Effect of surface texturing on friction and film thickness under starved lubrication conditions

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Ph.D. Thesis Defense
July 24th, 2015, Brno
- Non-conformal contacts
- Elastohydrodynamic lubrication
- Starved lubrication
- Micro-textures
Effect of micro-dimples size on the contact pressure

- No effect for small size of micro-dents.
- Positive effect for intermediate size (no cavitations).
- Negative effect for large size due to the cavitations.

Reducing friction and wear under lubricated sliding conditions compared to smooth surfaces.

Friction for a smooth and laser-textured steel discs.
STATE OF THE ART

Deep micro-texture

- Deep micro-cavities cause a reduction in film thickness.
- Shallow micro-cavities enhance film thickness.

Shallow micro-texture

- The beneficial effect on film thickness is lost as the contact becomes fully flooded.

[Images of deep and shallow micro-texture with graphs and diagrams]
STATE OF THE ART

Micro-textures in conformal contacts (hydrodynamic lubrication)


Micro-textures in EHL contacts


Micro-textures in starved EHL contacts


Undiscussed topics

Experimental study on the behavior of micro-textures in starved EHL contacts

Behavior of micro-textures in reverse and reciprocating motion in EHL contacts
Experimental and analytical investigations on the effects of shallow micro-textures (micro-dents and micro-grooves) on the coefficient of friction and film thickness in EHL contacts (ball-on-disc) under severe operating conditions and starved lubrication.

- Experimental study on the effect of micro-dents on the coefficient of friction in sliding motion in non-conformal surfaces under starved lubrication.
- Experimental study of micro-dents effects on film thickness under starved conditions.
- Effect of transverse limited micro-grooves on friction and film thickness in reciprocating and reverse motion.
- Comparing results with fully flooded conditions to ensure whether micro-dents are more effective under starved or fully flooded conditions.
- Experimental study on the behavior of transverse limited micro-grooves with length less than Hertzian diameter through EHL contacts.
- Effect of transverse limited micro-grooves on tribological performance under starvation.
- Numerical simulation to the behavior of transverse limited micro-grooves in EHL point contacts and experimental verification.
METHODS

Tribometer

- Simulator of the elastohydrodynamic contact
- Microscope equipped with a high speed camera
- Software for processing data and control

- Friction measurements in the EHL contact
Film thickness measurement

Surface topography measurement

Film thickness measurement

Film colorimetric interferometry

Surface topography measurement

White light Scanning Interferometry
Friction dependence on starvation in EHL contacts

- Degree of starvation based on relative friction

\[
\dot{\tau} = 1 - e^{-\left(\frac{\mu_s}{\mu_{ff}}\right)}
\]

Bair and Winer model

- Limiting shear stress:
  \[\tau_L = \tau_{L0} + \beta p_m\]

Degree of starvation:

\[
\mathcal{R} = \frac{h_{cs}}{h_{eff}}
\]
RESULTS AND DISCUSSION

Friction dependence on starvation in EHL contacts

- Degree of starvation and relative friction

Measured degree of starvation

Degree of starvation based on friction

- Experimental $R = h_{cs}/h_{cff}$
- Fitting
- $u_e = 42 \text{ mm/s}$
- SRR $=-0.2$
- Load $= 30 \text{ N}$

Calculated $\tau_{L0} = 15 \text{ MPa}$

- Experimental (30 N, $u_e = 42 \text{ mm/s}$, SRR $= -0.2$)

$1.5 < \lambda_{st}$
RESULTS AND DISCUSSION

Lubricant replenishment under starved lubrication

- Effect on film thickness for grease lubrication

Mechanism of artificial replenishment

Optical microscope images of the overrolled track with the corresponding interferometric images and film thicknesses in the contact for grease lubrication with a) without induced replenishment b) with induced replenishment.
Behavior of micro-dents under starvation

- Effect on coefficient of friction

Starved smooth

Starved textured

Distribution of micro-dents, D=35µm, h=0.6µm

Fully flooded smooth

Fully-flooded textured

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RESULTS AND DISCUSSION

Behavior of micro-dents under starvation

- Effect on film thickness

| Load=44N, SRR=-1.66, $u_e=4.8$ mm/s, 8µl |

- $u_e=9.5$ mm/s, SRR= -1.75
- $u_e=6.8$ mm/s, SRR= -1.93

Profile and dimensions of micro-dents
RESULTS AND DISCUSSION

Behavior of transverse micro-grooves under starvation

- Effect on film thickness

Closed vs. Opened micro-grooves

Load=63N, SRR=-1.96, \( u_e = 67 \text{ mm/s} \), 8µl
Behavior of transverse micro-grooves under reverse motion

- Effect on film thickness and friction

Load = 40 N, $u_e = 2.9$ mm/s, SRR = -5.8
Behavior of transverse micro-grooves in reciprocating motion

- Effect on film thickness and friction
RESULTS AND DISCUSSION

Numerical simulation of micro-grooves passage through EHL contact

3D visualization
Interval time = 4.42 ms
The modification of non-conformal mating surfaces by shallow micro-dents provides a reduction of friction (about 9%) under severe starved lubrication.

The benefits of micro-dents are negligible for fully flooded lubrication.

Micro-grooves act as powerful oil reservoirs when they are introduced on the surface as closed texture cells with length less than the diameter of Hertzian contact.

Transverse limited micro-grooves enhance significantly the film thickness of EHL contacts under thin films, reverse and reciprocating motion and under starved conditions.

The behavior of limited micro-grooves in EHL contacts can be successfully predicted by numerical methods.


Thank you for attention

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