

PhD Thesis progress

*Thesis: Shear loaded elastohydrodynamic films
under non-steady state conditions*

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Seminar IMID
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Institute of Machine
and Industrial Design

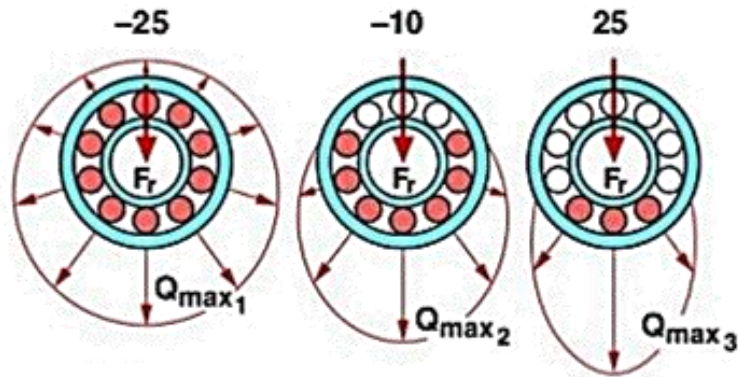
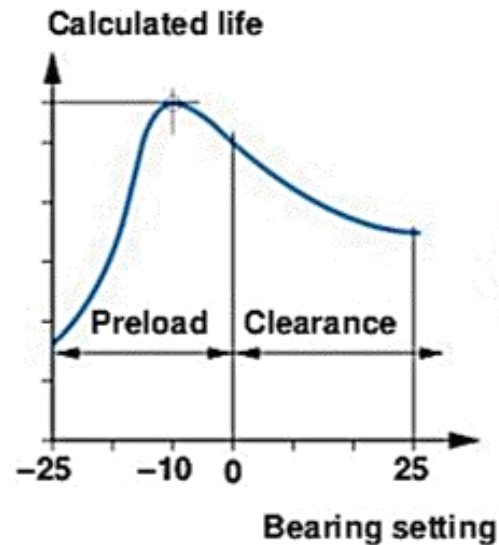
Introduction & Motivation

Vibrations in machine elements

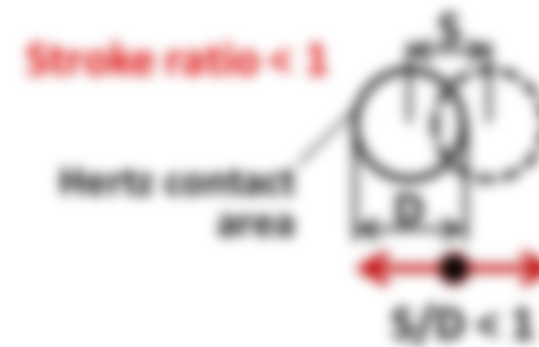
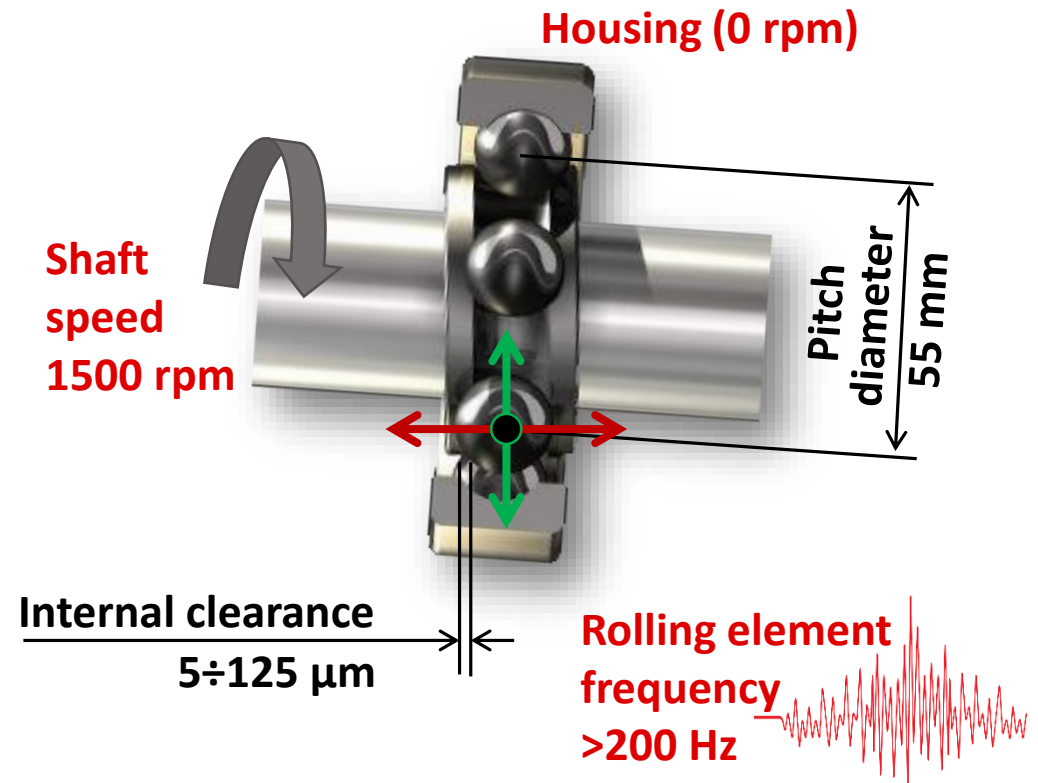
- ❖ Over 90 % of rotating machines have rolling bearings.
- ❖ Approximately 43 % of failures are attributed to lubrication film failure.

