University of Twente

Centrifugal Effects and Free Surface Thin Layer Flow in Roller Bearings

Ir. MT van Zoelen, dr. CH Venner, prof. PM Lugt

SKF

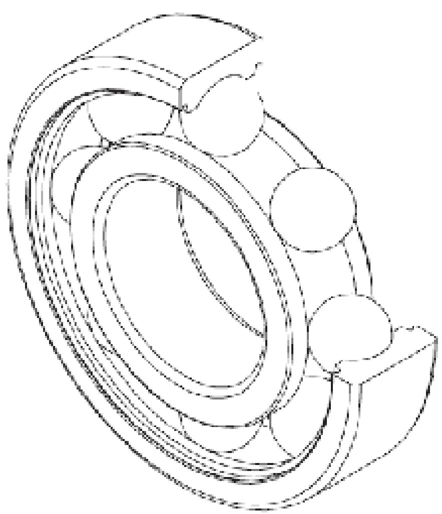
University of Twente
The Netherlands

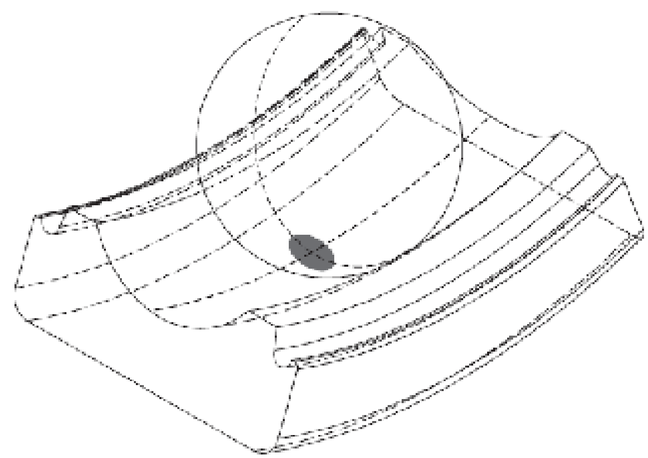
Overview

- Introduction
- The physical model
- Results
- Conclusions / Summary

Introduction

- How long will a bearing last?
- Bearings which are "greased and sealed for life", the service life is determined by the grease life.
- Grease life: Maintain a sufficiently thick lubricant film.
- Film thickness reduction due to: contact pressure, oxidation, evaporation and *pumping* effects.

