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Prediction of Film Thickness Decay in Starved EHL Contacts Using a Thin Layer Flow Model.

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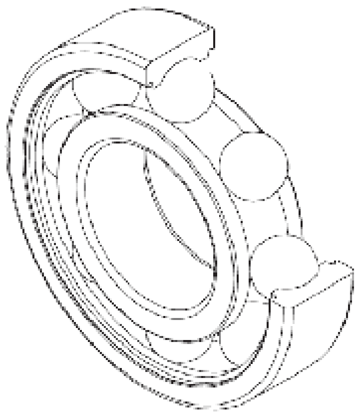
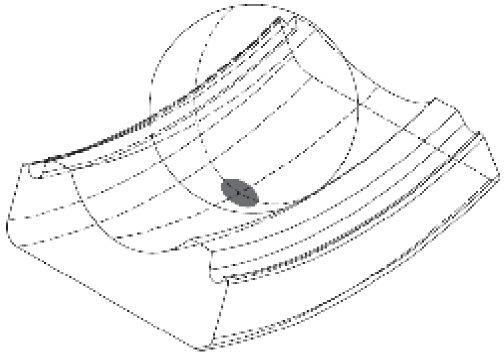
- Introduction
- Theory
- Theoretical results
- Experimental validation
- Conclusion

Introduction

<u>Background:</u>

- Prediction of service life of rolling element bearings.
- 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.

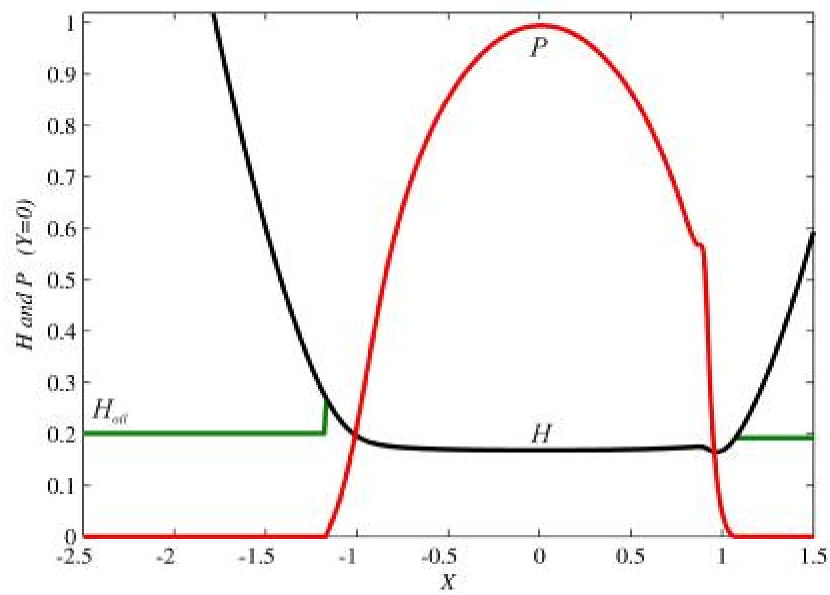




Introduction

Starvation:

- Lubricant supply to the contact is small.
- Pressure build up starts at a limited distance.
- Extra parameter: $H_{oil.}$



Aim of the research:

- To develop a model that predicts the change of the supply layer $H_{oil.}$
- Use this model to predict the long term film thickness decay.

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

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  - Layer thickness decay model
  - Increasing starvation: asymptotic regime
- Theoretical results
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Theory

