Hydrodynamic lubrication in porous journal bearings: comparison between experimental and simulation data

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Outline

Introduction

Experimental investigations - GKN

Comparison to simulation

Additional findings

Conclusions and questions to be answered
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Conclusions and questions to be answered
Remember the problem?
Remember the problem?

- prediction of cavitation
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- prediction of cavitation
- pressure in the lubrication gap
Remember the problem?

- prediction of cavitation
- pressure in the lubrication gap
- coefficient of friction
Remember why sintered bearings?
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- reliable products
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- reliable products
- expanding manufacturing area
  - highest raw material utilisation
  - lowest energy requirement

Wide range of applications: automotive, aerospace applications, household appliances.
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- wide range of applications
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Test parameters

- spherical iron bearings, \( \varnothing 8 \) mm
- porosities of 20\%, 25\%
- radial loads of 0.5 N/mm\(^2\), 1.5 N/mm\(^2\)
- 3 Ionic Liquids (IL) as lubricants
  - IL1 - VG32
  - IL2 - VG150
  - IL3 - VG220
- test rig configuration settings
  - 5 hours running-in at 3000rpm
  - 3 x Striebeck tests
Results - temperatures

- thermo-couple mounted on the side of the bearing

running in  

Striebeck tests
Results - friction number for IL1, IL2, IL3

Porosity

20%  25%

Applied load
0.5 N/mm²
1.5 N/mm²

μ [·]

ω [rpm]
Results - running surfaces (1)
Results - running surfaces (2)
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Comparison to simulation - concepts

- Strubeck measurements
  - hydrodynamic branch
Comparison to simulation - concepts

- Striebeck measurements
  - hydrodynamic branch
- load varied by the control parameter $\varepsilon$
  - numerical interpolation required
Comparison to simulation - concepts

- Striebeck measurements
  - hydrodynamic branch
- load varied by the control parameter $\varepsilon$
  - numerical interpolation required
- $\eta(T)$ included in the code by Ubbelohde-Walther relation:

\[
\lg \lg (\eta + a) = k - m \lg T
\]

$a, k, m \ldots$ empirical constants
Comparison to simulation - concepts

- Strubeck measurements
  ▲ hydrodynamic branch
- load varied by the control parameter $\varepsilon$
  ▲ numerical interpolation required
- $\eta(T)$ included in the code by Ubbelohde-Walther relation:

$$\lg \lg (\eta + a) = k - m \lg T$$

$a, k, m \ldots$ empirical constants

- value of the measured permeabilities included in the code
Comparison to simulation - low viscosities

20% porosity

IL1

25% porosity

IL2

IL1

IL2

Comparison to simulation - low viscosities

20% porosity

IL1

25% porosity

IL2
Comparison to simulation - high viscosity

20% porosity

IL3

25% porosity
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Density distribution

\[ \varepsilon = 0.2 \]

\[ \varepsilon = 0.5 \]

\[ \rho \]

Grid oscillations in circumferential coordinate \( \theta \) inevitably a density jump (spontaneous recondensation)
Density distribution

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\( \rho \) grid oscillations in circumferential coordinate \( \theta \)
Density distribution

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- grid oscillations in circumferential coordinate \( \theta \)
- inevitably a density jump (spontaneous recondensation)
Density jump

- assumptions
  - massive bearing
  - cavitation symmetric w.r.t. $\theta = \pi$
  - $H(\theta) \rho(\theta, z) = f(z)$
Density jump

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  - massive bearing
  - cavitation symmetric w.r.t. $\theta = \pi$
  - $H(\theta)\rho(\theta, z) = f(z)$

2D case

- infinitely long bearing
- Reynolds equation

$$P'_F(\theta) = \frac{H(\theta) - \bar{H}}{H(\theta)^3}$$
Density jump

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  - massive bearing
  - cavitation symmetric w.r.t. $\theta = \pi$
  - $H(\theta)\rho(\theta, z) = f(z)$

2D case

- infintinely long bearing
- Reynolds equation

$$P'_F(\theta) = \frac{H(\theta) - \bar{H}}{H(\theta)^3}$$

- $P_F = P_C$ at some $\theta = \pi \pm \varphi\pi$
  - impossible!
Density jump, cont’d

full 3D case

assumptions

\[ P_F(\theta, z) = P_{\text{symm}} + P_{\text{asymm}} \]

\( P_{\text{symm}} \rightarrow \) homogeneous elliptic equation, homogeneous BCs

\( P_{\text{asymm}} \rightarrow \) r.h.s. of Reynolds equation
Density jump, cont’d

Full 3D case

- assumptions
  - \( P_F(\theta, z) = P_{symm} + P_{asymm} \)
  - \( P_{symm} \rightarrow \) homogeneous elliptic equation, homogeneous BCs
  - \( P_{asymm} \rightarrow \) r.h.s. of Reynolds equation

- also no solution as shown by
  - mass conservation
  - extremal properties of \( P_{symm} \)
Density jump, cont’d

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  - \( P_F(\theta, z) = P_{\text{symm}} + P_{\text{asymm}} \)
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- also no solution as shown by
  - mass conservation
  - extremal properties of \( P_{\text{symm}} \)

- cavitation is shifted in \( \theta \) direction \( \rightarrow \) density jump
Coefficient of friction

\[ \varepsilon_{\text{crit}} = 0.55 \]

No solutions for extreme values of \( \varepsilon \)!
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  - best correlation for low viscosity lubricants and high loads
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  - discrepancy for high viscosity lubricants → non-Newtonian effects?
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- simulations
  - thorough numerical investigation of whether a threshold, $\varepsilon_{\text{crit}}$ exists
Conclusions

- experiments
  - best correlation for low viscosity lubricants and high loads
  - discrepancy for high viscosity lubricants → non-Newtonian effects?

- simulations
  - thorough numerical investigation of whether a threshold, $\varepsilon_{\text{crit}}$ exists
  - validity of Darcy’s law and coupling term by homogenisation
Thank you for listening!