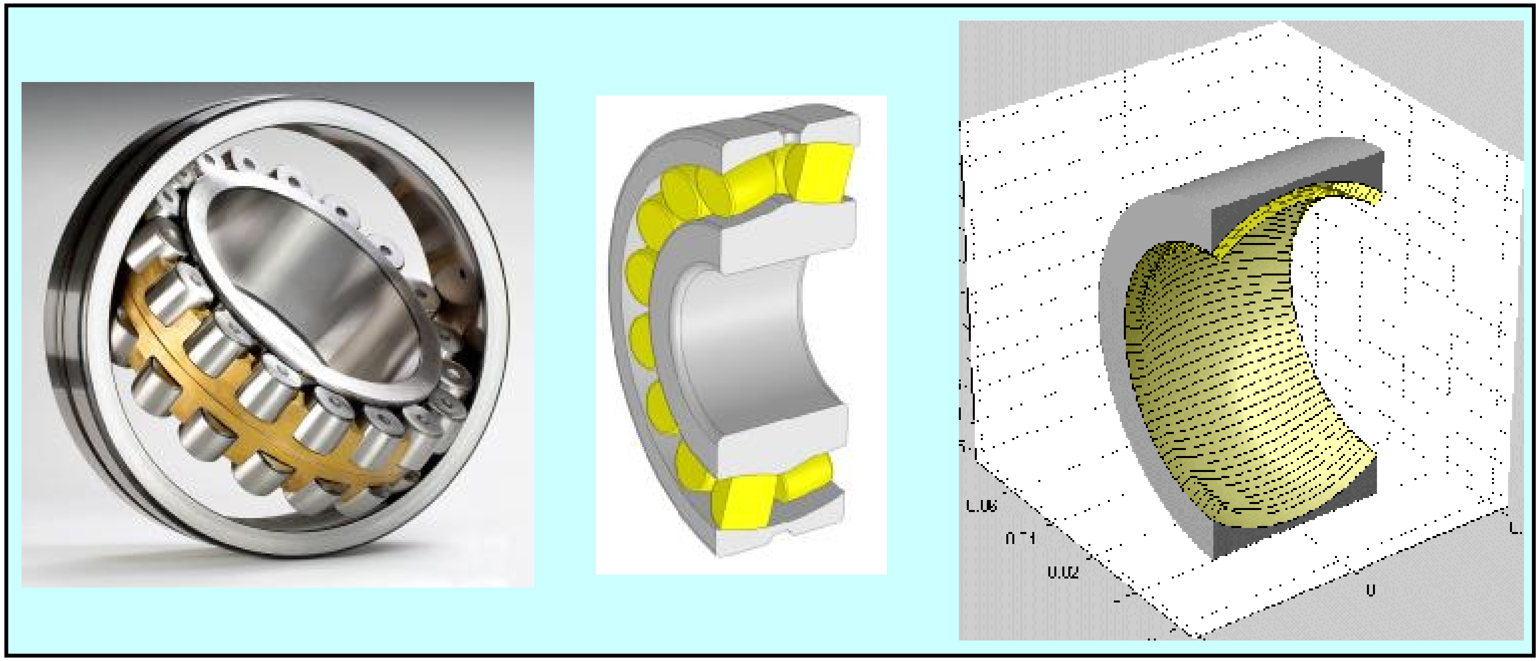




Introduction - Pumping effects

- Pumping effects: the effects of rotation on the distribution of the lubricant.
- Empirical grease life models indicate that "*pumping effects*" may influence bearing life.
- Main research goal: quantification of the pumping effects.

Example



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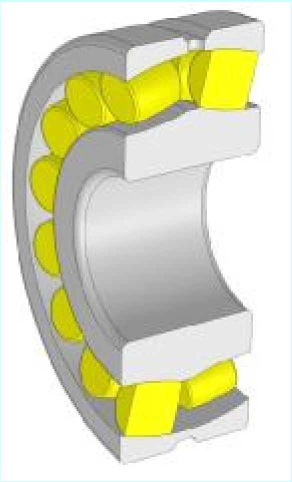
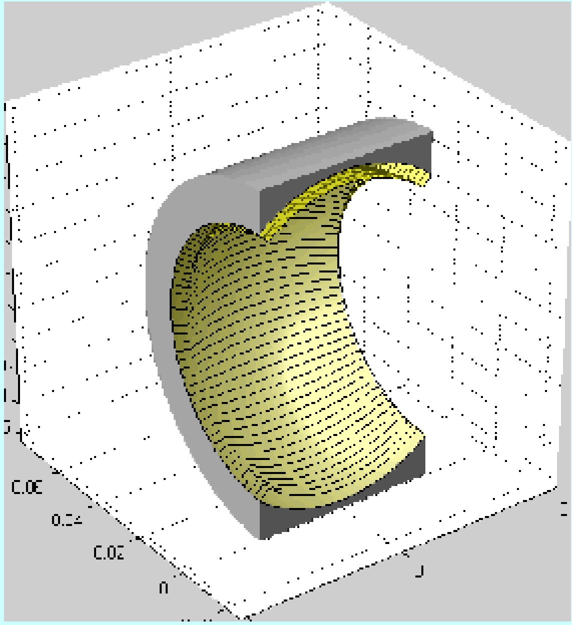


