Study of the behavior of a non-Newtonian fluid in a hydrodynamic plain bearing with textured surface

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Abstract: Many current studies focus on the interaction of fluids – structures of different components and fluids (rotor, bearings, bearing supports, lubricating fluid, and surrounding fluids) of rotating machines such as turbines and electric motors operating under hydrodynamic lubrication.

The present work is parametric numerical study of the behavior of a non-Newtonian fluid in a hydrodynamic plain bearing with a textured surface. This study is simulated by the ANSYS –CFX computer code, the numerical analysis is carried out by solving the Navier-Stokes continuity equation, the numerical results show that the most important hydrodynamic characteristics such as the pressure is overestimated by a textured and lubricated bearing with a fluid whose behavior is not Newtonian.

Keywords: Textured hydrodynamic plain bearing, non-Newtonian fluid, tribological behavior, Newtonian fluid, hydrodynamic characteristics, pressure.

1. INTRODUCTION

Rotating machines occupy a preponderant place in industry and have a very varied use. In machines, hydrodynamic bearings are tribological components that support a load and guide transmission shafts in rotation.

Non-Newtonian fluids, on the other hand, see their viscosity change under the effect of mechanical stress. They become either more viscous or more fluid when tapped, shaken or stirred. Non-Newtonian effects can be of two types: shear thinning effects and viscoelastic effects. Shear thinning effects, often called non-Newtonian effects.

A fluid is said to be Newtonian when its viscosity is independent of the mechanical stress applied to it.

Kane in 2003 shows the effect of roughness and non-Newtonian effects in severe contact lubricants such as bearings. He presented a new modified Reynolds equation called non-Newtonian, using rheological laws and the basics of continuum mechanics applied to thin layers. The resolution of this equation gives the influential parameters on the geometry and rheology, these results have been validated with non-Newtonian theory.

In 2005 Fatu presents a numerical and experimental modeling of the lubrication of motor bearings subjected to severe operating conditions with the laws of variation of the appropriate viscosity, it can highlight the respective influence of non-Newtonian and piezoviscous effects in the complex case of large end bearings. Fatu showed that the piezoviscous effect turns out to be the most significant effect on the behavior of the bearing.

Additionally, since polymer-containing oils are expected to have a decrease in viscosity and normal stresses at high shear rate, thus having non-Newtonian behavior, the rheological properties were examined as a function of operating condition levels by Moritsugu KASAI in 2010. The results show temperature and pressure in the supposed non-Newtonian fluid film are high, with a coefficient n greater than 1, that is to say for viscoelastic fluids.

In 2016 Javorova and colleagues presented a study of a hydrodynamic bearing examining flexible deformation and non-Newtonian fluids, using the Rabinowitsch fluid model. They showed that higher values of membrane pressure and load capacity were obtained on dilute lubricants, while false lubricants and oil film pressure were less significant.

Mehala and his collaborators presented in 2016 a study on the impact of the behavior of a non-Newtonian fluid for plain bearings working under severe operating conditions. The non-Newtonian behavior of lubricants (oils containing PM3 polymers) was analyzed numerically, the effect of temperature in laminar regime is also introduced, by solving the energy equation by the finite difference method.

2. THE DIFFERENT TYPES OF NON-NEWTONIAN FLUIDS

There are 5 types of non-Newtonian fluids.

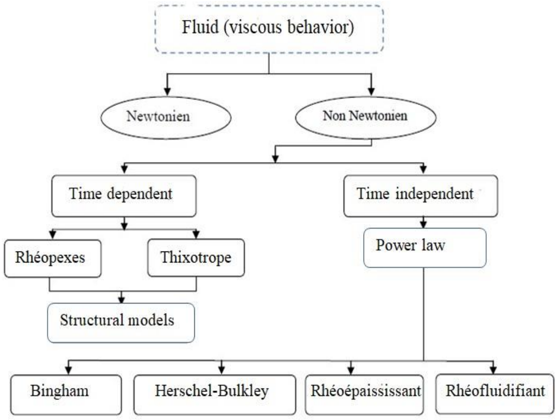

Figure 1. Classification of rheological behaviors.

