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Pressure Distribution in Hydrodynamic Journal Bearing with Lubricants Additives

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Abstract. In this paper, the effects of additives on the base lubricants has been investigated and reported, aiming for enhancement and the improvement of hydrodynamic journal bearing performance. A pair of additives volume fractions with a viscosity ratio were considered as blended with the base binder. A dimensionless pressure distribution with improved viscosity over the lubricant film has been identified. The results show an increase on the pressure distribution in response to increase in volume fraction of the additives.

1 Introduction

For the past few decades, a number of research studies were carried out attempting to improve the performance of blended lubricants with additives, which have contributed to a better performance of hydrodynamic journal bearing. The common practice to such improvement is by adding or appending particles that possess a desirable properties that can potentially improve the base lubricant, some researchers have recognized the micro-scale properties of the additives for base lubricant, with specific interest on the thin film lubrication, they enhanced the blend mixture additive with an approach built by developing relationship among the additive important properties such as density, viscosity and volume fraction [1]. Nowadays, most of the modern lubricants consist of polymeric additives that can influence the base lubricants to slight shear thinning and mostly viscoelastic [2]. This further classifies the fluid as non-Newtonian, which exhibits non-linearity in the relationship between shear stresses and shear rates. Many researchers have studied to determine the possible effects of such non-Newtonian lubricants may have a significance on the performance of bearings [3]. The analysis show that such fluid played an important role on lubricating of moving parts [4, 5]. Lin *et. al* [6] studied the effect of lubricant rheology on hydrodynamic journal bearings, and approached the non-Newtonian behavior of the lubricating oil based on modern continuum point of view.

Hence, the present work's objective is to investigate and explore the effect of additives blended within the base as binder lubricant to enhance the performance of hydrodynamic journal bearing. The fundamental approach utilized here incorporates a modified form of Reynolds equation [7] which accounts for the viscosity and volume fraction effects of base lubricants and additive mixture. Comparisons between Newtonian and non-Newtonian fluid effects are analyzed.

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2 Analysis

Modifying the viscosity of base lubricants with addition of volume fraction v_2 of additive materials [1].

$$\mu = \mu_1 v_1 + \mu_2 v_2 \tag{1}$$

Where μ_1 and μ_2 are viscosities of the binder lubricant and the additive respectively, v_1 and v_2 are corresponding volume fraction.
Where,

$$v_1 + v_2 = 1 \tag{2}$$

$$\mu = (1 - v_2)\mu_1 + \mu_2 v_2 \tag{3}$$

The dimensionless form of equation (3) can be acquired as,

$$\bar{\mu} = 1 + v_2(\eta - 1) \tag{4}$$

Where, $\bar{\mu}$ is the dimensionless viscosity and η is viscosity ratio of additive to the base binder.

Finally, using the non-dimensional mean film pressure presented by Hsu *et. al* [7], and incorprating the viscosity viration due to volume fraction

$$P = -12 \times \lambda^2 \times \varepsilon \times \bar{\mu} \times h^{-(n+2)} \times \left(Z^2 - \frac{1}{4}\right) \times \sin\theta \tag{5}$$

