Quantitative modeling of steady-state EHL problems: what are the current limits?
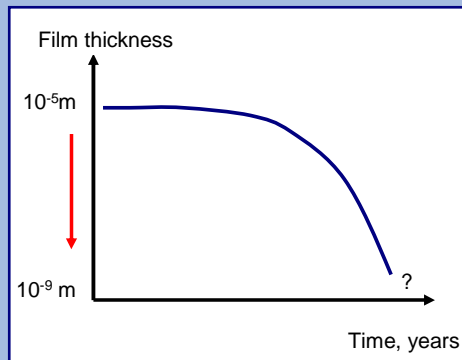
P. Vergne[1], W. Habchhi[2], N. Fillot[1], S. Bair[3], G.E. Morales-Espejel[4,1]

[1]LaMCoS, INSA-Lyon [2]LAU, Lebanon, [3]Georgia Tech, USA, [4]SKF-ERC, The Netherlands

CONTEXT: Highly Loaded Lubricated Contacts

Nowadays challenges:
- Smaller
- More powerful
- Less energy losses
- More boundary regime
- More tribochemistry
- Less lubricant
- Less pollution
- Cheaper
- …

EHL modeling objectives:
- Open to multi physics
- Any restriction on basic equations
- Representative
- Based on primary laboratory data
- Physically relevant
- Experimentally validated
- Numerically efficient
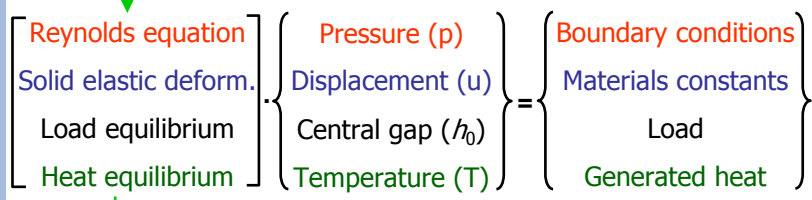- Easy to couple with macro/nano approach
- …

Current advanced solution*

- FEM approach
- Strong coupling between all physics
- Direct solver (within 1 system)
- Open multi physic modeling
- No restriction (Elasticity, Reynolds, N. Stokes)
- Adapted mesh (gradients), ~n.ln(n) complexity
- Fast convergence, reduced memory
- Numerical results confirmed by experiments

*Habchi et al., **Tribology Letters**, vol. 30 (1), 2008, p. 41-52,
Tribology International, http://dx.doi.org/10.1016/j.triboint.2009.10.002

Direct coupling **Linearization**

$$\begin{bmatrix} \text{Reynolds equation} \\ \text{Solid elastic deform.} \\ \text{Load equilibrium} \\ \text{Heat equilibrium} \end{bmatrix} \cdot \begin{Bmatrix} \text{Pressure } (p) \\ \text{Displacement } (u) \\ \text{Central gap } (h_0) \\ \text{Temperature } (T) \end{Bmatrix} = \begin{Bmatrix} \text{Boundary conditions} \\ \text{Materials constants} \\ \text{Load} \\ \text{Generated heat} \end{Bmatrix}$$
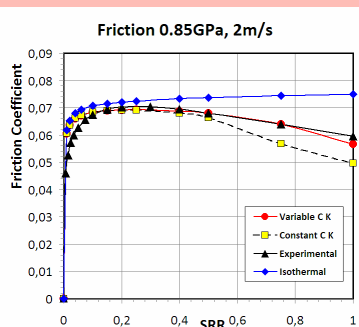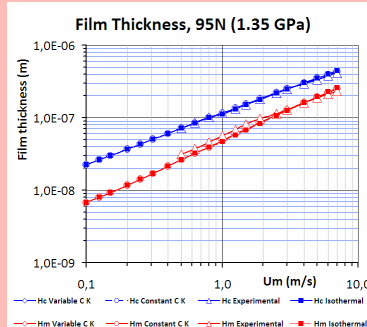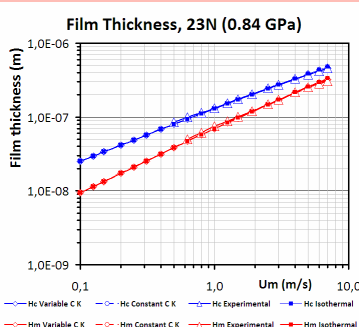
Furthermore:
Full coupling between physical, rheological and thermal properties with pressure and temperature through EOS and free-volume based relationships

Film thickness and friction prediction

Film Thickness, 23N (0.84 GPa)

Film Thickness, 95N (1.35 GPa)

Friction 0.85GPa, 2m/s

Friction 1.35GPa, 2m/s
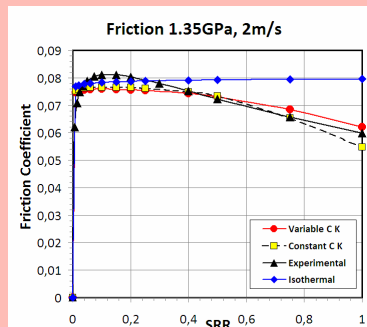
Current limits

Key-points to advance before achieving a full quantitative modeling of the EHD contacts:

- Limiting shear stress concept:
  - **observed under steady state conditions, applicable under dynamic conditions?**
  - **So far, almost temperature independent…**
- How far the lubricant's response is considered as time independent?
- Wall-lubricant slip, apparent slip: is this related to:
  - **Limiting shear stress?**
  - **Physical, thermal, rheological phenomena?**
- What is the lower limit for continuum mechanics validity?
- Can Molecular Dynamics approach provide appropriate answers?

Laboratoire de Mécanique des Contacts et des Structures