Preloaded bearings/bearings with clearance:

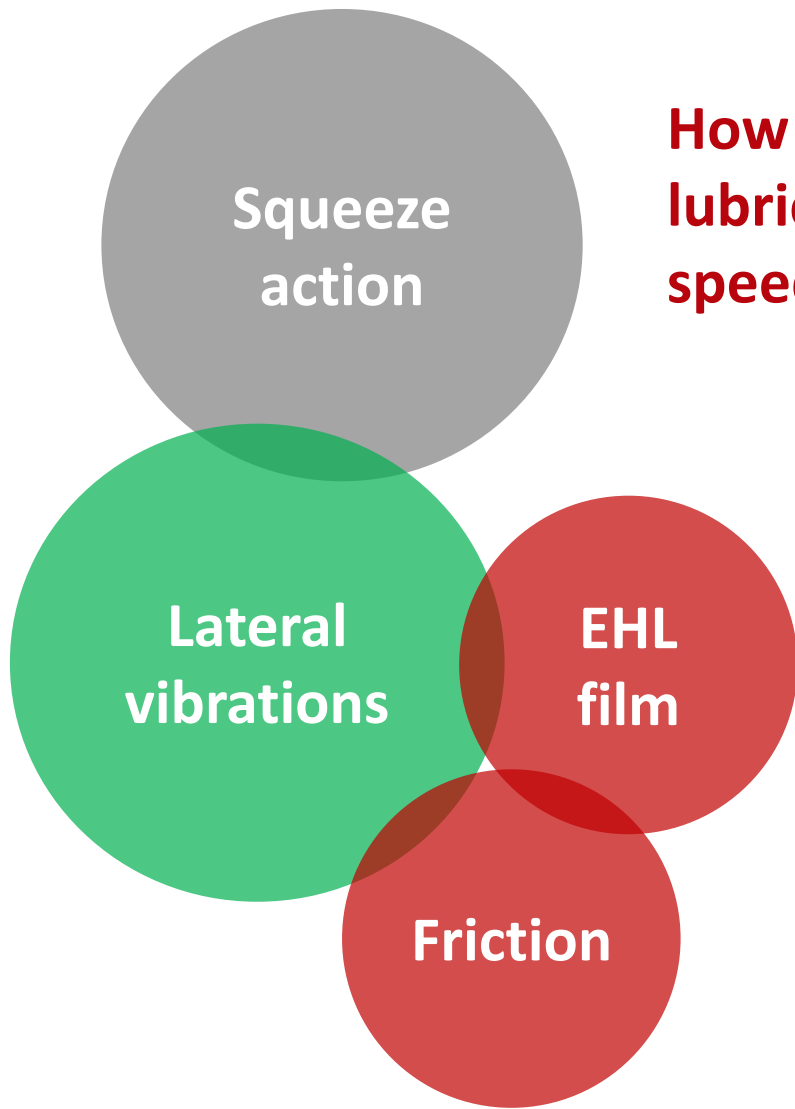
- | | | |
|----------------------|---|----------------------|
| ❖ Lateral vibrations | ➔ | ❖ EHL film thickness |
| ❖ Squeeze action | | ❖ Friction (wear) |



