The issue of dissertation and its current state

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Outline

- Introduction
- Mathematical model
- Numerical algorithm
- Results
- Conclusion and future work
Title:  
Advanced Solver of Elasto-hydrodynamic Problems

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Aim of dissertation

- Stable and fast numerical solver for elastohydrodynamic (EHL) problems (steady state and transient solution)
- Incorporate to the solver artificial roughness and non-Newtonian model of the lubricant
- Comparison with experiments
Deformation of roughness in rolling/sliding EHL contact

- study of surface roughness
  - experimental (Kaneta, 1992; Wedeven et al., 1978)
  - numerical (Lee, 1990; Chang 1991)
- effect of operating conditions on the roughness (Venner et al., 1995)
- amplitude reduction model (Hooke, 2005; Lubrecht et al., 1999) - introducing a single parameter
- Non-Newtonian lubricant response (Felix-Quinonez, 2004)
Deformation of roughness in rolling/sliding EHL contact

- Lubricant non-newtonian response
- Low sliding conditions: appropriate lubricant rheology model?
- High sliding conditions: limiting shear stress

$$\tau_L = \Lambda p$$
Reynolds equation

\[
\frac{\partial}{\partial x} \left( \frac{\rho h^3 \eta_x}{12\eta} \frac{\partial p}{\partial x} \right) + \frac{\partial}{\partial y} \left( \frac{\rho h^3 \eta_y}{12\eta} \frac{\partial p}{\partial y} \right) - u_m \frac{\partial (\rho h)}{\partial x} - \frac{\partial (\rho h)}{\partial t} = 0
\]

Film thickness equation

\[
h(x, y, t) = h_0(t) + \frac{x^2}{2R_x} + \frac{y^2}{2R_y} - R(x, y, t) + \frac{2}{\pi E_r} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \frac{p(x', y') \, dx' \, dy'}{\sqrt{(x - x')^2 + (y - y')^2}}
\]

- force balance equation
- pressure-viscosity relation
- pressure-density relation
1. EHL smooth contact + Newtonian fluid model

2. EHL non-smooth contact (dent, ridge, ...) + Newtonian fluid model

3. EHL smooth contact + Non-Newtonian (Eyring) model

4. EHL non-smooth contact under Non-Newtonian conditions

5. Non-Newtonian models: limiting shear stress, ...
Numerical solution

- for the solution of Reynolds equation **multigrid method** is used
- to solve the elastic deformation and film thickness equation **multilevel multi-integration** is applied

*The full multigrid (FMG) scheme - Goodyer (2001)*
Algorithm

The model is solved in programming language C, and visualization of the solution is provided in Matlab.

- domain up to $1025 \times 1025$ discrete points
- residuals up to $O\left(10^{-9}\right)$
Surface feature type - Dent

\[ R(x, y, t) = \begin{cases} \frac{h_{dent}}{2} \left(1 + \cos(\pi r)\right) & \text{if } r \leq 1 \\ 0 & \text{else} \end{cases} \]

\[ r = \sqrt{\left(\frac{x-x_0 - \frac{u_1}{u_{im}} t}{l_x}\right)^2 + \left(\frac{y}{l_y}\right)^2} \]
Dent

\[ w = 27N, \ u_m = 0.15m/s, \ \Sigma = 0, \ \alpha = 22GPa^{-1}, \ \eta_0 = 0.421Pas, \]
\[ E_r = 123.8GPa, \text{ etc.} \]
Surface feature - transverse ridge

\[ R(x, y, t) = \text{amp} \left( 10^\frac{-10r^2}{\text{wav}^2} \right) \cos \left( \frac{2\pi r}{\text{wav}} \right) - 0.4\text{amp} \left( 10^\frac{-10r^2}{0.25\text{wav}^2} \right) \cos \left( \frac{2\pi r}{0.5\text{wav}} \right) \]

\[ r = x - x_0 - \frac{u_1}{u_m} t \]
Transverse ridge

\( w = 49.9N, \ u_m = 0.2m/s, \ \Sigma = 1, \ \alpha = 23.6GPa^{-1}, \ \eta_0 = 0.2016Pas, \ E_r = 123.8GPa, \) etc.
Newtonian vs. Eyring fluid model

- incorporating variables $\eta_x$ and $\eta_y$ into Reynolds equation

- rheological function

$$f \left( \frac{T}{T_0} \right) = \frac{T_0}{T} \sinh \left( \frac{T}{T_0} \right)$$
Conclusion and future work

- work continues on developing the numerical solver:
  - Eyring model
  - rheology models: limiting shear stress, Rabinowitsch model (Chapkov, 2006)
- time steps - 2nd order discretization scheme
- join roughness solver with non-newtonian model
Thank for your attention.