7^{th} *World Tribology Congress, WTC 2022*
July 10-15, 2022, Lyon, France

Pressure evaluation in a porous medium hydrodynamic bearing

D.H. Nguyen, N. Herzig and R. Glovnea

Department of Engineering and Design, University of Sussex, United Kingdom

Lubrication with a porous medium is found in nature, for example in animal joints, where the porosity of the cartilage allows the additional squeeze film mechanism to contribute to the lubrication of the joint. In this study the pressure generated on a bearing surface sliding against a porous medium imbibed with liquid is evaluated experimentally and theoretically. A purposely designed and built test rig is used to measure the pressure distribution on a plain geometry and the results compared to the full film hydrodynamic bearing and theoretical predictions.

Key Words: Poroelastic, Permeability, Lubrication

Introduction

The mechanism of porous lubrication was studied relatively intensely starting with about fifty years ago, in the context of the lubrication of human joints (e.g. [1] [2]). Much more recently it was recognised that this type of lubrication can be applied to the lubrication of other, biological or non-biological systems involving porous media [3]. The analysis by Pascovici [4], for pressure in plain and step slider bearings, using the Carman-Kozeny law for the variation of the permeability with the porosity, for compressible porous layer, gives maximum pressures 2-4 orders of magnitude larger than that of similar geometry hydrodynamic bearings. Gacka et al [5] evaluated experimentally the pressure generated in a plane pad which slides against a highly porous material.

Methodology and results

In this study the pressure by poroelastic lubrication generated in a plane sliding bearing geometry was evaluated theoretically. The pressure gradient along the length of the slider is given by equation (1), which is basically the Reynolds equation [3].

$$\frac{dp}{dx} = \frac{\mu U}{k}\left(\phi - \frac{\phi^* h^*}{h}\right) \qquad (1)$$

In this equation p - pressure, x - coordinate in the direction of sliding, μ - dynamic viscosity, U - sliding velocity, k - permeability, h - separation between the solid surfaces, ϕ - porosity, while the * indexed quantities represent the values at the maximum pressure location.

The Carman-Kozeny [3] and Nogai and Ihara [5] approaches for estimating permeability for fibrous porous media were employed. Both of these equations rely on empirical constants however it was thought that the Nogai and Ihara equation would provide better fit to the experiments, given the fact that its constants change different materials and proved to be accurate for a high range of porosities. The side pressure leakage was not considered in these analysis, in other words, the bearings are treated as they are infinitely long.

Figure 1 compares the pressure distribution obtained with Carman-Kozeny [3] and Nogai-Ihara models for permeability, for a fibrous material with the fibre diameter of 24 μm, imbibed with water. The pad has dimensions 50x50 mm, and a slope of 0.04 and moved at a speed of 0.1 m/s. The value of β was taken 1.5 in these calculations.

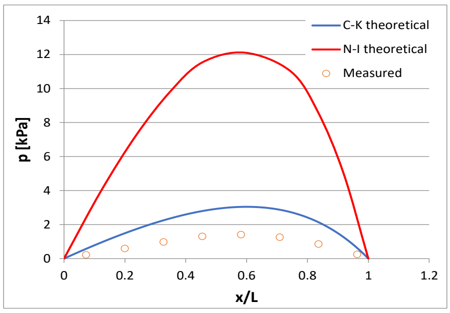

Figure 1. Pressure distribution

The initial porosity of the material was taken as 0.6 and the un-deformed thickness 10 mm.

An experimental rig was designed and built to investigate the validity of theoretical models with fluids as the lubricant and a similar porosity range. Glass tubes were attached to sliding pad, such that the height of the fluid columns inside the tubes would indicate the pressure over the pad. For the same working conditions used in the simulations, it was found that the maximum pressure was 1.4 kPa, which is very close to the theoretical predictions given by the Carman-Kozeny model. This is probably because the Nogai-Ihara model for permeability was developed for air as working fluid.

References

[1] Dinnar, U, “Two-Porous-Layers Lubrication in Human Synovial Joints”, Ann. Bio. Eng., (1976), 4, 91-107

[2] A. Unsworth et al. “Some new evidence on human joint lubrication”, Ann. Rheum. Dis. (1975), 34, 277-285

[3] J. Feng, S.Weinbaum, “Lubrication theory in highly compressible porous media: the mechanics of skiing, from red cells to humans”, J. Fluid Mech. (2000), 422, 28-317

[4] M.D. Pascovici, “Lubrication Processes in highly compressible, porous layer” Proc. Intern. Conf. of Francophone Tribology, Poitiers, 2007

[5] T. Gacka et al. “From red cells to soft lubrication, an experimental study of lift generation inside a compressible porous layer”, J. Fluid Mech. (2017), 818, 5-25

[6] T. Nogai and M. Ihara, “Study on Air Permeability of Fiber Assemblies Oriented Undirectionally” J. of The Textile Machin. Soc. Japan, (1980), 26, No. I, 10-14