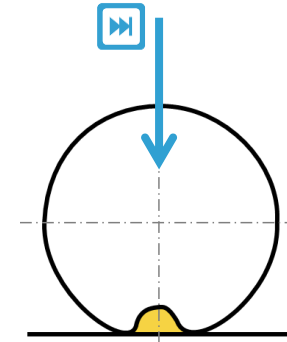
Load distribution



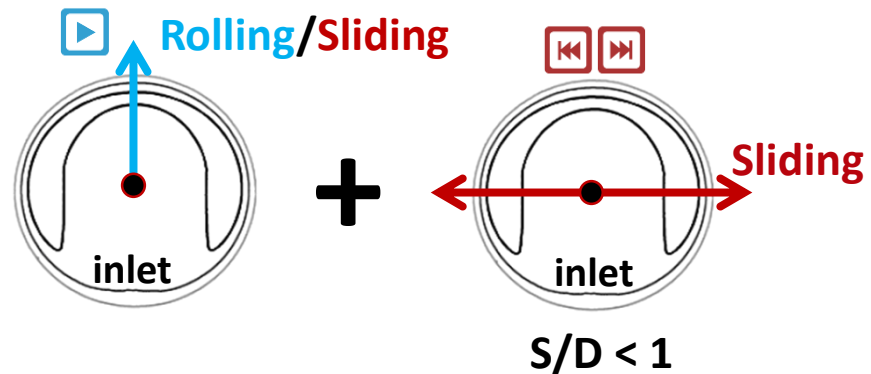
Aims



How is EHL squeezed film affected by lubricant rheology and impact/loading speed?

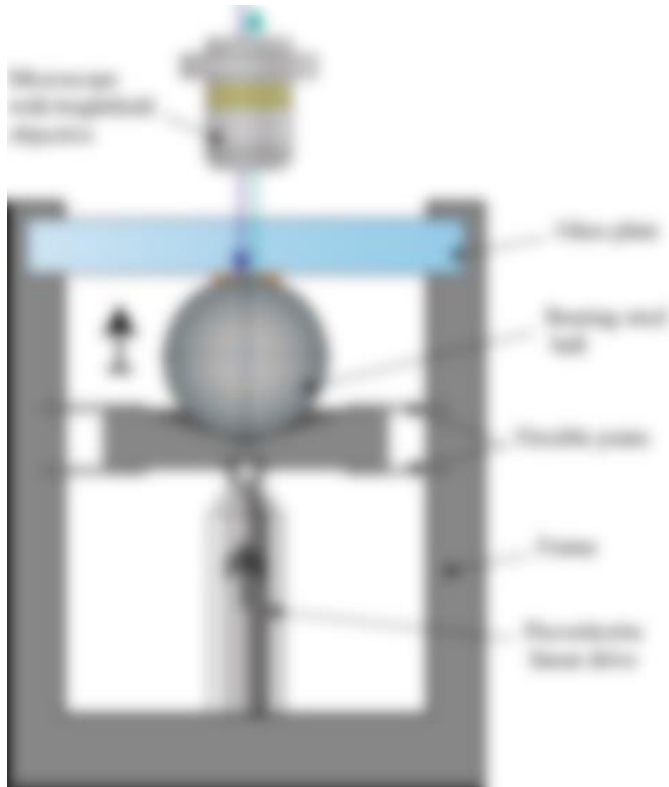


How side vibrations with low value of stroke ratio affect EHL film and friction?