3 Results

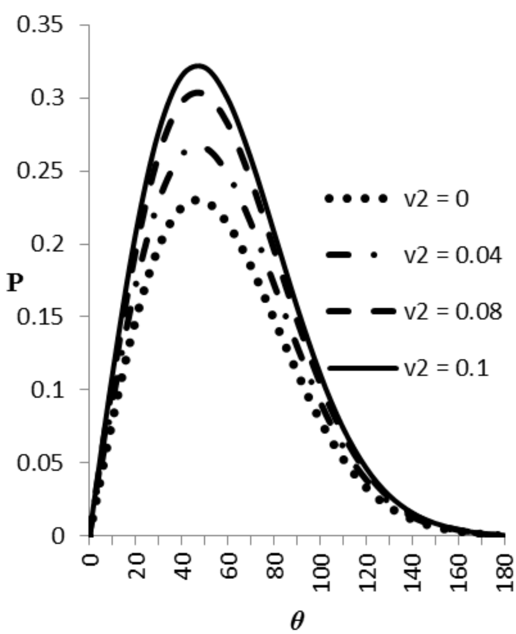

Figure 1. P vs θ under various volume fraction

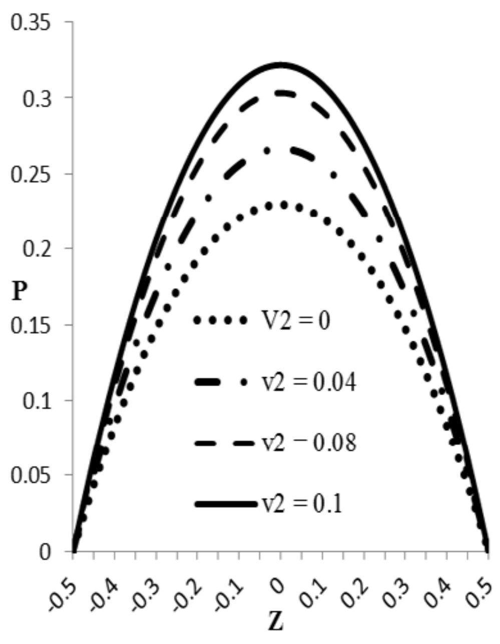

Figure 2. P vs Z under various volume fraction

A pair of volume fraction of additives blended with the base lubricants have been used with different viscosity ratio. Dimensionless pressure distribution over the lubricant film has been identified. Fig. 1 and fig. 2 show the relationship between dimensionless pressure (P) versus circumferential coordinate (θ) and dimensionless coordinate in the z-direction (Z) respectively. The plots generated under different volume fraction of additives. The lubricant fluid treated as Newtonian in both figures. The pressure generated in the fluid film is low without addition of additives ($v_2 = 0$). However, at each increase of volume fraction of additives ($v_2 = 0.04, 0.08, 0.1$) blended with the lubricants, the pressure lubrication increases in the fluid film. This increase of pressure in the fluid film in the journal bearing prevents contact between relatively moving parts of machineries. In return, it also improves the load carrying capacity of journal bearing.

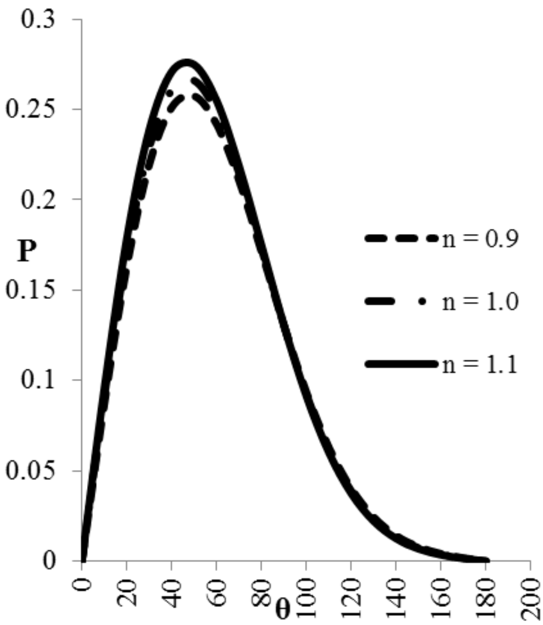

Figure 3. P vs θ under various flow behavior

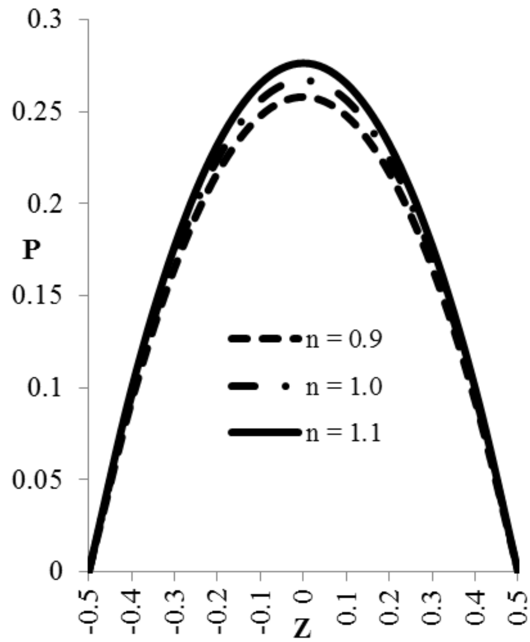

Figure 4. P vs Z under various flow behavior index

On the other hand, fig. 3 and fig. 4 are generated under various power law indexes, whereby, the fluid lubricant treated as non-Newtonian. Both show the relationship between dimensionless pressure (P) versus the circumferential coordinate (θ) and dimensionless coordinate in the z-direction (Z) respectively. The results have the same trend as in fig. 1 and fig. 2 with slight deviation from the Newtonian assumptions. It is concluded that, the pressure distribution in the fluid film is directly proportional to the portion of blended additives.

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Nomenclature

C	Radial clearance
e	Eccentricity, $e = \varepsilon C$
h	Thickness of lubricant film $h = 1 + \varepsilon \cos \theta$
n	Power law index
μ	Viscosity parameter
η	Viscosity ratio, $\eta = \mu_2/\mu_1$
$\bar{\mu}$	Dimensionless viscosity, $\bar{\mu} = \mu/\mu_1$
P	Film pressure
R	Radius of the journal
x, y, z	Rectangular coordinates
Z	Dimensionless coordinate in the z-direction, $Z = z/L$
ε	Eccentricity ratio, $\varepsilon = e/C$
θ	Circumferential coordinate, $x = R/\theta$
λ	Length-to-diameter, $\lambda = L/2R$