2.1 Non-Newtonian fluid with time-independent behavior

These are fluids whose effective viscosity does not decrease with time when we apply a constraint on their behavior. Structural changes occurring in the fluid over time.

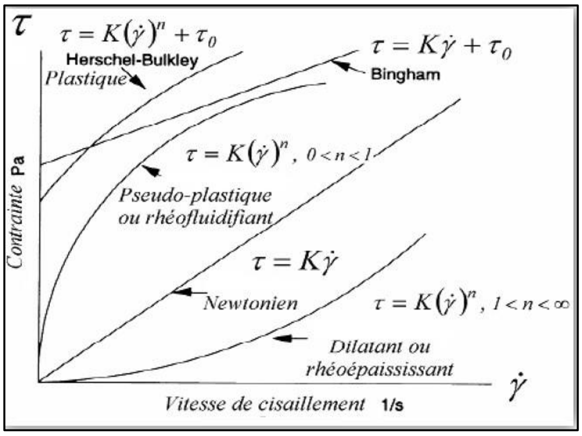

Figure 2. Rheogram of some categories of fluids.

2.2 Non-Newtonian fluid with behavior dependent on Time

There are also fluids influenced by duration, these are thixotropic fluids and anti-thixotropic fluids.

3. DEFINITION OF HYDRODYNAMIC BEARNINGS

The hydrodynamic bearings are frequently used, the simplest are made up of two elements, a cylindrical shaft generally made of steel of radius Ra which rotates inside a bore, (Figure 3) and the bearing made of bronze or regulated steel of radius interior in steel Rc and length L the characteristics of our bearing are indicated in figure 4.

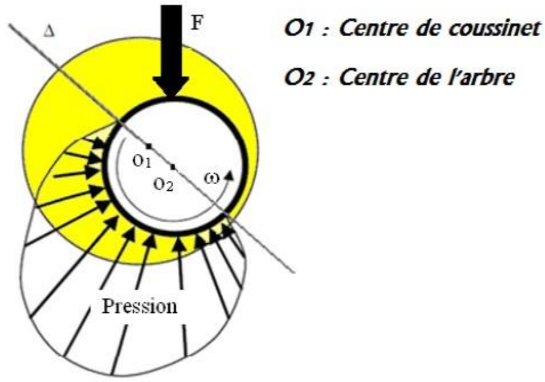

Figure 3. Hydrodynamic bearing with hydrodynamic pressure fields.

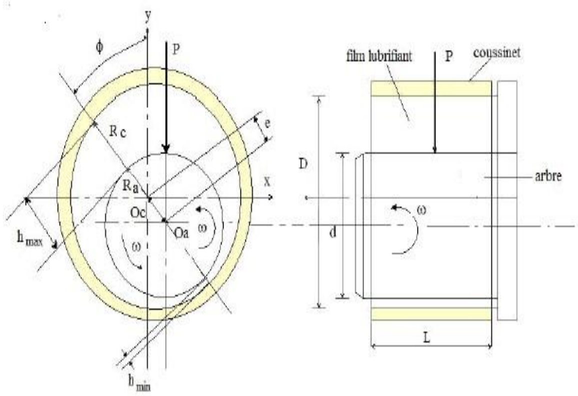

Figure 4. Hydrodynamic bearing operating characteristics.

In this case, a viscous fluid completely separates the surfaces present. The pressure in the film is created by the relative displacement of the surfaces and the geometry of the contact. HD bearings are fluid elements used to guide the shaft lines of rotating machines. These bearings fall into two categories: radial bearings and axial bearings also called thrust bearings.