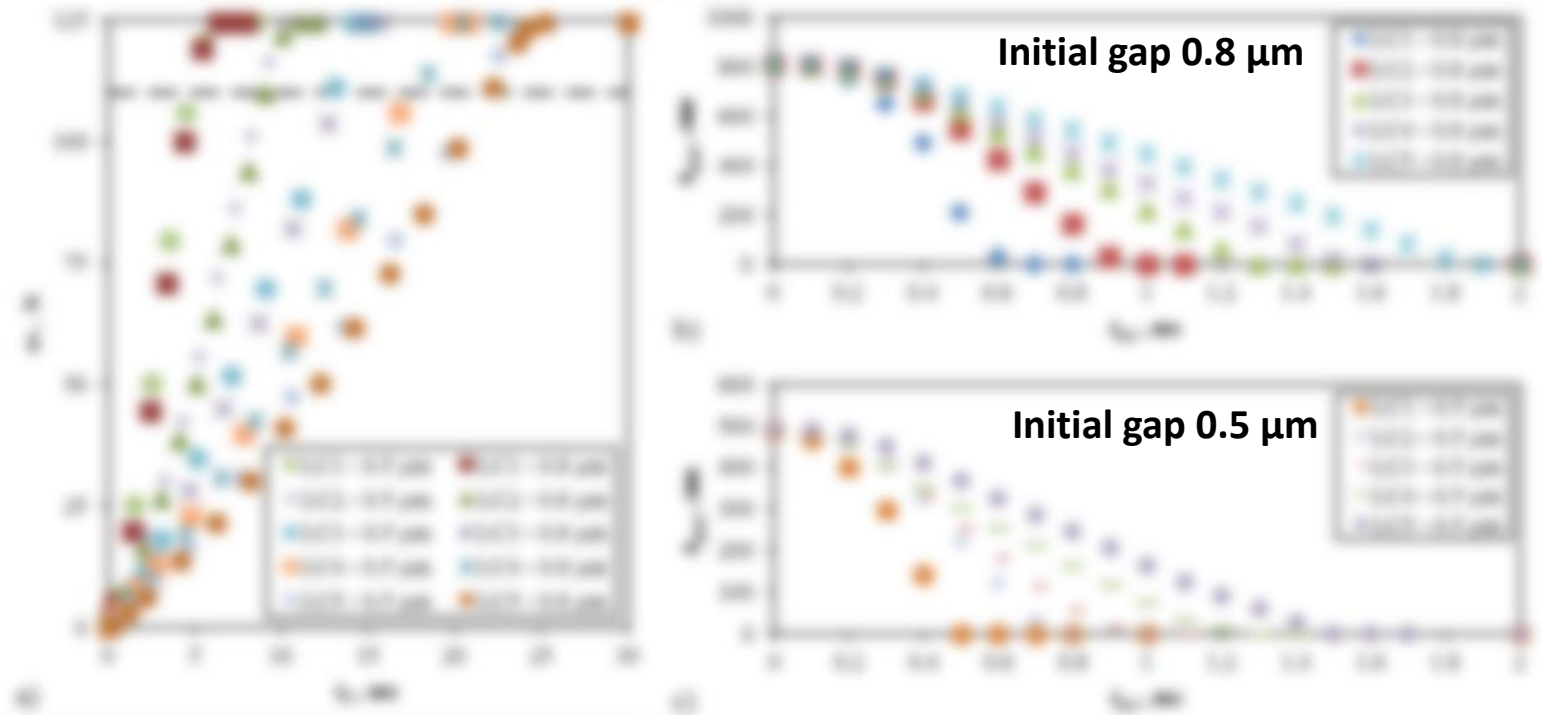


Squeeze action – experimental conditions

Loading and approaching speeds for dry contact:



Experimental apparatus



Lubricant	GC	SQ	PAO 4	PAO 6	BS	CAS	DMPS	KTF-1	SR 90	SR 150	SR 600
Viscosity (Pa·s)	1.01	0.025	0.023	0.046	0.903	0.75	1	0.062	0.032	0.056	0.245
PVC (GPa ⁻¹)	5.4	22.3	11.9	11.1	22.67	14	15.2	34.8	21.9	22.8	24
Mol. wt. (g/mol)	92	423	437	529	≈ 600	927	≈ 32 000	≈ 250	≈ 410	≈ 430	≈ 450

Squeeze action – results

Effect of initial gap on resulting central film thickness:

Results published in article:
<http://www.sciencedirect.com/science/article/pii/S0301679X16303851>

Results published in article:
<http://www.sciencedirect.com/science/article/pii/S0301679X16303851>

- ❖ Dimple apex occurs at the same time regardless of initial gap (for same loading speed and lubricant).
- ❖ The approaching speed is more important for film thickness than loading speed.