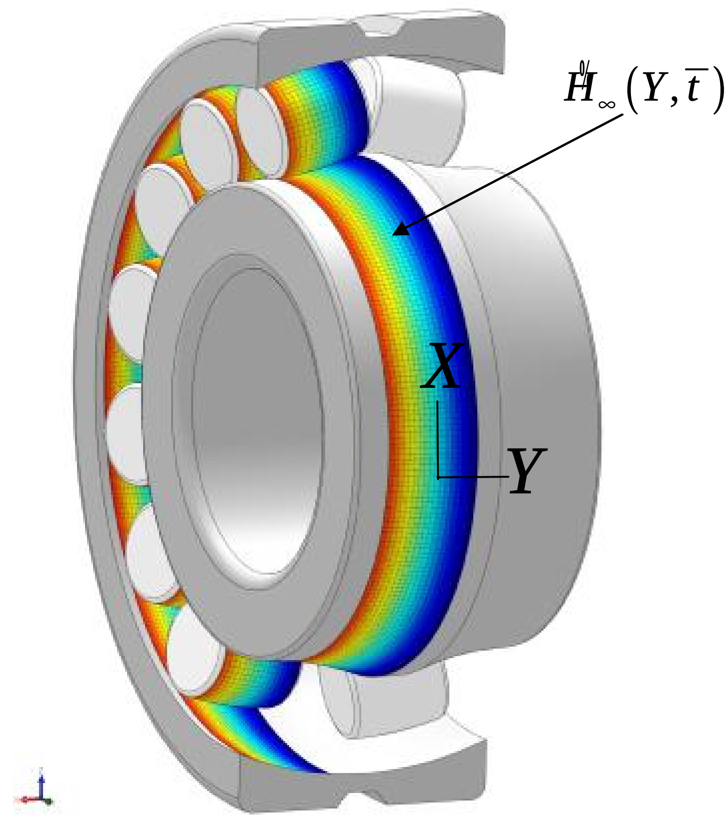
- The rolling tracks are covered by a thin layer of lubricant.
- In is assumed that the lubricant is distributed evenly along the tracks.
- The layer is forced by the pressure in the EHL contact(s).
- Considering a symmetrical distribution with respect to Y = 0.

Free surface layer thickness:

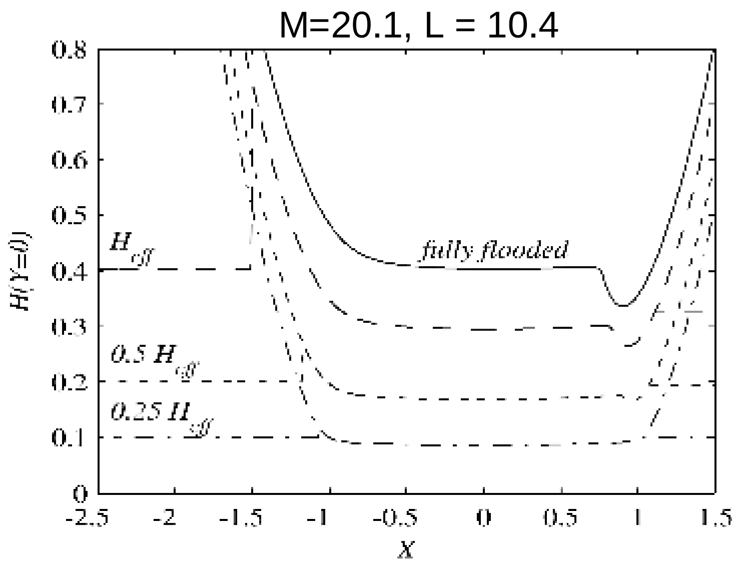
$$\tilde{H}_{\infty}(\bar{t}) = \left(2\int_{0}^{\bar{t}} \frac{\partial \hat{Q}_Y}{\partial Y} d\bar{t} + \tilde{H}_{0,\infty}^{-2} \right)^{-1/2}$$

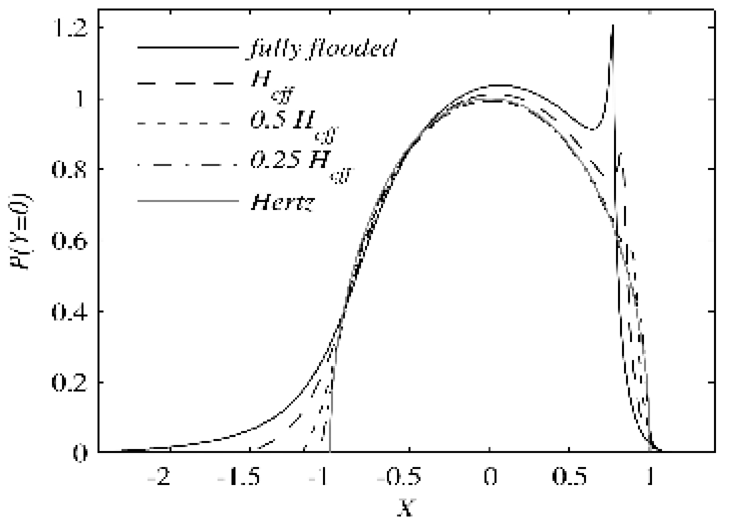
Side flow flux gradient:

$$\frac{\partial \hat{Q}_Y}{\partial Y} = \frac{\partial}{\partial Y} \int_{\bar{a}^-}^{\bar{a}^+} \left(-\frac{H^3}{H_{oil}^3} \frac{\bar{\rho}}{\bar{\eta}} \frac{\partial P}{\partial Y} \right) dX$$