4. DIFFERENT TYPES OF HYDRODYNAMIC PLAIN BEARINGS

This type of bearing is designed to operate in severe conditions (high loads and rotation frequencies). Therefore, to perform their function in perfect conditions, hydrodynamic bearings must be carefully designed.

There are two types of hydrodynamic bearing configuration:

- Fixed geometry bearings.
- Variable geometry bearings.

5. DIGITAL SIMULATION

This study aims to better predict the non-Newtonian behavior of the oil film in bearings operating under more severe conditions. The rotation speed varies from 1000 to 9000 tr/min and the radial load varies from 2 to 10 kN. The temperature and pressure within the supposedly non-Newtonian fluid film are high, with a coefficient n greater than 1 that is to say for viscoelastic fluids.

5.1 The digital resolution strategy

The digital resolution strategy for an ANSYS CFX code is:

-Modeling of the structure.

-Mesh.

-Load modeling.

-Resolution of the Navier stocks equation by the finite volume method.

-Calculation of the operating characteristics of the bearing.

5.2 Overview of the problem

The simulation is carried out for a hydrodynamic plain bearing of finite dimensions. The diameter of the bearing is 100mm and the length is 80mm, the diameter of the shaft is 99.98. The main geometric characteristics as well as the characteristics of the lubricant are reported in table 5.1.

Table 1. Geometric characteristics of the bearing and lubricant characteristics

parameter	value
Bearing diameter (mm)	100
Shaft diameter (mm)	99.91
Bearing length (mm)	70
Radial clearance (mm)	0.09
Pad thickness (mm)	4
Feed port diameter (mm)	14
Groove length (mm)	70
Starting speed (tr/min)	1000-9000
Radial load (N)	2000-10,000
Supply temperature Ta (°C)	60
Supply pressure Pa (MPa)	0.04
Type of lubricant	PMA 3
Density (Kg/m^3)	800
Specific heat (J/Kg.K)	2000
Kinematic viscosity (mm^2/s)	17.49
Rotation speed (tr/min)	1000-9000
Radial load (N)	2-10
Ambient temperature	60
Supply pressure	0.04

5.3 Geometric representation of the bearing

The geometry is made using ICEM CFD, figure 5 illustrates the geometry of the bearing studied while respecting its dimensions.
The geometry was discretized with a mixed structured mesh; the shaft and the bearing were divided into 20 nodes following the circumference, 103 nodes following the length.

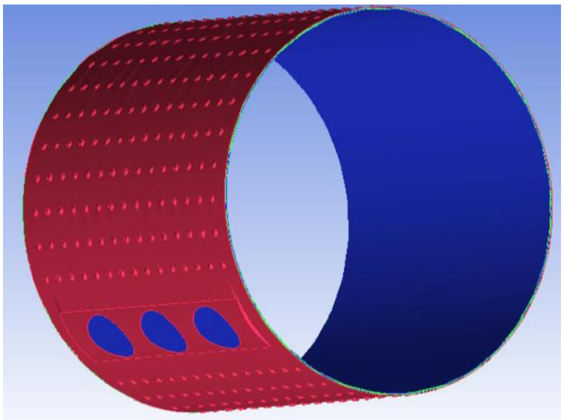

Figure 5. Geometry of the bearing.

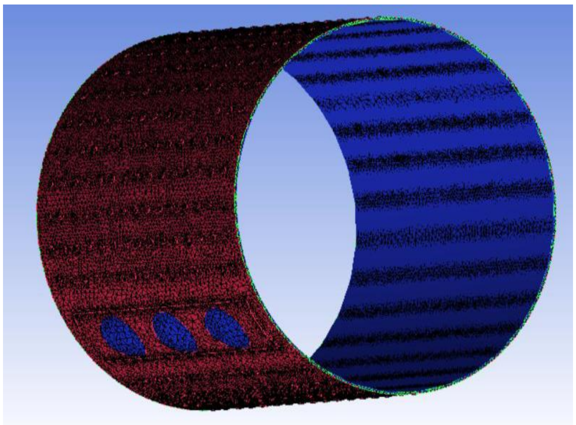

Figure 6. Mesh presentation of the textured surface bearing.