Squeeze action – results

Effect of loading speed and rheology on dimple shape:

Results published in article:
<http://www.sciencedirect.com/science/article/pii/S0301679X16303851>

Results published in article:
<http://www.sciencedirect.com/science/article/pii/S0301679X16303851>

- ❖ Dimple side shape depends mainly on viscosity build-up



Squeeze action – results

Effect of lubricant viscosity on initial speed of film thickness reduction:

Results published in article:
<http://www.sciencedirect.com/science/article/pii/S0301679X16303851>

Results published in article:
<http://www.sciencedirect.com/science/article/pii/S0301679X16303851>

- ❖ Central film thickness is mainly determined by the approaching speed and lubricant viscosity and independent of pressure-viscosity coefficient



Squeeze action – results

Comparison with analytical results published by Venner (2016):

Results published in article:
<http://www.sciencedirect.com/science/article/pii/S0301679X16303851>

Results published in article:
<http://www.sciencedirect.com/science/article/pii/S0301679X16303851>

- ❖ Influence of impact times/speeds on film thickness can be estimated from basic rheological properties of lubricants



Lateral vibrations

Estimated distribution of lubricant

◆ Time dependent values (°) of velocity vectors, angles and slide-to-roll ratio

$$u_{xy}' = 2\pi f \frac{S}{2} \sin(2\pi f t)$$

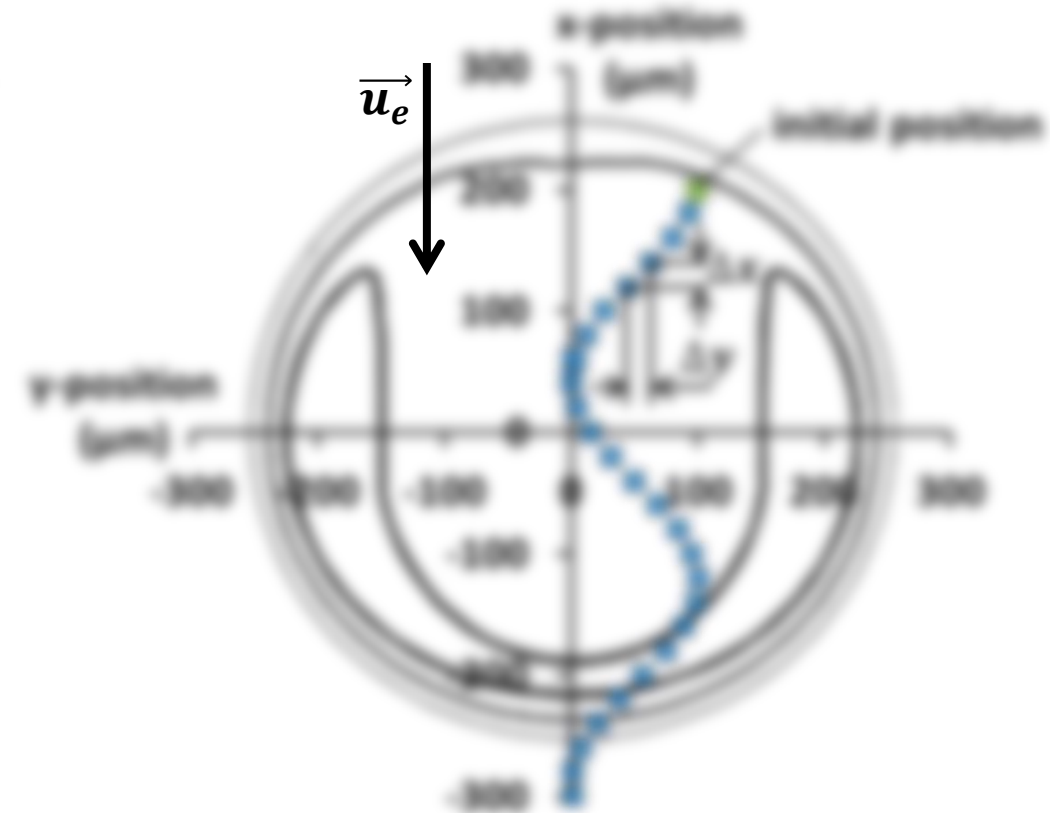
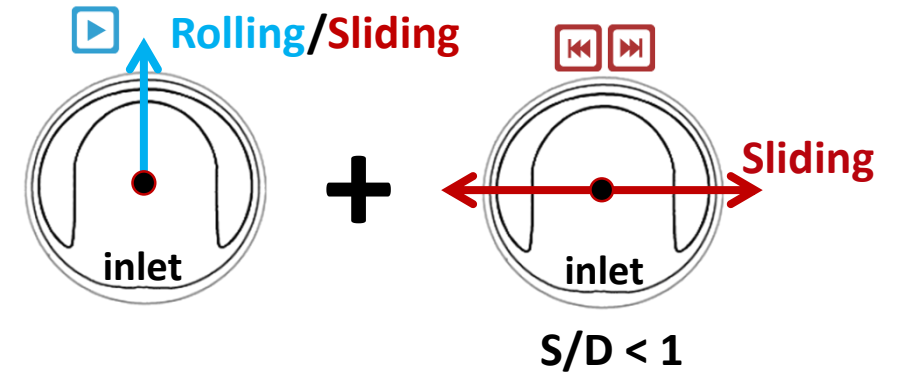
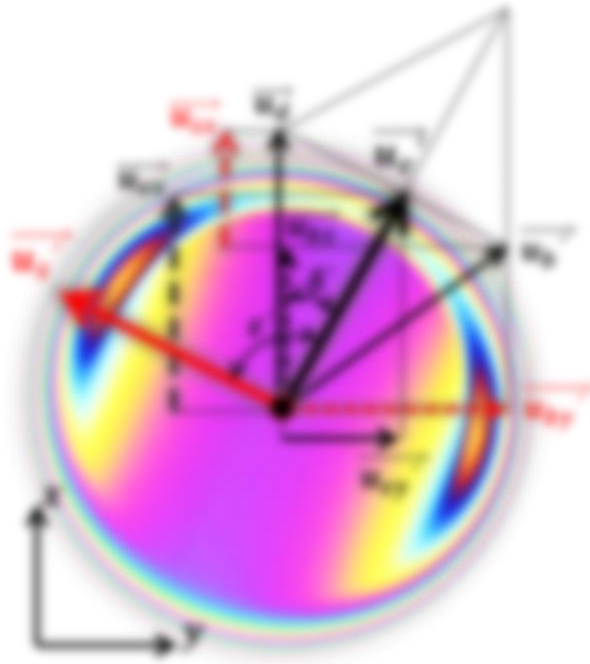
$$u_x' = \left| \frac{u_{xy}'}{2} \right| \sqrt{1 + \left(\frac{2u_{xy}'}{u_{xy}'} \right)^2}, u_{xy}' = 0 \Rightarrow u_x' = u_{xy}'$$