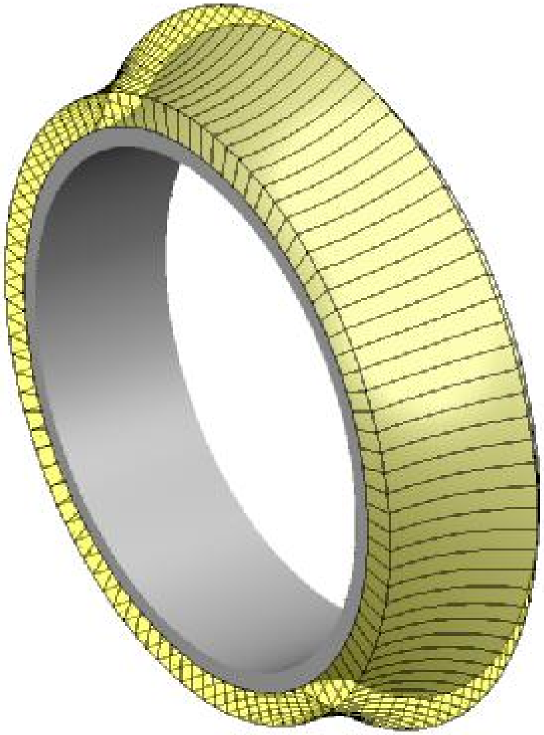


Overview

- Introduction
- The physical model
  - Assumptions
  - Raceway
  - Roller
  - Raceways + rollers
  - Parameters
- Results
- Conclusions / Summary

The model - assumptions

- Base oil is the lubricating medium.
- Oil is driven by inertia forces due to the rotation. (not by contact pressure)
- Thin film approximation H/L<<1
- Solid and liquid surfaces are smooth and axisymmetric. R/L<<1



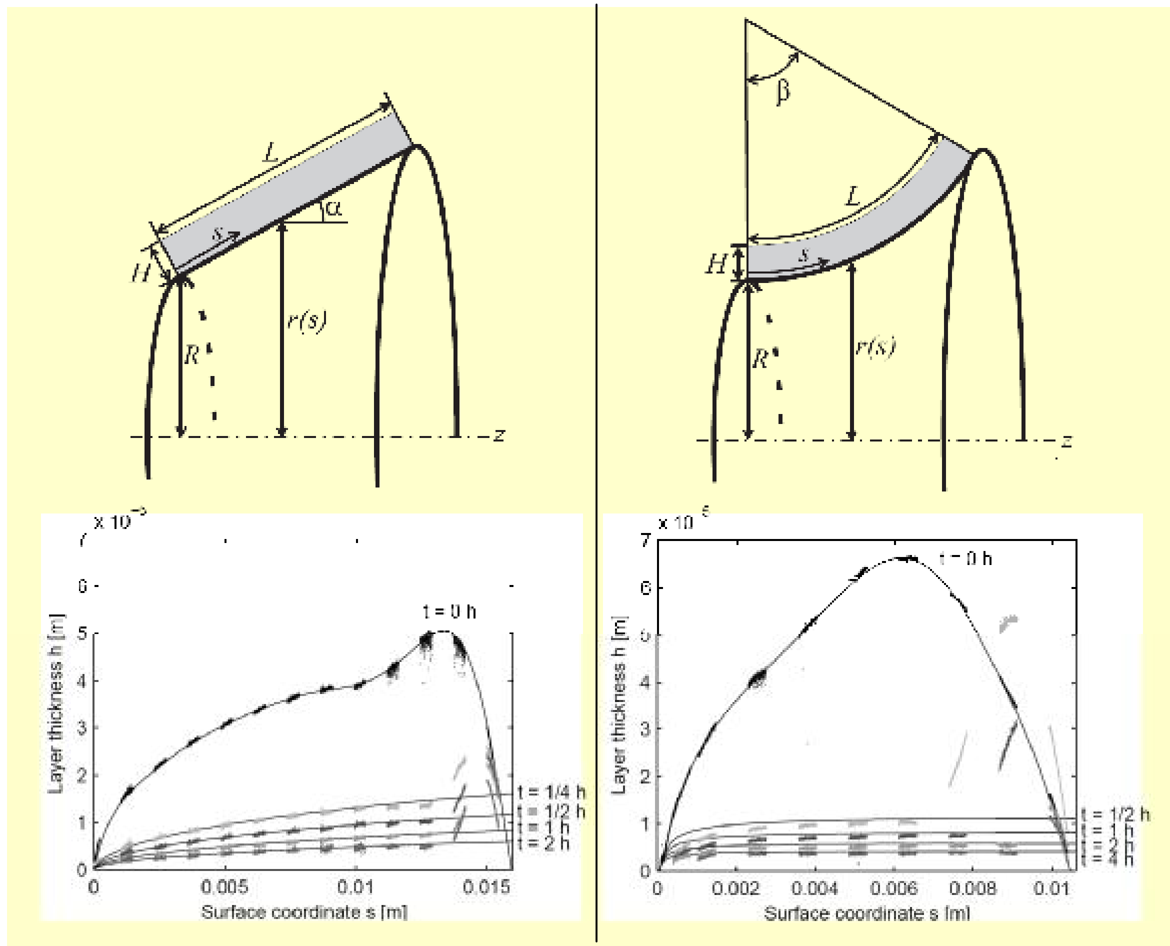
The model – raceway

Flow equation

$$\frac{1}{r}\frac{\partial}{\partial s}\left(\frac{h^3}{3h_0} r\, f_s\right)+\frac{\partial h}{\partial t}=0$$

