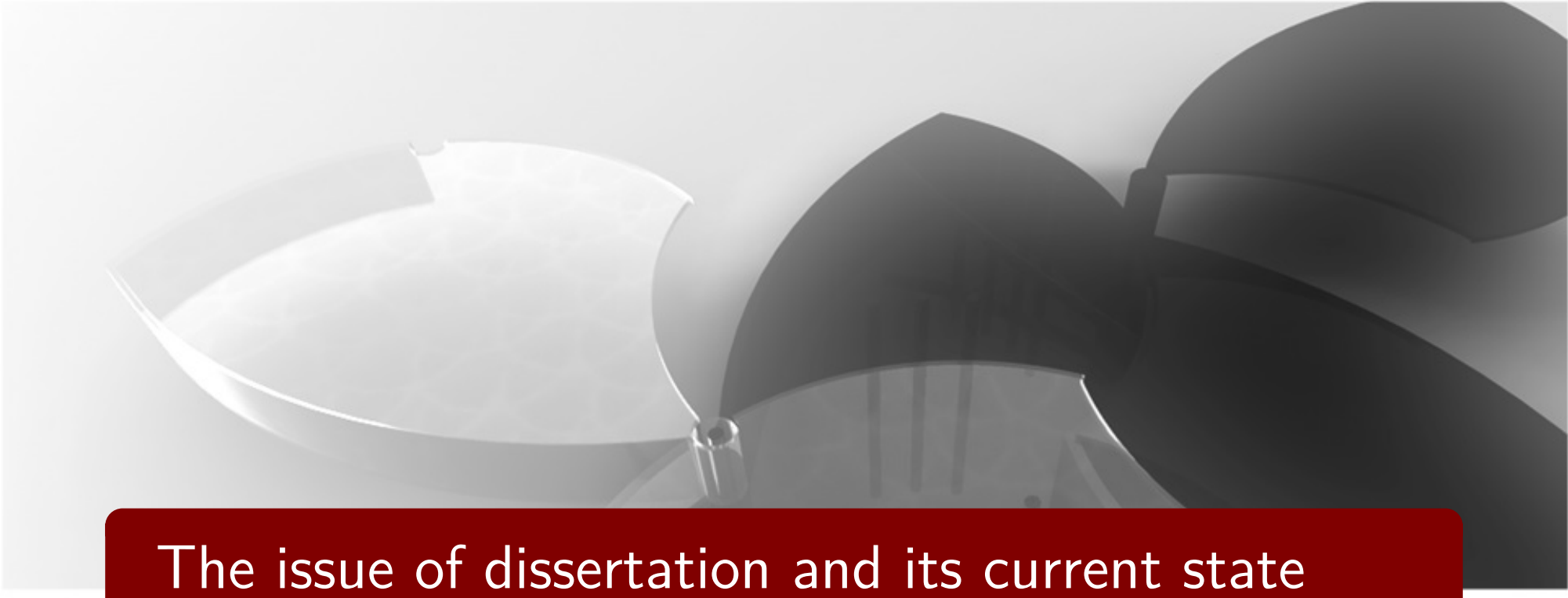


The issue of dissertation and its current state

Ildikó Ficza

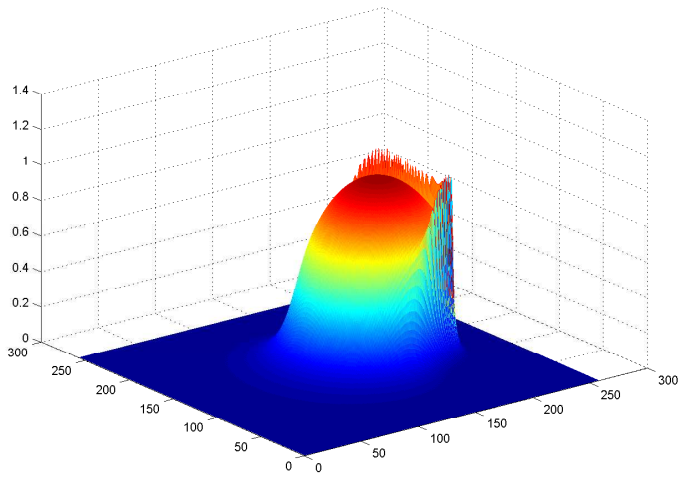
April 17, 2013

Institute of Machine and Industrial Design
Faculty of Mechanical Engineering
Brno University of Technology
Czech Republic

Institute of Machine and Industrial Design

Outline

- Introduction
- Mathematical model
- Numerical algorithm
- Results
- Conclusion and future work



Title:
Advanced Solver of Elasothydrodynamic Problems

Supervisor:
prof. Ing. Martin Hartl, Ph.D.