$$u_y' = |u_{xy}'| \sqrt{1 + \left(\frac{u_{xy}'}{2u_{xy}'} \right)^2}, u_{xy}' = 0 \Rightarrow u_y' = u_{xy}'$$

$$\delta = \left| \tan^{-1} \left(\frac{u_{xy}'}{2u_{xy}'} \right) \right|, u_{xy}' = 0 \Rightarrow \delta = 0$$

$$\epsilon' = 90 + \delta - \tan^{-1} \left(\frac{u_{xy}'}{|u_{xy}'|} \right), u_{xy}' = 0 \Rightarrow \epsilon' = 0$$

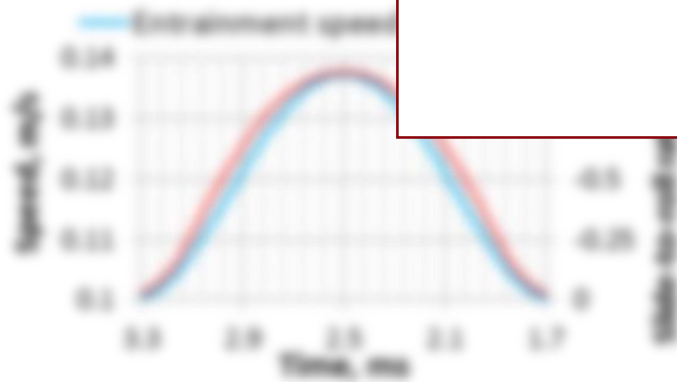
$$\Sigma = \frac{u_x' \cos \epsilon'}{u_y'}$$



Film thickness under side vibrations

3.3 2.8 2.5 1.9 1.7 Time at inlet, ms

Article in progress



Lateral vibrations – conditions of parametric study

Experimental conditions

	Lubricant	η_0 (Pa·s)	α (1/GPa)	Mol. wt. (g/mol)
CAS	Castor oil	0.239	12.4	927
SQ15PIP	Squalane + 15 %wt polyisoprene	0.071	20.9	423 40000
PGLY	Polyglycol	16.3	13.2	12000

Parameter	Min	Max
Speed u_e' (m/s)	0.006	0.55
SRR Σ' (1)	0	-1.99
Frequency f (Hz)	0	300
Stroke S (μm)	80	400
Acceleration a_y' (m/s^2)	0	670
S/D ratio (1)	0.1	0.9
Pressure p_h (GPa)	0.45	0.88