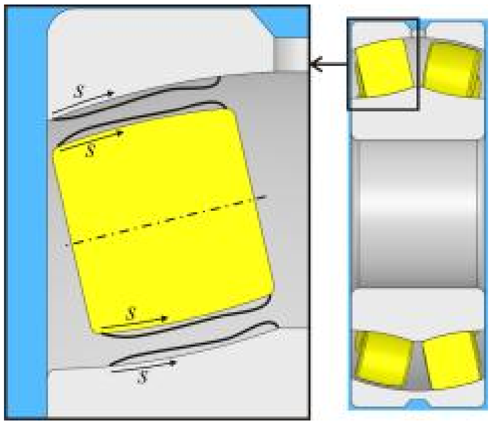
Body force equation

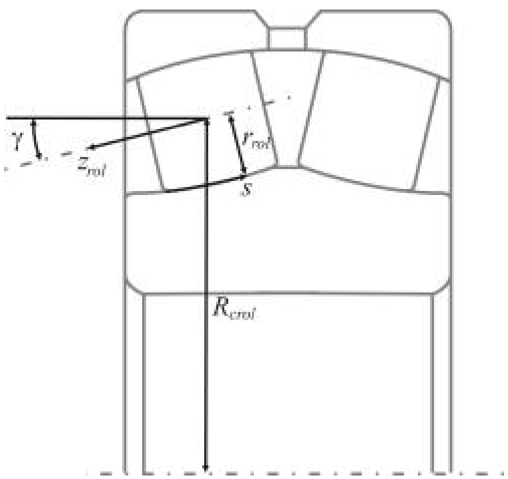
$$f_s = r\Omega^2 r\frac{dr}{ds}$$



van Zoelen, M. T.; Venner, C. H. & Lugt, P. M. "*Free Surface Thin Layer Flow on Bearing Raceways,*" *Journal of Tribology, ASME,* **2008***, 130*, 021802

The model – rollers





Flow equation

$$\frac{1}{r}\frac{\partial}{\partial s}\left(\frac{h^3}{3h_0} r\, f_s\right)+\frac{\partial h}{\partial t}=0$$

Body force equation

Raceways:

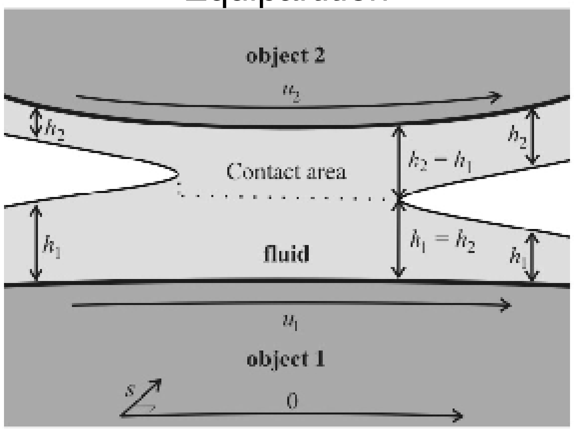
$$f_{s,rw} = r\Omega_{rw}{}^2 r\frac{dr}{ds}$$

Rollers:

$$f_{s,rol} = r\,\Omega_{ca}{}^2\left(\sin^2(g)\,z_{rol}+\sin(g)\,R_{crol}\right)\frac{dz_{rol}}{ds}$$
$$+\left(\left(\tfrac{1}{2}\cos^2(g)+\tfrac{1}{2}\right)\Omega_{ca}{}^2+2\Omega_{ca}\Omega_{rol}\cos(g)+\Omega_{rol}{}^2\right) r\,r_{rol}\frac{dr_{rol}}{ds}$$