Theory





With an increasing degree of starvation:

$$\left.\begin{aligned} \lim_{h_{oil}\downarrow 0} H &= \frac{H_{oil}}{\bar{\rho}} \\ \lim_{h_{oil}\downarrow 0} P &= \sqrt{1-X^2-Y^2} \end{aligned}\right\} \Rightarrow \lim_{H_{oil}\downarrow 0} \frac{\partial \hat{Q}_Y}{\partial Y} = C$$

$$\text{with} \quad C = \int_{-1}^{1} \left(\bar{\rho}^{-2} \bar{\eta}^{-1} \left(1-X^2\right)^{-\frac{1}{2}} \right) dX$$

Free surface layer thickness:

$$\tilde{H}_{\infty}(\bar{t}) = \left(2C\bar{t} + \tilde{H}_{\infty,0}^{-2}\right)^{-\frac{1}{2}}$$

Central film thickness:

$$\lim_{h_{oil}\downarrow 0} H_{cs} = \frac{2\tilde{H}_{\infty}}{\bar{\rho}_c}$$

$$H_{cs}(\bar{t}) = \left(\tfrac{1}{2}\bar{\rho}_c^{2} C\bar{t} + H_{cs,0}^{-2}\right)^{-\frac{1}{2}}$$

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Theoretical results

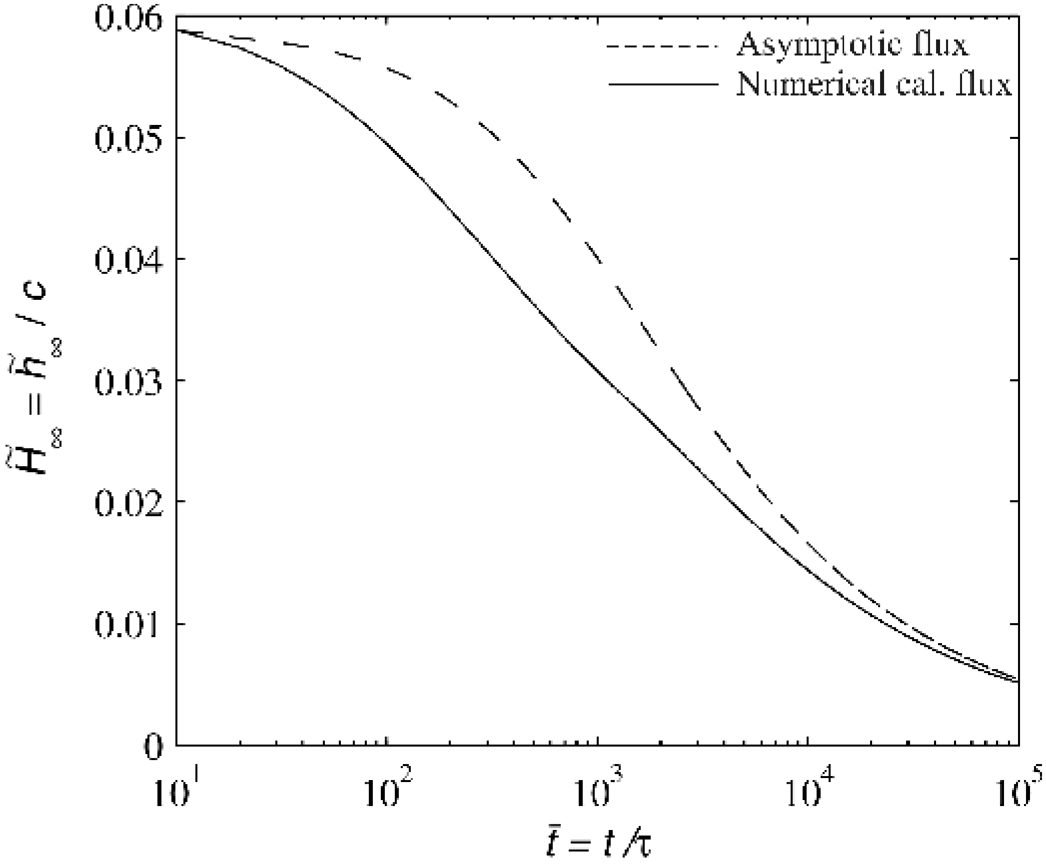
Free surface layer thickness:

$$\tilde{H}_\infty(\bar{t}) = \left(2\int_0^{\bar{t}} \frac{\partial \hat{Q}_Y}{\partial Y} d\bar{t} + \tilde{H}_{0,\infty}^{-2} \right)^{-1/2}$$

Asymptotic regime:

$$\tilde{H}_\infty(\bar{t}) = \left(2C\bar{t} + \tilde{H}_{\infty,0}^{-2} \right)^{-1/2}$$

N = 100, L = 10, Rx/Ry = 0.1



Theoretical results

Influence of physical parameters on the film asymptotic film decay rate.

$$h_{cs}(t) = \left(C_2\, t + h_{cs,0}^{-2}\right)^{-1/2} \qquad C_2 = C_2\left(h_0, l_t, F, E', geometry\right)$$

Velocity u_m	↑	Decay rate	–
Viscosity h_0	↑	Decay rate	↓
Total track length l_t	↑	Decay rate	↓
Load F	↑	Decay rate	↓

Remarkable: optimizing the EHL performance, i.e. maximizing the film thickness, may not mean minimizing the load!

Damiens, B., et al. Starved lubrication of elliptical EHD contacts. *ASME, Journal of Tribology*, 2004, **126** (1), pp. 105-111.

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  - Results
    - Influence of speed: circular/elliptic contact
    - Influence of load
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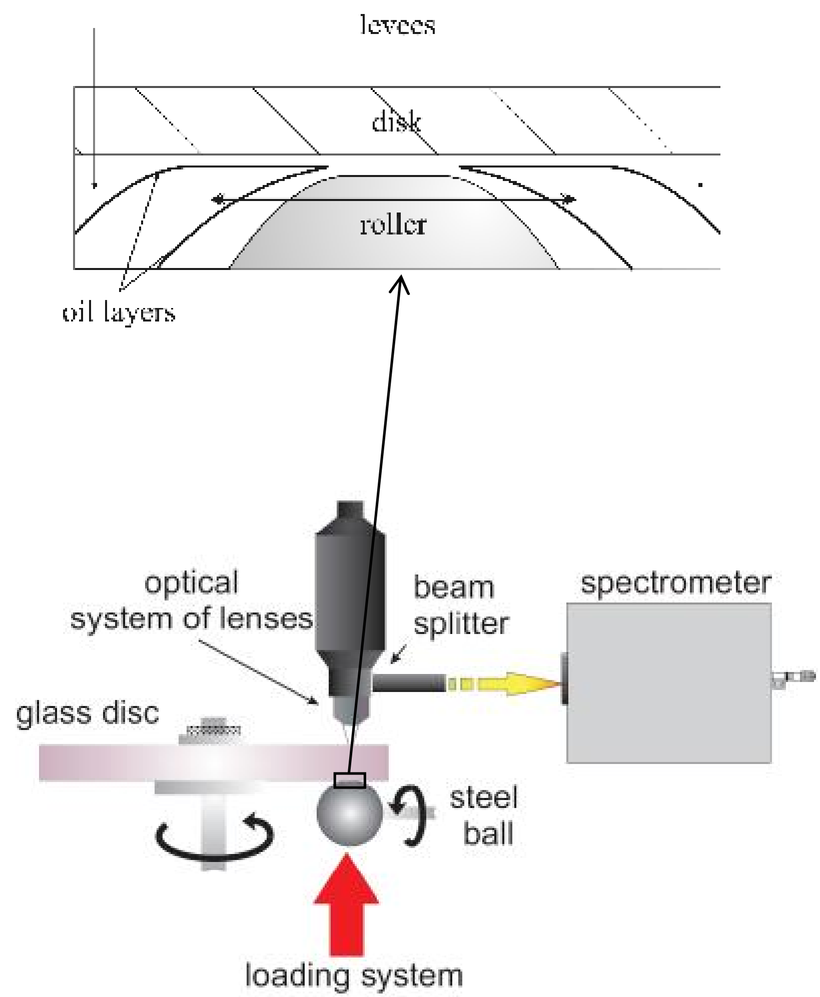
Experimental approach

