similarly, Goyal and Sinhasan (1991) developed two lobes journal bearing. From their study, it was shown that as the load increases the minimum film thickness reduces. The side flow rate also increases as the load increases. These efforts result in higher stability but lower in load carrying capacity. To complement the above findings, Dimofte (1995) conducted a study by developing three wave liner journal bearing with ratio of wave amplitude to radial clearance was 0.2 and 0.4, as in Figure 1.1. The result shows an increase in load carrying capacity.

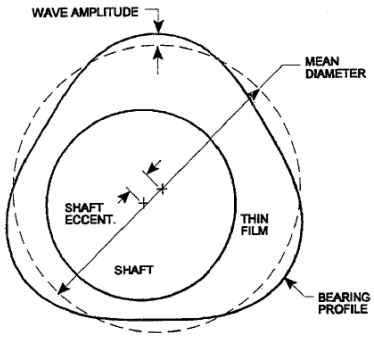

Figure 1.1 : Three wave liner journal bearing, Dimofte (1995)

Groove location has also been considered in the study of journal bearing. As reported by Costa *et al.* (2000) who has developed a steady load journal bearing in order to investigate the effect of three different axial groove location mounted on the bearing. They reported that the changes in groove locations have significantly affect the pressure characteristic in journal bearing. Moreover, other researchers also investigated the journal bearing with journal groove shape assorted to achieve a good performance, as mentioned by Sahu *et al.* (2006) and Hirayama *et al.* (2009). They found that the modification cause higher eccentricity.

The thermal effect on the journal bearing performance has also been studied. Van Ostayen and Van Beek (2009) have investigated the thermal effect on lemon bore liner journal bearing. They concluded that the result, in the condition of various shaft speeds and load constant, have shown that the maximum temperature remains constant. Also, the maximum temperatures are affected significantly by changed in type and viscosity of lubricant. As the theoretical study has been carried out by Ene

et al. (2007) on a wave journal bearing was shown that maximum temperature of the bearing take place in the vicinity of minimum fluid films thickness then decreased in region of maximum fluid films thickness. In addition, increases in the load experienced by the bearing also cause a raise in temperature distribution. Furthermore, Chauhan *et al.* (2010) has carried out the study concerning thermo-hydrodynamics analysis on the elliptical journal bearing (see Figure 1.2) with different grades lubricant. They found that as the shaft speed and eccentricity ratio increases, it affects the film temperature and thermal pressure.

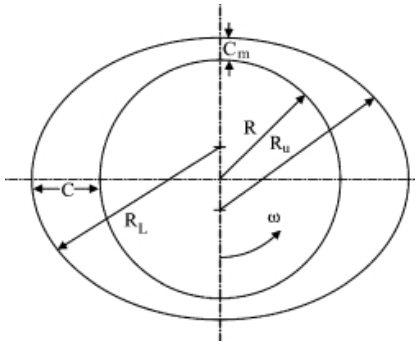

Figure 1.2 : Elliptical journal bearing, Chauhan *et al*. (2010)

Various types of journal bearings have an important role in assisting the machine work although the data of about the characteristics and performance it under various operating conditions are lack and not abundantly available. Although numerous studies done in various methods that involve numerical analysis and experimental investigations. Based on the previously mentioned findings, generally the studies are focused on the liner-shape and groove arrangement on journal bearing. The combination of wave and groove on surface of liner bearing are a gap that would be adopted as topic in the present study associated with journal bearing.

From the previous studies, modifications of the liner have been show to increase the load carrying capacity of the journal bearing. However other problem could occur if modifications are not done correctly. This study introduces several new types of liner bearings and performance of the bearing has been evaluated. The effect of other lubricant, in order to study the effect of different lubricant properties, is also included.

1.2 Problem Statement

The modifications on the liner bearing have been studied and produce the improvement on journal bearing performance. The performance of journal bearing with liner modifications is very dependent on the operating conditions as well. There are variety operating conditions that might encounter in practice. Temperature operation, load imposed, shaft speed, lubricant condition are among other that have many effects on journal bearing performance. Either the parameter that most influence on the journal bearing operation was the change in the shape of the liner. Its changes to give effect to the pressure distribution, oil flow rate, load carrying capacity and journal bearing temperature. It was identified there is some profile of liner surface that have not been investigated. The changes of liner shape may affect on heat generated, pressure distribution, and lubricant flow behavior in journal bearing, are aims of the study. New types of various shapes wave liner are introduced in order to complement the lack of data. The effect of different types of lubricants to the modification was also studied.

1.3 Objectives

The objectives of present study are, to determine the effect of new type of liner, such as square wave, semi-circular wave and sinusoidal wave on:

i.) The side flow rate of journal bearing

ii.) The temperature change of the lubricant journal bearing

iii.) The eccentricity of journal bearing

iv.) The pressure distribution of journal bearing

v.) Comparisons of wave liner bearing performance to a plain liner journal bearing.

vi.) Pressure distribution of wave liner journal bearing experimentally and numerically aims to comparison.

1.4 Scope of Research

The scopes of this study directed as follows:

1. Numerical and experimental approach have been used for comparison
2. Mineral oil has been used as reference (SAE 20W-40)
3. One type of other lubricant, that is palm olein, has been analyzed.
4. Specific range of speed has been applied (1000 RPM -3000 RPM)
5. Load increment is limited up to 450 N to avoid metal contact.
6. Ambient pressure and temperature standard operating conditions where the experiment is carried out in laboratory.
7. The wave liner bearings (semi circular wave, square wave, sinusoidal wave) compared to a plain liner journal bearing.
8. The gravity oil supply system has been applied to reduce operational effect.

1.5 Research Contributions

1. This study provides the completeness of data to journal bearing with the effect of wavy liner surface for various wave shapes.

2. The data of this study can be used to support the design of journal bearing.

3. The non-mineral oil performs analysis can be used as feasibility data of lubricant for journal bearing applications.

4. This study will supplement the similarity and universality aspects of deficit lubricant behavior on type of wave liner bearing, as already known in the narrow gap, so then a practical characterization of the gap is complete possible.

1.6 Outline of Thesis

As an introduction to the whole of thesis the background of problem, problem statement, objectives, scope of research, and research contribution were outlined in this chapter.

Literature reviews about of the studies of journal bearing were outlined in Chapter 2. The chapter initiated with the review in relation to main component that was found in the journal bearing. Then followed by reconsider on some studies that are possible to support the use of bio-based as lubricant. To obtain the guidelines in the discussion of the results should be reviewed several studies, among others, about the thermal characteristics and pressure distribution. Subsequent to examine the extent to which the development of liner bearing deformation in recent years are summarized in a study of non-circular liner bearing and grooved journal bearing. At

the end of this chapter closes with an overview of research methods such as numerical study in the journal bearing.

Chapter 3 are the pages to describe the research methodology used during the study. In it contains the description of the lubricants, experimental setup, wavy liner bearing concepts, fluid film pressure measurement, fluid film thickness measurement, oil side flow measurement and data processing. The numerical by using Fluent CFD components were reviewed and then the validation has been conducted.

Results and discussion on the act of journal bearing were presented in Chapter 4. Some achievements were realized in the form of oil side flow, oil temperature, eccentricity, and pressure distribution in journal bearing.

Chapter 5 is to be the last place to express the essence of this study. This chapter contains the conclusion and recommendations in the future work.

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