The model – raceways and rollers

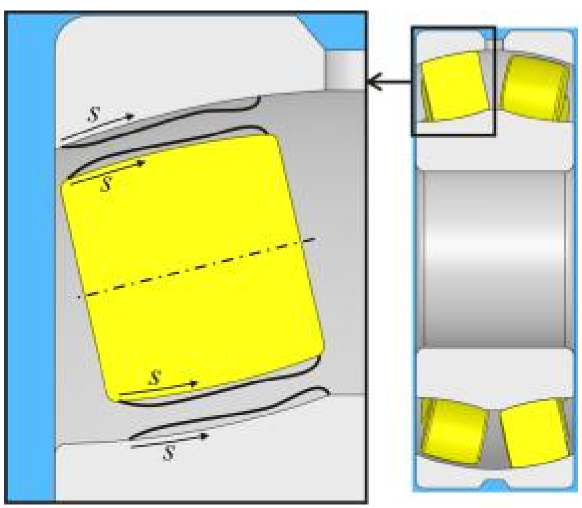
Equipartition



h is approximately :

- Equal on the rollers and the raceways
- Constant in circumferential direction.

$$h_{rol}(s,q_1,t) \approx h_{av}(s,t)$$
$$h_{irw}(s,q_2,t) \approx h_{av}(s,t)$$
$$h_{orw}(s,q_3,t) \approx h_{av}(s,t)$$



Combined flow equation:

$$\frac{1}{r_{sum}} \frac{\partial}{\partial s}\left(\tfrac{1}{3} h_{av}^3 \, q\right) + \frac{\partial h_{av}}{\partial t} = 0$$

with, $$q(s) = \frac{1}{h_0} \sum_{i=1}^{n_{parts}} \left(r_i \, f_{s,i}\right)$$

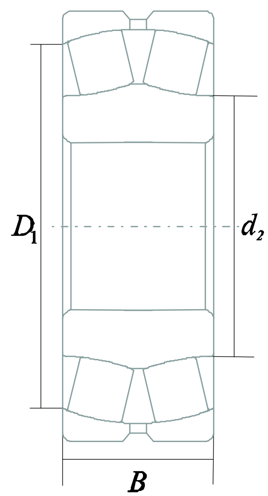
The model – parameters

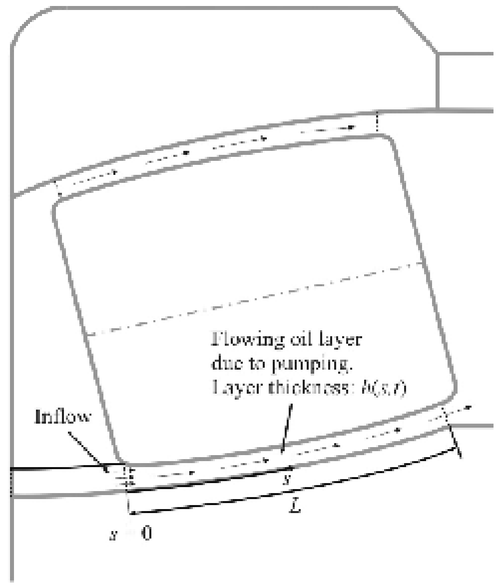
Time parameter:

$$t = \frac{h}{H^2 r \Omega^2}$$

Shape parameters:

$$\frac{L}{B}, \frac{B}{D_1}, \frac{d_2}{D_1}, n_{rol}$$





Overview

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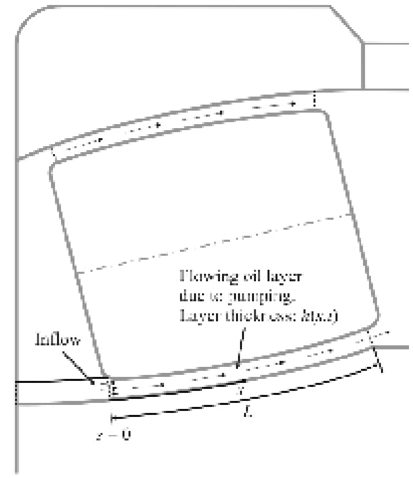
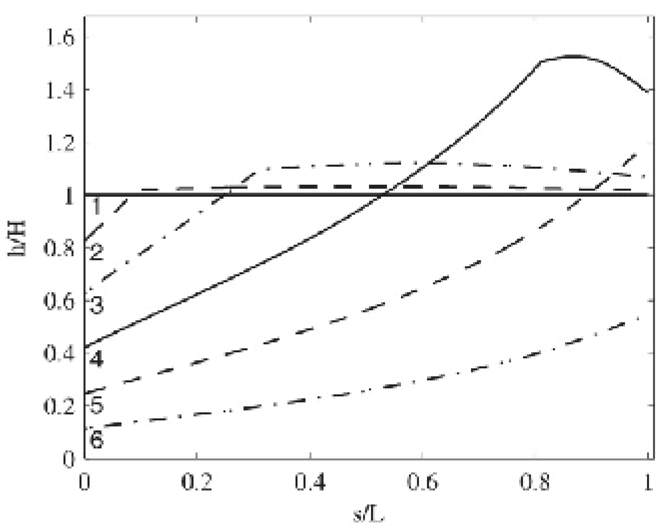
- The physical model
- Results
  - Layer thickness distribution
  - Thinning speed.
- Conclusions / Summary