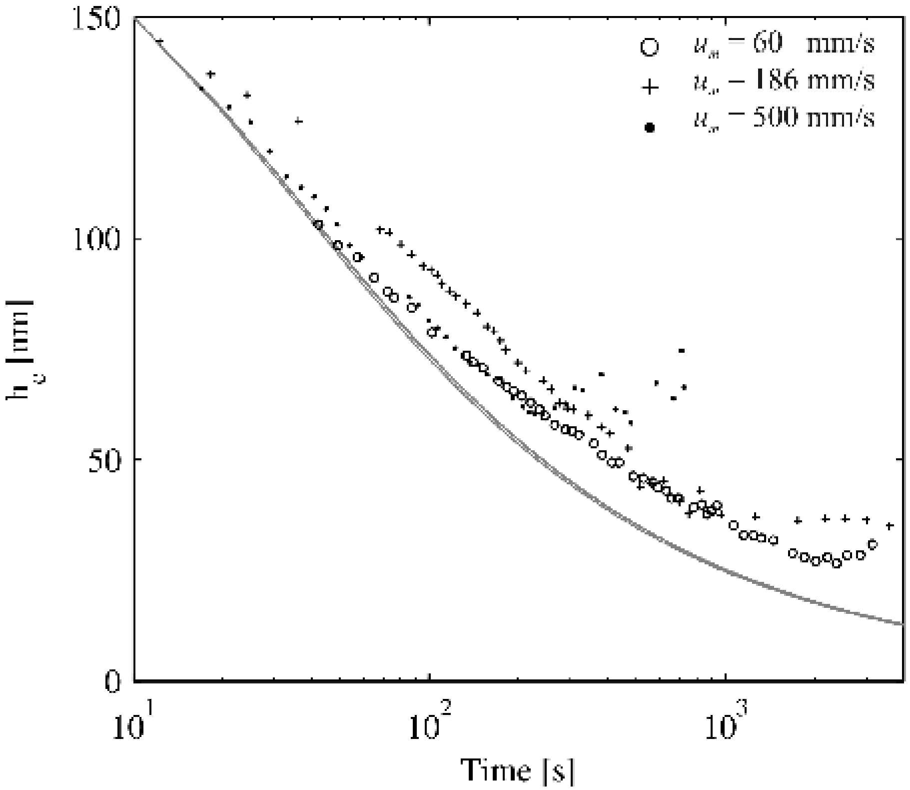
- Ball/roller loaded against a rotating glass disk.
- Film thickness is measured using optical interferometry.
- Small droplet of oil.
- After running in the side levees are pushed to the sided, reducing reflow effects.



Experimental results

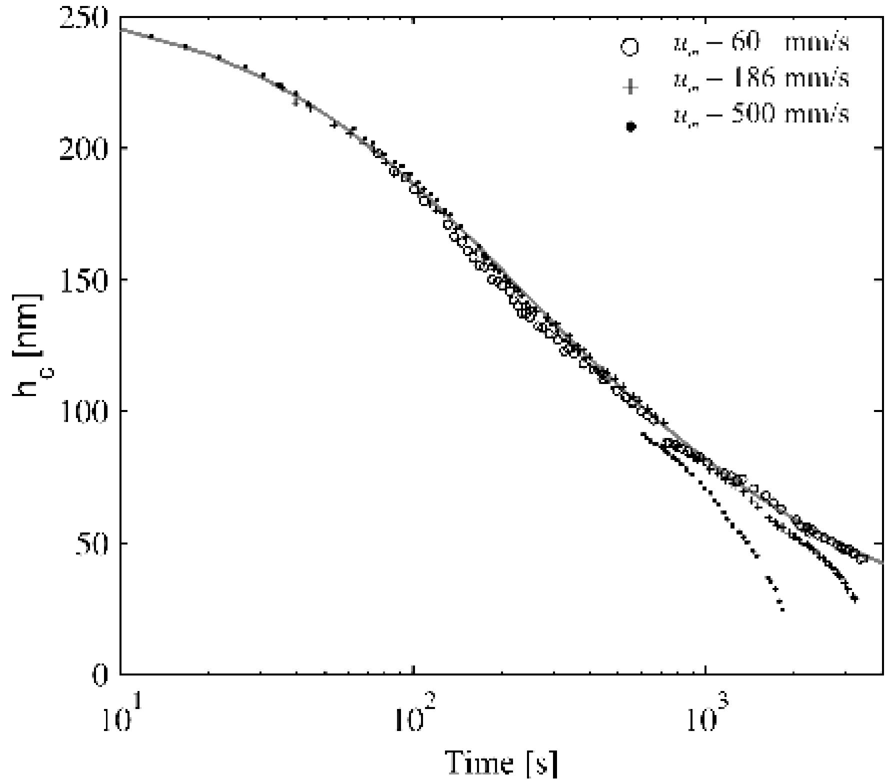
Central film thickness - Different speeds

