SUPERVISOR DECLARATION

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

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Supervisor: ....

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STUDY OF FLOW PATTERN AND PRESSURE DISTRIBUTION IN JOURNAL BEARING FOR DIFFERENT GROOVE TYPE USING CFD

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A thesis submitted in fulfillment of the requirements for the award of the degree of Bachelor of Mechanical Engineering (Thermal and Fluid)

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DECLARATION

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

Signature: ....

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ABSTRACT

The main purpose of this study is to compare the flow pattern and pressure distribution in journal bearing for different groove using Computational Fluid Dynamics (CFD). The groove types selected in this study are plain, wave, and rectangular. Operating condition of the system such as lubricant type, journal bearing ratio (L/d) and operating speed (N) are fixed respectively. Computational Fluid Dynamics (CFD) will be used to model the flow of journal bearing with different groove types. Navier-Stokes equations will be solved under unsteady conditions with the ANSYS FLUENT software. A 3-dimensional geometry is used to model the bearing, and the modeling will be created using 3D CAD design software SOLIDWORK. By performing numerical solution to this study, the flow pattern and pressure distribution profile for different groove type of journal bearing will be outlined. The results obtained are found to be the same agreement as previous studies. The results show same pattern for pressure profile for each journal bearing studied with wave-grooved journal bearing having the lowest pressure profile amongst other journal bearing

ABSTRAK

Tujuan utama kajian ini adalah untuk membandingkan pola aliran dan pengagihan tekanan dalam galas jurnal terhadap jenis-jenis lurah galas jurnal yang berbeza menggunakan Computational Fluid Dynamics (CFD). Jenis-jenis lurah yang dipilih dalam kajian ini adalah datar, gelombang, dan segi empat tepat. Syarat operasi sistem seperti jenis minyak pelincir, nisbah galas jurnal (L/d), dan laju operasi (N) masing-masing akan ditetapkan. "*Computational Fluid Dynamics*" akan digunakan untuk memodelkan aliran galas jurnal terhadap jenis-jenis lurah galas jurnal yang berbeza. Persamaan "*Navier-Stokes*" akan diselesaikan dengan perisian komputer ANSYS FLUENT. Geometri 3-dimensi akan digunakan untuk memodelkan galas dalam kajian ini, dimana permodelan tersebut akan dilaksanakan dengan menggunakan perisian computer rekabentuk 3D iaitu SOLIDWORK. Dengan perlaksanaan kaedah berangka terhadap kajian ini, profil pola aliran dan pengagihan tekanan bagi jenis lurah galas jurnal yang berbeza akan dihuraikan secara terperinci. Keputusan yang diperolehi didapati sama secara teori apabila dibandingkan dengan kajian-kajian yang telah dijalankan sebelum ini. Keputusan kajian ini menunjukkan corak profil tekanan yang sama untuk setiap galas jurnal yang dikaji dalam kajian ini. Di antara galas jurnal yang dikaji, galas jurnal dengan jenis lurah gelombang didapati mempunyai profil tekanan yang paling rendah.

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c	=	Clearance, c = R_b-R_j (mm)
C_p	=	Specific Heat At Constant Pressure (J/kg.K)
cm	=	Centimeter
d	=	Journal Diameter (mm)
e	=	Eccentricity (mm)
h, h_o	=	Film Thickness (mm)
K	=	Kelvin
L	=	Bearing Length (mm)
m/s	=	Meter Per Second
mm	=	Millimeter
N	=	Rotational Speed (rpm)
P	=	Pressure (Pa)
R_b	=	Radius Bearing (mm)
R_j	=	Radius Journal (mm)
rpm	=	Revolutions Per Minute
Ɵ	=	Bearing Angle (˚)
ε	=	Dissipation Of Kinetic Energy (m^2/s^2)
ρ	=	Lubricant Density (kg/m^3)
ω	=	Rotational Speed Of Journal (rad/s)

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CHAPTER I

INTRODUCTION

1.1 INTRODUCTION

Water has been used to drive machinery for decades ago, by using flowing water as an alternative to operate machinery. Water power has been applied to contribution of generating approximately 20% of world electricity in modern age. Electricity generation by means of hydro-power is now widespread around the world. Now, hydro-powers played a major role to generate electricity as a part of everyday life and also helped in industrial development.

Hydro-electric power generating plant is continuously undergoing development with the aim of improving efficiency and performance to maximize generating capacity from smaller machine, where friction between moving parts is one of the major consideration of engineer accounting the efficiency problem. Therefore, some form of lubrication is required to reduce friction between mechanical components as they always moving in close proximity to one another. Lubrication is a process to reduce friction, wear of one or both surfaces in close proximity such as sliding surfaces of a bearing and a shaft in relative motion. By applying a substance called lubricant between the surfaces, it helped in carrying the load smoother between the opposing surfaces. In this case, a typical example of mechanical components which are always moving in close proximity to one another can be referred to bearings with the corresponding shaft and the journal. When lubricant is applied between opposing surfaces, it will produce some sort of fluid film which build a layer of sufficient thickness to separate the two opposing surfaces, reducing the friction within.