Results

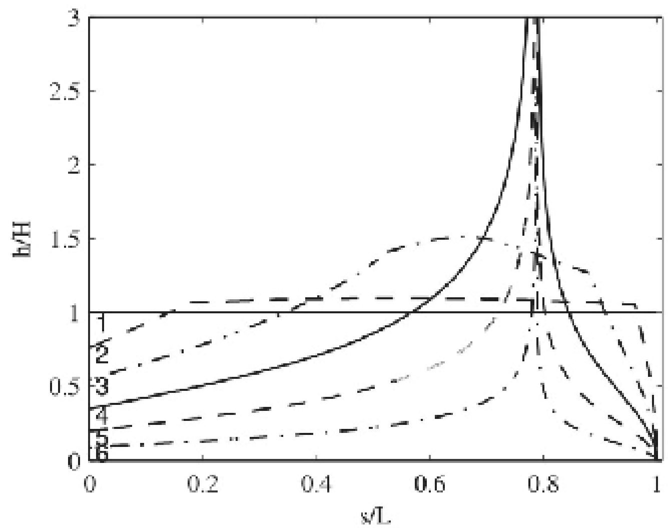


- Spherical Roller bearing: Rotating inner ring.
- Figures show the flow of a initial uniform layer
- Different shape parameters
- Time steps: $t/t = \dfrac{h}{H^2 r\,\Omega^2} = 0,\ 0.3,\ 1,\ 3,\ 10,\ 50$