Circular contact



F = 20 N, p_h = 0.5 GPa, $\eta_0 \approx$ 0.8 Pa.s

Elliptical contact

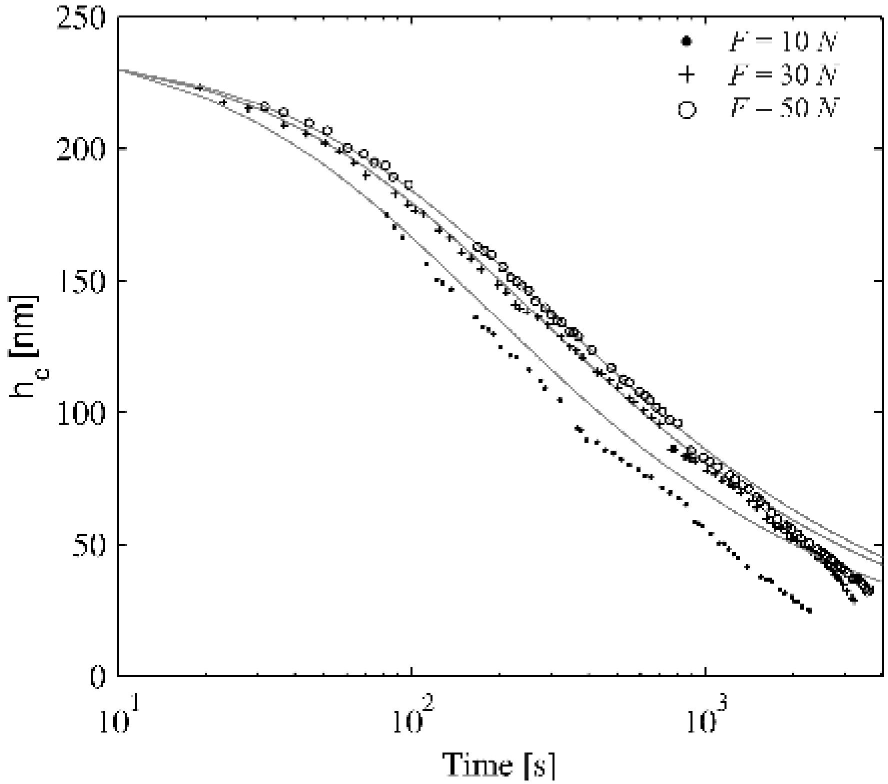


F = 30 N, p_h = 0.33 GPa, $\eta_0 \approx$ 0.85 Pa.s

Experimental results

Central film thickness - Different Loads

Elliptical contact



u_m = 186 mm/s, $\eta_0 \approx$ 0.8 Pa.s

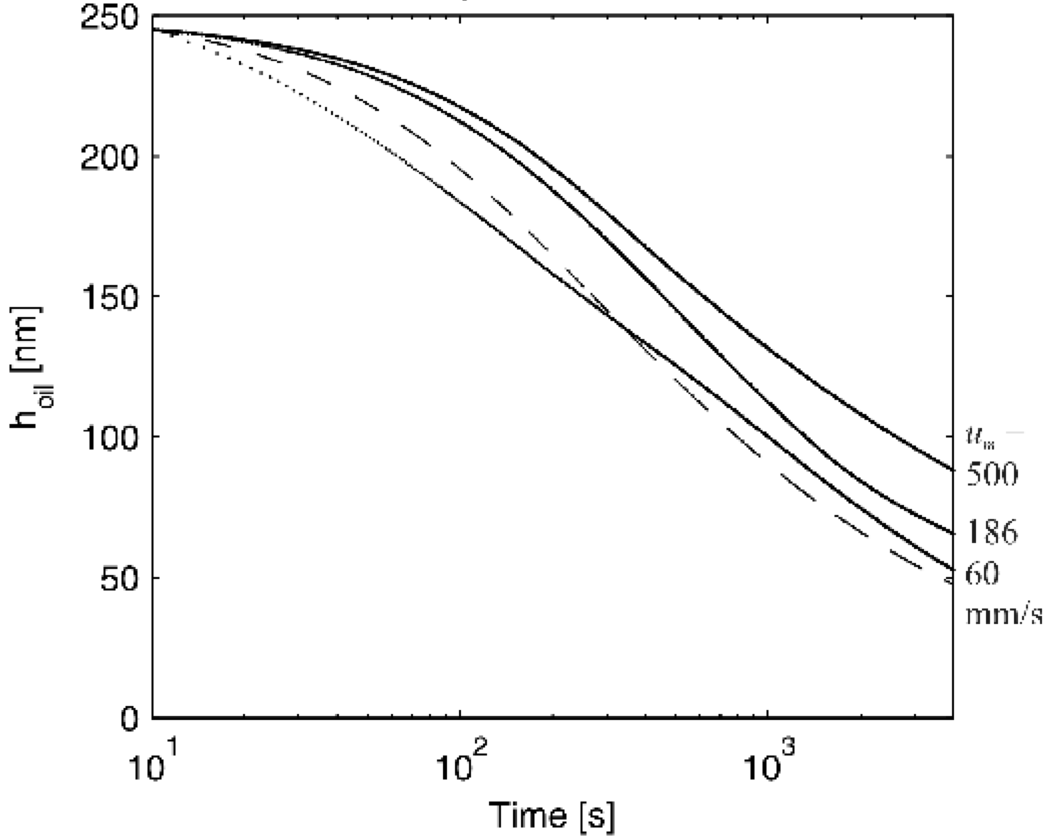
Conclusion

- A model is developed to predict the change of the supply layer to a starved EHL contact.
- The model is used to predict the central film thickness decay for circular and elliptic contacts.
- The model was validated experimentally.
- The asymptotic decay rate is independent of the speed and higher load give lower decay rates.

Questions??

Layer decay model Damiens

Elliptical contact



F = 30 N, p_h = 0.33 GPa, $\eta_0 \approx$ 0.85 Pa.s