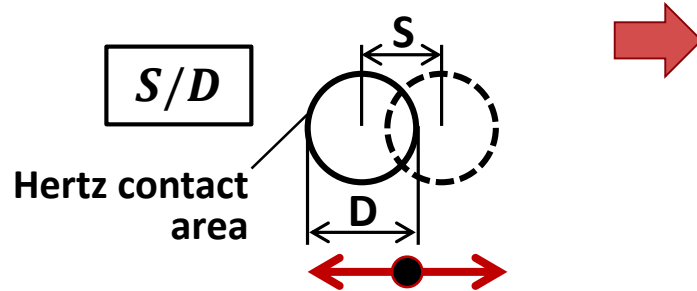
Article in progress



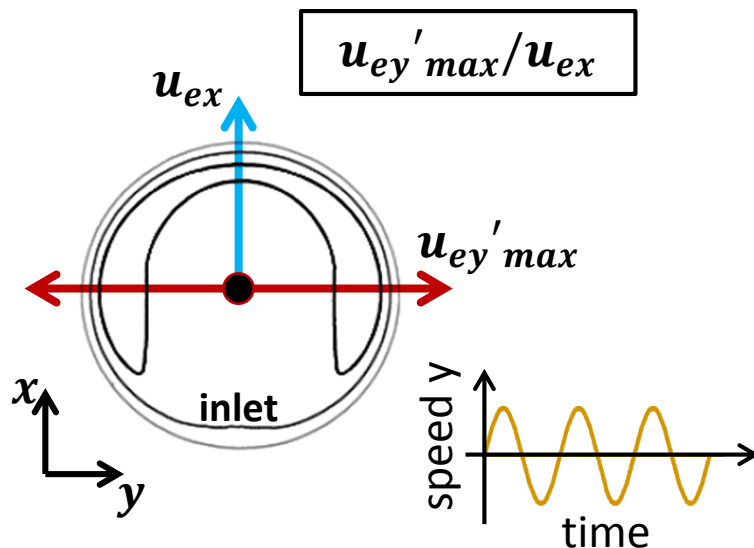
Influence of side vibrations on central film thickness

Rate of vibrations

- ❖ Stroke (displacement) ratio:



- ❖ Entrainment speeds ratio:



Reciprocating motion

- ❖ MARUYAMA, T. and T. SAITOH. (2010)
“Oil film behavior under minute vibrating conditions in EHL point contacts.”

Lubricant replenishment

- ❖ NAGATA, Y., K. KALOGIANNIS and R. GLOVNEA. (2012)
“Track replenishment by lateral vibrations in grease-lubricated EHD contacts.”

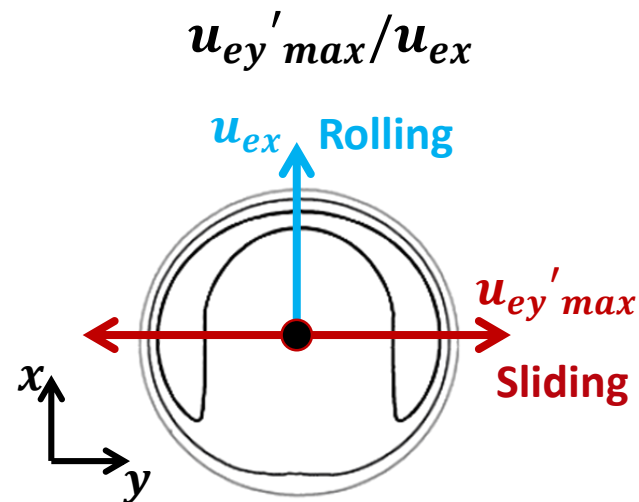
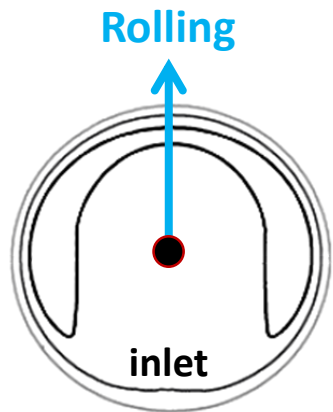
Influence of side vibrations on central film thickness

