7th World Tribology Congress, WTC 2021
September 5-10, 2021, Lyon, France

Optimisation of bearing geometry for linear sliders lubricated with piezo-viscous fluids

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Already 1918, Lord Rayleigh discovered the step-bearing geometry which maximises the load carrying capacity (LCC), under conditions when the lubricant's density and viscosity can be assumed to be constant. Rayleigh's approach was analytical and founded on calculus of variations. With the introduction of computers, successors have been employing numerical optimisation methods with which they have studied more complex lubricant behaviour, other bearing configurations and operating conditions. This paper presents one of these, and here the Reynolds equation for incompressible and piezo-viscous fluids has been adopted as the governing equation for the fluid flow and it was implemented in the FE-based software COMSOL Multiphysics. The optimisation employs the globally convergent method of moving asymptotes (GCMMA) for topology optimisation, and with the film thickness as the control variable both the LCC and the coefficient of friction (COF) have been considered as objective functions.

Keywords: *Topological optimisation, piezo-viscous, Reynolds equation, step-bearing, MMA.*

1. Introduction

One of the main factors affecting bearing performance is the lubricant rheology. For an infinitely-wide slider lubricated with a Newtonian (iso-viscous) and incomepressible fluid it is the step bearing that Rayleigh found, which we reproduced with the GCMMA in COMSOL Multiphysics [1], see left part of Fig. 1. We have also presented results for finitely wide sliders [2]. In this work, we have added the piezo-viscous behaviour of the lubricant to the study, and we optimise both to obtain geometries that maximises the LCC and that minimises the COF. The results are validated against the Rayleigh step bearing and the results presented by Rohde [4].

2. Methods

For a lubricant exhibiting of piezo-viscous behaviour according to Barus' law, i.e.

$$\mu(p) = \mu_0 e^{\alpha p}, \tag{1}$$

there the following change of variables (similar to that Muskat and Evinger presented in [3])

$$q(x) = 1/\mu\big(p(x)\big), \tag{2}$$

may be used to linearise the Reynolds equation. In dimensionless form, with $X = x/L$, $Q = \mu_0 q$ and $H = h/h_0$, for the stationary 1D case, with the pressure $P = 0$ on the boundaries $\partial\Omega$ it reads

$$\frac{\partial}{\partial X}\left(\Lambda H + H^3 \frac{\partial Q}{\partial X}\right) = 0 \text{ in } \Omega, \qquad Q = 1 \text{ on } \partial\Omega. \tag{3}$$

With the film thickness, H, as control function the dimensionless load carrying capacity (LCC):

$$W = \frac{\alpha w}{L} = -\int_0^1 \ln(Q)\ dX, \tag{4}$$

and the coefficient of friction (COF)

$$F = f/\left(\frac{\mu_0 U L}{h_0}\right) = \int_0^1 \frac{1}{Q}\left(\frac{1}{H} - 3\frac{H}{\Lambda}\frac{dQ}{dX}\right) dX, \tag{3}$$

were specified as objectives for the GCMMA-based optimisation method.

3. Results & Discussion

The LCC maximisation results are depicted in Fig. 1, which shows that the Rayleigh step geometry, obtained with $\Lambda = 1$, is the optimal geometry for piezo-viscous fluids, however, the pressure solution is not bi-linear as Rayleigh's solution. Moreover, the LCC increases considerably as the effect of piezo-viscosity increases. The results for the COF are depicted in Fig. 2, including Rohde's optimal geometry obtained with $\Lambda = 1$.

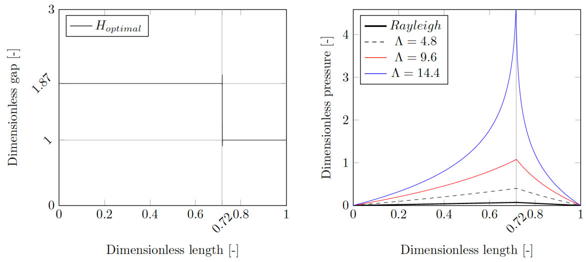

Figure 1: **Left:** the Rayleigh step-bearing geometry obtained with the MMA, for all four values of Λ. **Right:** the corresponding optimal pressure solutions.

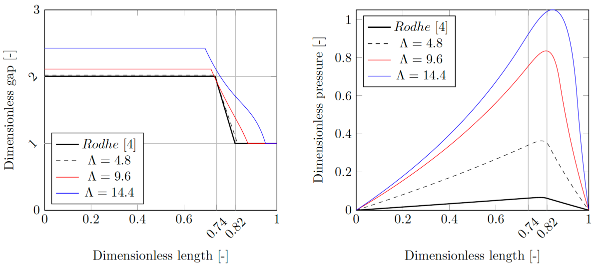

Figure 2: **Left:** the optimised bearing geometry by Rodhe [4] (continuous black) reproduced with the MMA-routine and geometries for four values of Λ. **Right:** the corresponding optimal pressure solutions.

4. References

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