Damiens, B. Modélisation de la Lubrification Sous-Alimentee dans les Contacts Élastohydrodynamiques Elleptiques. PhD thesis, 2003, I.N.S.A. de Lyon, France

N	L	D	H_{eff}	$\partial\hat{Q}_Y / \partial Y$			
				$H_{oil}/H_{eff} = 1$	$H_{oil}/H_{eff} = 0.5$	$H_{oil}/H_{eff} = 0.25$	$\lim_{H_{oil}\downarrow 0}$
20	2.5	1	$2.31\ 10^{-1}$	0.884	0.910	0.916	0.924
20	5.0	1	$3.03\ 10^{-1}$	0.481	0.476	0.467	0.467
20	10	1	$4.21\ 10^{-1}$	0.237	0.232	0.226	0.225
100	2.5	1	$7.11\ 10^{-2}$	0.763	0.589	0.559	0.550
100	5.0	1	$9.43\ 10^{-2}$	0.406	0.299	0.273	0.265
100	10	1	$1.33\ 10^{-1}$	0.199	0.150	0.132	0.129
1000	2.5	1	$1.21\ 10^{-2}$	0.582	0.280	0.248	0.245
1000	5.0	1	$1.64\ 10^{-2}$	0.307	0.149	0.126	0.120
1000	10	1	$2.37\ 10^{-2}$	0.150	0.077	0.065	0.060
100	10	0.1	$1.18\ 10^{-1}$	0.747	0.226	0.201	0.167
100	10	0.01	$9.92\ 10^{-2}$	1.2231	0.280	0.289	0.186