Journal bearing is considered one source of power loss in many power systems. Shaft rotating in the journal bearing continuously provides energy to the lubricant. Energy dissipation formed in the lubricant is resulted in fluid shear, reducing the efficiency of the system [1]. Lubrication is one of the methods to solve power loss problem, by applying a film of lubricant between the shaft and the journal to separate them, reducing the friction within. This can help in achieving an extension of component life through limitation of material damage.

Friction was always meant to be minimized for every hydrodynamic system. Previous studies have stated a few alternatives to decrease the friction such as reduce the lubricant viscosity, operate the system at lower loads or shear rates or modifying the geometry of the contact [1]. The alternative taken in this study will be similar to the third alternatives mentioned, where the geometry modified can be referred to the different types of groove journal bearing. The alternative was chosen based on proves that previous research have verified surface texturing as one of the alternatives of improving the performance of a journal bearing.

Lubricant is also one of the important operational parameter in the rolling bearing applications which will bring this statement to the importance of lubricant selection for bearing applications due to various factors unique to any specific precision bearing environments [2]. Mineral oils have been used as a lubricant in various mechanical applications for ages with good technical properties and the reasonable price. However it is recognized that mineral oil present a danger to the environment at each and every stage of their production, use and even after disposal, especially when environmental problems associated with the production and use of chemicals and the limited capacity of nature to tolerate pollution became obvious. Mineral oils have poor biodegradability; can remain in the ecosystem for a long period of time and thus its potential for long-term pollution; and cause increasing of atmospheric carbon dioxide and thus contribute to global warming [2].

Continued growing environmental concern has opened a path for vegetable oils as lubricants for industrial and transportation applications. Vegetables oils are renewable and biodegradable, and these have helped in providing satisfactory performance in bearing applications. Synthetic ester based fluid lubricants are also found to offer such benefit, but they might cost a lot when compared to vegetable oils. Challenges come along when formulating vegetable oils, especially with the highly saturated oils where the problems associated are temperature viscosities, oxidative, and hydrolytic instabilities with the triglyceride. Although palm oils are found to be unsuitable or restricted to some limited applications, it comes in as a common and commercially available vegetable oils due to their applicability [3]. Therefore in this study, bio-based lubricant which is palm oil will be used as one of the approach to investigate alternative lubricant in journal bearing system to help reduce dependence on mineral oils.

From the statements above, it will bring to the tribological point of view, which will form a main particular interest as stated below:

- How the load carrying capacity of the bearing can be increased while at the same time improving performance within existing dimensional constrains, where the term existing dimensional constrains here is referred to bearing surface texture such as groove types.

Different groove types of journal bearing as a manipulation of surface texturing has been a subject of several theoretical and experimental studies where small improvements in bearing performance may allow for savings of an enormous amount of energy, saving cost. Such study may give valuable insight of designing a smart journal bearing.

1.2 OBJECTIVE

The objective of this study is to compare the flow pattern and pressure distribution in journal bearing for different groove with plain journal bearing. CFD (Computational Fluid Dynamic) will be used in the prediction of the flow pattern and pressure distribution, and the simulation result will be analysed, discussed and compared between different groove types of journal bearing.

1.3 SCOPE

The scope of this study includes:

1. 3 types of groove will be chosen (plain, wave, and rectangular)
2. Journal bearing ratio, l/d is fixed (l/d = 0.80)
3. Lubricant type used is fixed, which is palm oil with constant parameter as stated below:
    - Density, ρ = 865.1 kg/m^3
    - Cp = 1006.43 J/kg.K
    - Viscosity, μ = 81.2 kg/ms
    - Thermal conductivity, k = 0.0242 W/mK

4. Material of journal bearing is steel with constant parameter default to ANSYS FLUENT database
5. Operating speed, N is constant (N = 2000 rpm)

1.4 PROBLEM STATEMENT

Journal bearings are widely used in rotating machinery, especially when shafts are submitted to both high speeds and heavy applied loads. Bearing elasto-hydrodynamic behaviour and its effect on performance has been studied decades ago. Bearing surface texture is one of the key parameters of elasto-hydrodynamic behaviour study, whereas an additional groove will dramatically affects flow patterns and pressure profiles inside the bearing. Therefore, problem accounting journal bearing lubrication with operating conditions with fixed lubricant, L/d ratio, operating speed and alternating of different grooves types of journal bearings, is essential to the study. In this study, CFD (Computational Fluid Dynamic) tool, ANSYS FLUENT will be used and the simulation results will be analysed, discussed and compared between different groove types of journal bearings.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