Aim of dissertation

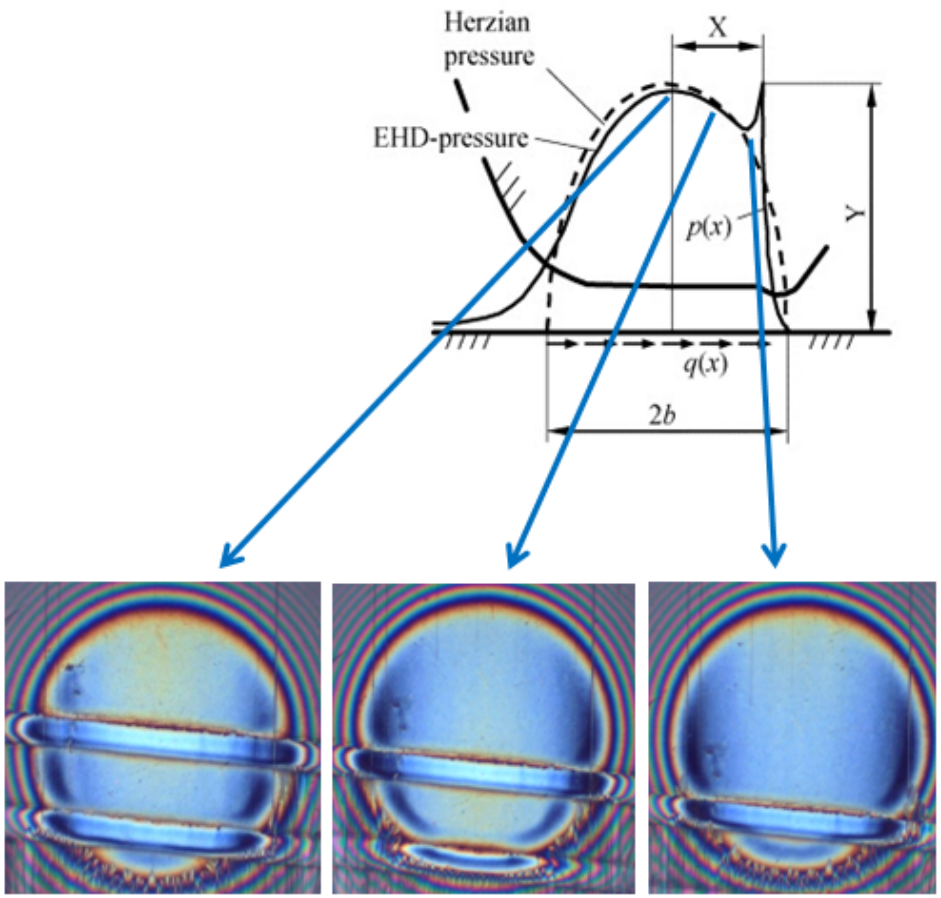
- Stable and fast numerical solver for elastohydrodynamic (EHL) problems (steady state and transient solution)
- Incorporate to the solver artificial roughness and non-Newtonian model of the lubricant
- Comparison with experiments

Deformation of roughness in rolling/sliding EHL contact

- study of surface roughness

  - experimental (Kaneta, 1992; Wedeven et al., 1978)
  - numerical (Lee, 1990; Chang 1991)