6. RESULTS AND DISCUSSION

6.1 Influence of rotational speed radial load 2000 N and n=1.25 texture bearing.

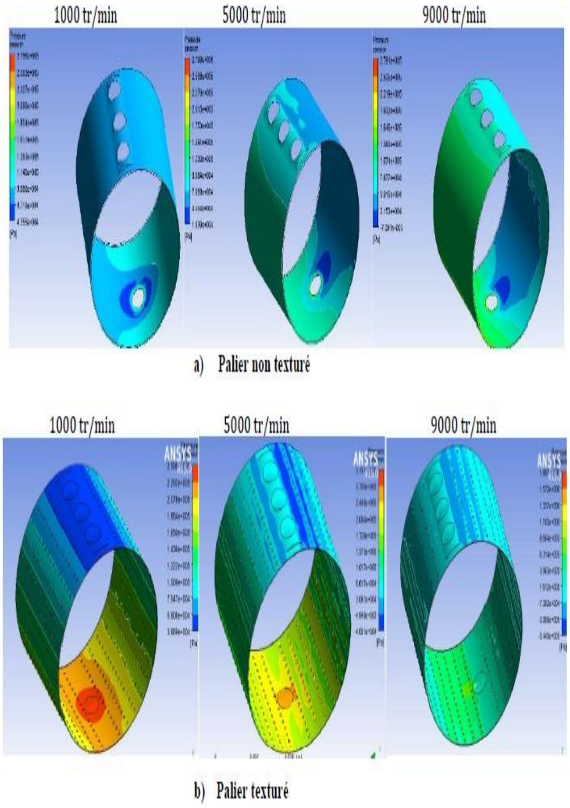

Figure 7. Pressure distribution 3D view.

The maximum pressure values are noted for the high speed (1000 rpm) and decrease with increasing rotation speed.
The pressure drops for a rotation speed ranging from 1000 to 9000 tr/min.
The maximum values are positioned at the angular coordinate levels.

6.2 Influence of power coefficients n NFLUENCE OF POWER COEFFICIENTS n

The pressure evolution for different power coefficients n is shown in Figure 8.

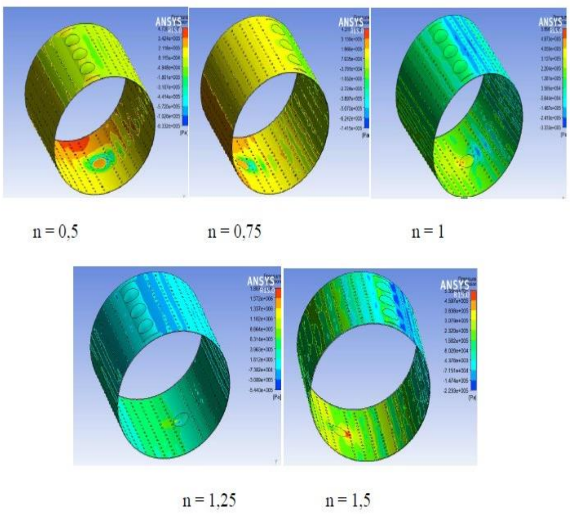

Figure 8. 3D pressure for a plain bearing for different n.

There is a creation of a rupture zone of the oil film for non-Newtonian fluids with a power coefficient less than 1 (n = 0.25 and 0.75), case of a rheofluidifying fluid.
The increase in the power coefficient n causes the pressure to decrease.

7. CONCLUSION

A numerical analysis of the behavior of non-Newtonian fluid on the operating performance of a hydrodynamic plain bearing with a finite-dimensional textured surface. This study is simulated by the CFD code, which provides accuracy, reliability, speed and flexibility in potentially complex flow domains.

The numerical study is validated with results from Dr. MEHALA, found in the literature.

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