Flow type 1



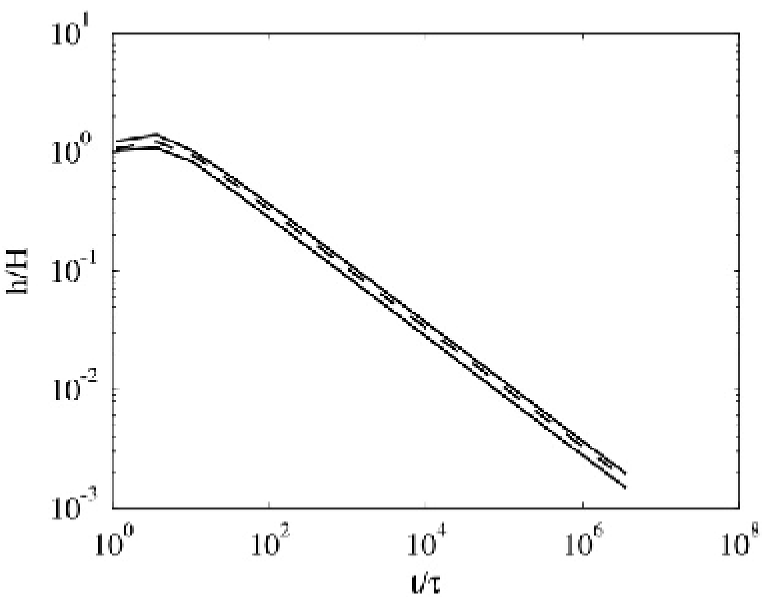
Flow type 2

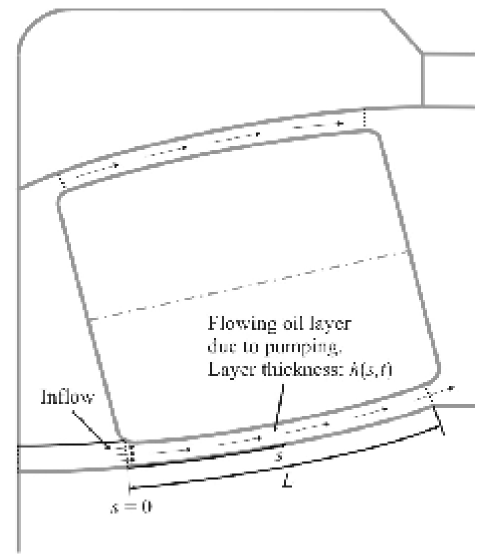


Results

Central layer thickness decrease due to pumping, for various spherical roller bearing with bore diameter 25, 50, 100, 200, 400 and 800 mm

Layer thickness at *s* = 0.5





Rotational speed: $\Omega = 10^3$ rad/s, initial layer thickness $H = 10^{-7}$ m and $\eta/\rho = 10^{-5}$ m^2/s à time scale of $\tau = 10^3$ s. the layer thickness reduces by a factor of ten in 10^6 s ≈ 278 h.

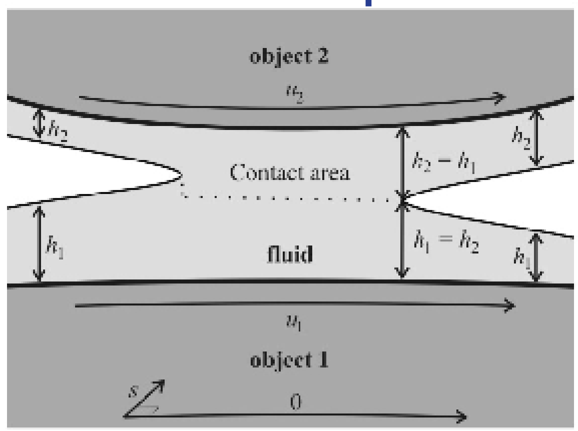
Conclusions / Summary

- Thin layer flow models has been developed for “pumping effects”.
- Characteristic time and shape Parameters.
- SRB: two flow types.
- Central film thickness: different bearings sizes give similar results.
- SRB: pumping effects are significant.

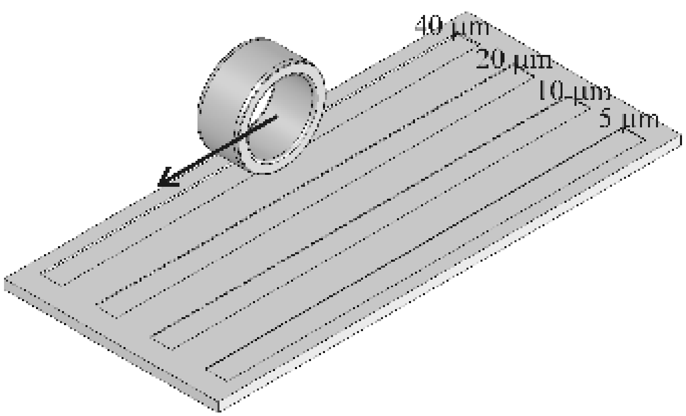
End

The model – raceways and rollers

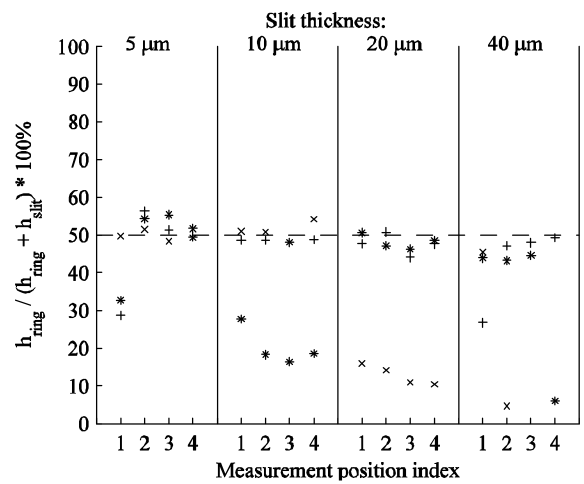
The concept



Measurement setup



Measurement Results



Measurements have been carried out by H. de Ruig and R. Meeuwenoord at SKF ERC