Article in progress

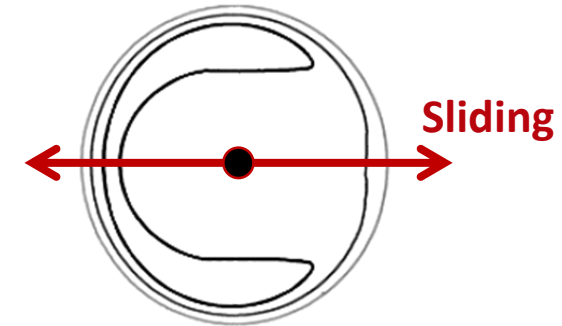


Influence of side vibrations on central film thickness

Steady-state conditions

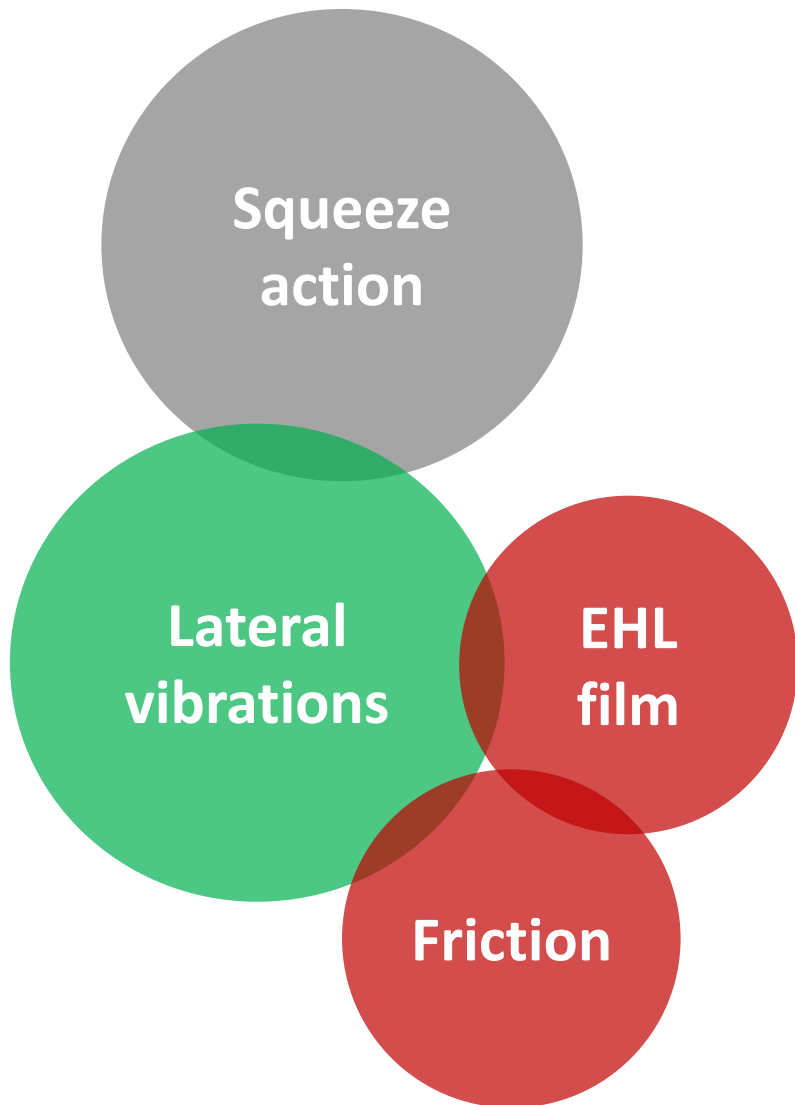


Reciprocating motions (pure sliding)



- ❖ NISHIKAWA, H. and M. KANETA. (1995)
“Behavior of EHL films in reciprocating motion.”
- ❖ SUGIMURA, J. and H. A. SPIKES. (1998)
“EHD film thickness in non-steady state contacts.”
- ❖ GLOVNEA, R. P. a H. A. SPIKES. (2002)
“Behavior of EHD films during reversal of entrainment in cyclically accelerated/decelerated motion.”

PhD Thesis progress



- ❖ **Article published**
- ❖ FRÝZA, J.; ŠPERKA, P.; KANETA, M.; KŘUPKA, I.; HARTL, M. Effects of lubricant rheology and impact speed on EHL film thickness at pure squeeze action. *Tribology International*, 2016, č. 106, s. 1-9. ISSN: 0301-679X.
- ❖ **Article in progress.. (December 2016)**
- ❖ **Preparation of experiments**
 - ❖ STLE 2017 (May 2017)
 - ❖ Article



Thank you for your attention

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