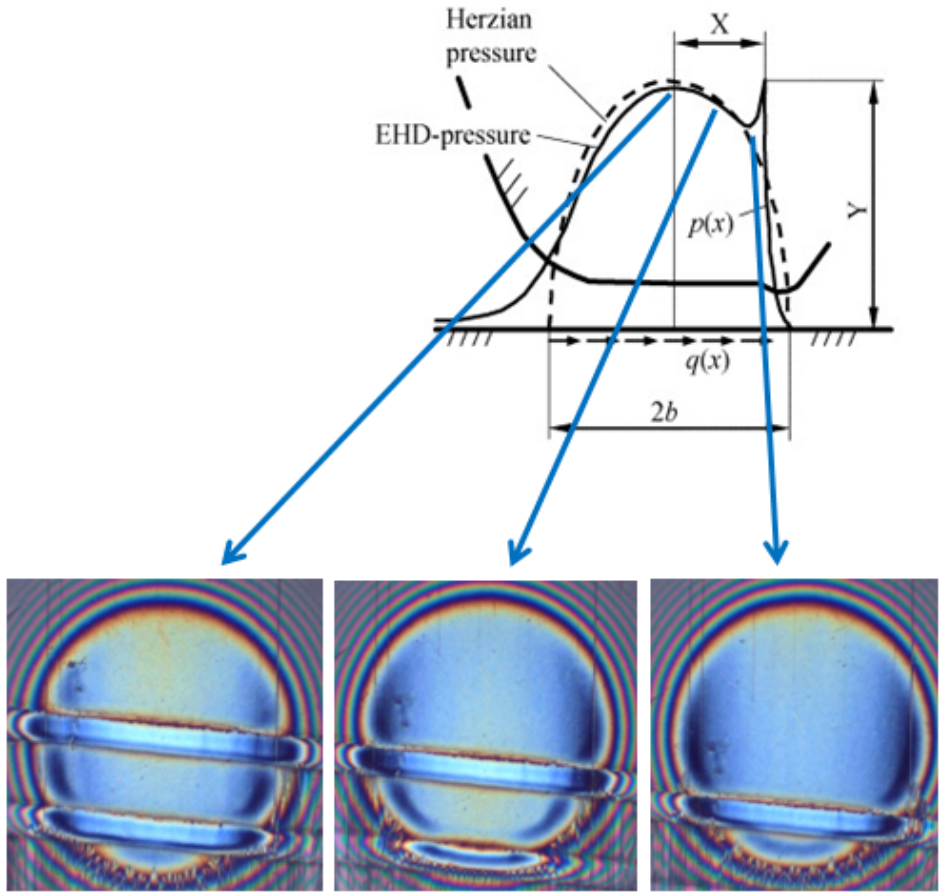
- effect of operating conditions on the roughness (Venner et al., 1995)
- amplitude reduction model (Hooke, 2005; Lubrecht et al., 1999) - introducing a single parameter
- Non-Newtonian lubricant response (Felix-Quinonez, 2004)



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

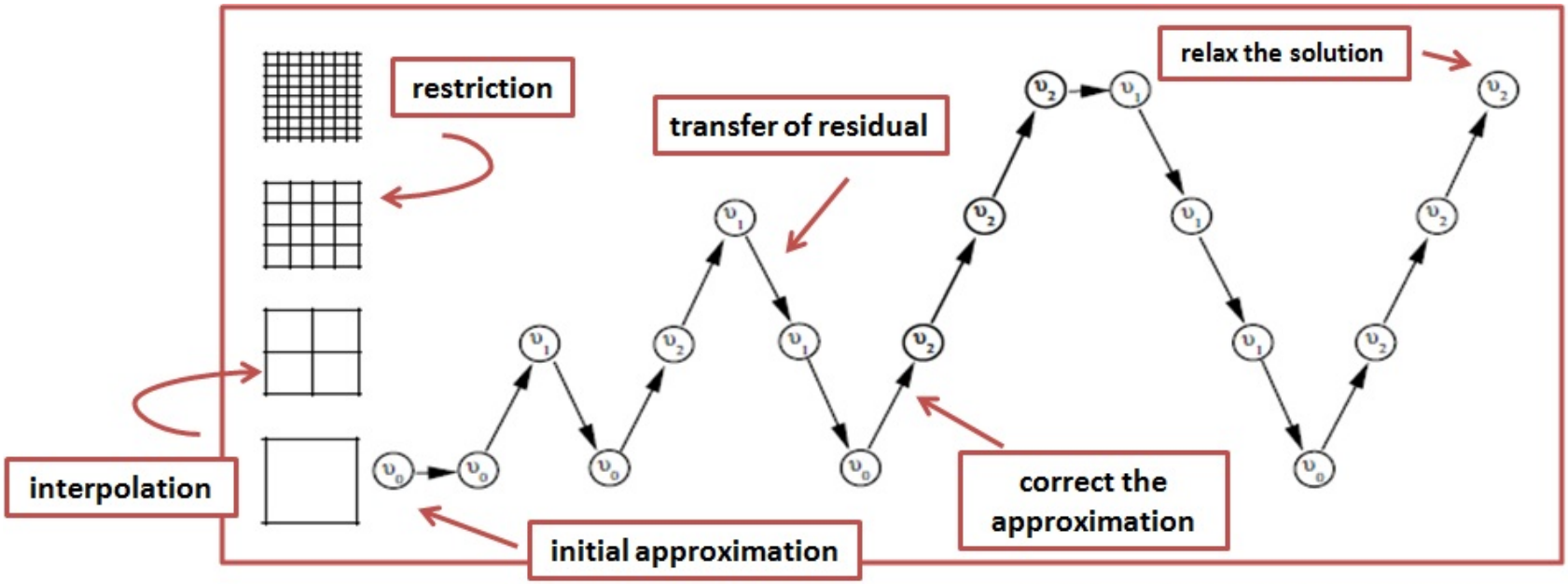
$$h(x,y,t)=h_0(t)+\frac{x^2}{2R_x}+\frac{y^2}{2R_y}-R(x,y,t)+\frac{2}{\pi E_r}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\frac{p(x',y')\,dx'dy'}{\sqrt{(x-x')^2+(y-y')^2}}$$