Frankly speaking, a bearing is one of the structural members of a machine that is designed to convert dry and wearing friction to wearless fluid friction where the motion involved can be plain sliding motion (cross head, cylinder and piston), or an oscillatory motion (piston pin and bushing, spring shackle), or a rotating motion crankshaft and connecting rod bearings). The member involved in rotational or oscillatory motion can be a plain or sleeve bearing, or an anti-friction bearing [4]. Bearing proper, and the journal or axle are two main units of plain bearings. The bearing surface is made of one the materials such as wood, plastics cast iron, bronze, silver, alloys of lead, and alloys of tin, where the alloys of lead or tin that are employed in bearings are commonly referred to as the soft bearing metals.

2.2 CFD ANALYSIS OF JOURNAL BEARING

Designing of smart journal-bearing systems create a possibility for semiactive dynamic control of bearing behaviour. Conformal contacts found in journal bearings can be discovered in various machine applications, from small engines to large turbines. Due to environmental and economic concerns, machines are required to operate with minimal power loss as small improvements in bearing performance can be greatly economically beneficial. Many ideas accounting design modifications of bearing have been proposed in order to decrease bearing power consumption.

Previous research has studied on the effect of grooves on load support for a thrust washer focusing on groove depth, width, shape, and quantity. From the study, it was found that an optimum groove depth provides maximum load support as well as providing optimum number of grooves [5, 6, 7].

Amir, J. et. al. have conducted a study on CFD Analysis of a Journal Bearing with a Microgroove on the shaft [1]. In their study, they claimed that Snegovski and Bulyuk conducted an experiment to study journal bearings with and without micro-grooves on the shaft. By using vibrating roll-forming method, parts of the shaft that had a micro-relief surface formed by a system of non-intersecting sinusoidal microgrooves is obtained. From the study, it was found that the load carrying capacity was increased by 1.5-2 times compared to a smooth shaft for sliding velocities ranging from 30 to 60 m/s. As for grooves greater than 12-15 μm,there was no improvement achieved in bearing performance. From the study, the same bearings were tested again in low operating speed range and it was found that frictional losses were reduced by 10 to 15% when dimpled shaft is used. Bulyuk also conducted a research on thermal analysis of sliding bearings with micro-channels on the shaft and claimed that there is a forced turbulization in the loaded zone where the heat removal from the shaft becomes 1.8 to 4 times greater with micro-channels when compared to the smooth shaft.

2.3 SURFACE TEXTURING

The main reason to measure bearing surface roughness is to predict the performance of the component as a certain level of surface texture is required for bearing surface, so that lubricant is allowed to be retained in small pockets as well as allowing the bearing to roll with minimum friction. High level of roughness on surface texture can cause wear to quickly develop; however, surface texture that is too smooth can cause inadequate lubrication and seizure. Therefore, it can be concluded that surface texture can affect the friction and wear behaviour of boundary lubricated sliding surfaces. However, the tribological properties of the lubrication can be improved by introducing controlled depressions and undulations in an otherwise flat surface. Then the lubricant can be supplied even inside the contact by the small reservoirs, which helped in reducing friction and prolong the lifetime of the tribological contact [7].

Due to the fact that small improvements in bearing performance can decrease power losses and thus saving cost, the effect of surface texturing on bearing performance has been a subject of a numbers of theoretical and experimental studies. [1]. Amir, J. et. al. claimed that Arghir et al. predicted pressure build up with the presence of macro-roughness and Sahlin et al. confirmed this finding later and an optimization of the geometry is presented. Amir, J. et. al. [1] also claimed that Cupillard et al. have studied a journal bearing with surface texture using the full Navier-Stokes equations and a cavitation model. From the study, the authors illustrated claimed that when dimples of suitable width are introduced, the coefficient of friction can be reduced. They also claimed that this result can be achieved either in the region of the maximum hydrodynamic pressure for a bearing with a high eccentricity ratio or downstream of the maximum film for a bearing with a low eccentricity ratio. However, a new effect of pressure build up was identified at low eccentricity ratio during the experiment. The mechanism of pressure build up due to the existing texture in a convergent gap between two sliding surfaces was also investigated. The authors claimed that when the fluid receives energy from the moving wall, they identified lower losses in the inlet than in the outlet part which produce positive variation of the mechanical energy in the inlet part and pressure is built up due to that. Pressure gradient decreases were identified when recirculation occurs. From these statements, it can surface texturing is one of the alternatives to improve the performance of a journal bearing. So far, research on shaft texturing conducted was only experimental and there are less identified research on complete study of the textured shaft effect on improving bearing performance using the full Navier-Stokes. If conducted, such study might create a possibility to give valuable insight of pressure build-up under the presence of a dimpled rotor.

2.4 PRESSURE DISTRIBUTION

For proper operation of the bearing, lubricant is required in order to convert dry friction to fluid friction where a moderately compressible and viscous fluid is preferable as it can supply a complete fluid film between the journal and bearing. It will be highly preferable if there are any means to prevent the lubricant, fluid, air to escape. The principle of fluid lubrication regarding bearing performance is illustrated as shown in Figure 2.1. In the sketch, it is shown that the bearing has a certain clearance with respect to the journal. At start, the journal pumps the lubricant and builds up a pressure which lifts the journal from the bearing, where the escape of the lubricant is retarded by its viscosity. Three factors to be considered in the design of bearings are higher viscosity, longer bearing, and smaller clearance act as they can decrease the escaping tendency. If less lubricant escape is present, the shaded peak shown in the sketch will be higher and the load capacity of the bearing will be increased. If greater pressure is produced by higher viscosity, it will produce higher frictional heat. If this happens, it must be carried away by tile journal, the bearing, and the flow of the lubricant. From Figure 2.1, it can be deduced that the pressure established is great in excess of the feed pressure. Lubricant that is fed into the area of high pressure from the lower pressure feed line will decrease the pressure necessary for proper bearing operation and this explore another design factor which must be considered [4].

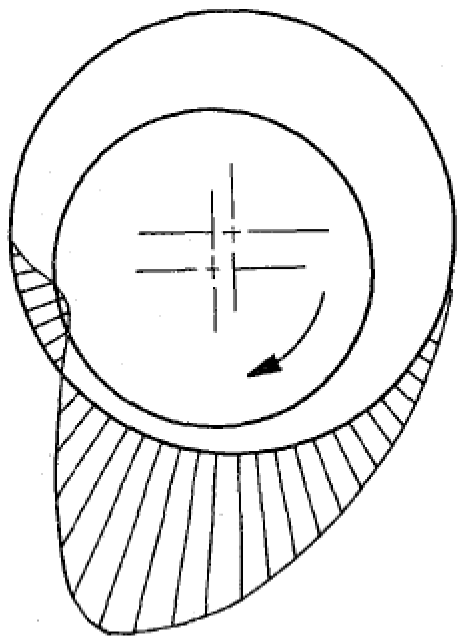

Figure 2.1: Pressure distribution (shaded area) in lubricant film of plain bearing [4]

Dimensional characteristics of the bearing hold an important role in the bearing assembly operation where oil grooves that are commonly employed in bearings imply another design factor that are needed to be considered.

Figure 2.2 illustrates the effect of an oil groove placed in the high-pressure area of a bearing. When the groove is absent, the pressure distribution bearing is illustrated by dashed “u" curve. It is to reduce the pressure to avoid built up in normal load capacity from the unit. However, placing an oil distributor groove in the low-pressure area for a portion of the bearing length is preferable as any grooving that crosses the high-pressure area is objectionable. This is also exception in some rare cases under certain particular operating conditions where fluid lubrication might be impossible.

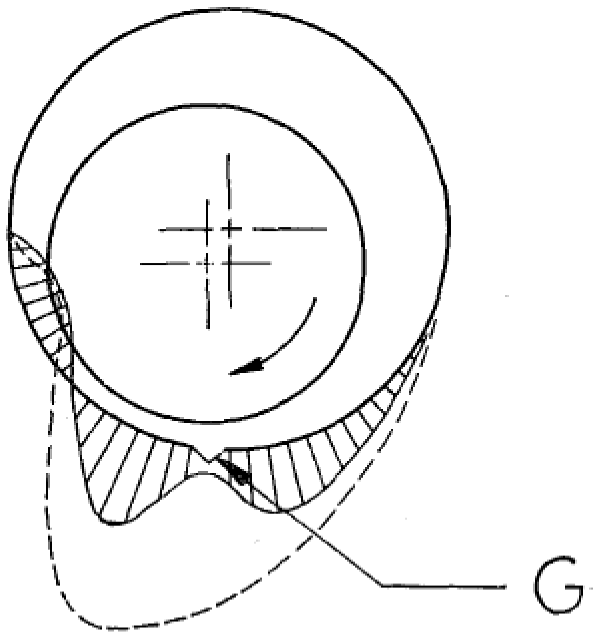

Figure 2.2: Pressure distribution (shaded area) in lubricant film of plain bearing containing axial groove *G* [4]

Circumferential oil grooves may be the cheapest way of feeding oil to the connecting rod bearings, but this approach is objectionable. The effect of circumferential oil grooves groove on the pressure distribution along the length of a bearing is illustrated in Figure 2.3, where the dashed curve indicates the normal