- 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

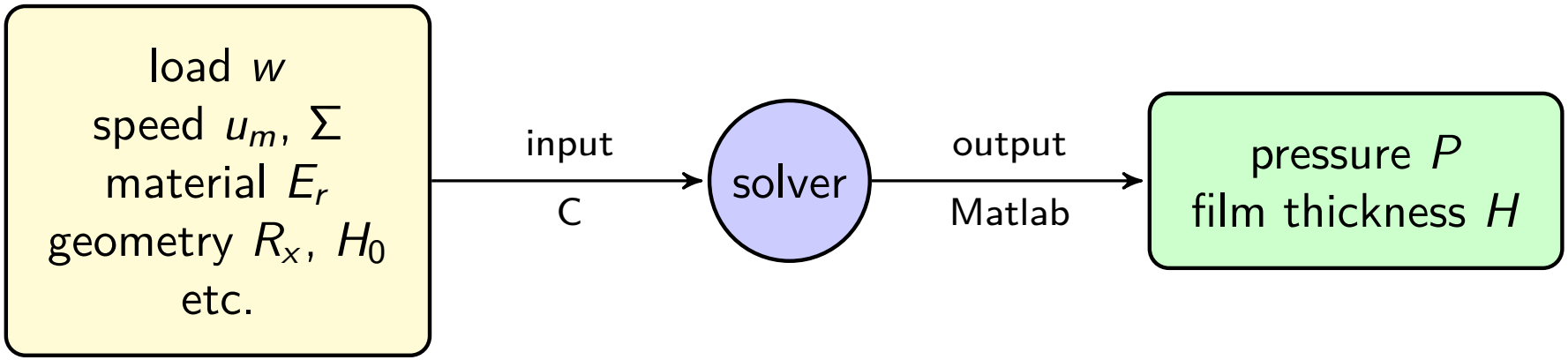


The full multigrid (FMG) scheme - Goodyer (2001)

Algorithm

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

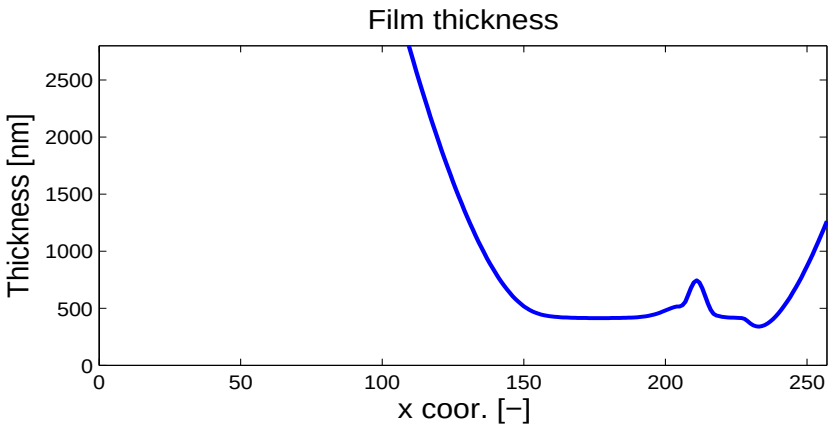
- domain up to 1025×1025 discrete points
- residuals up to $\mathcal{O}\left(10^{-9}\right)$

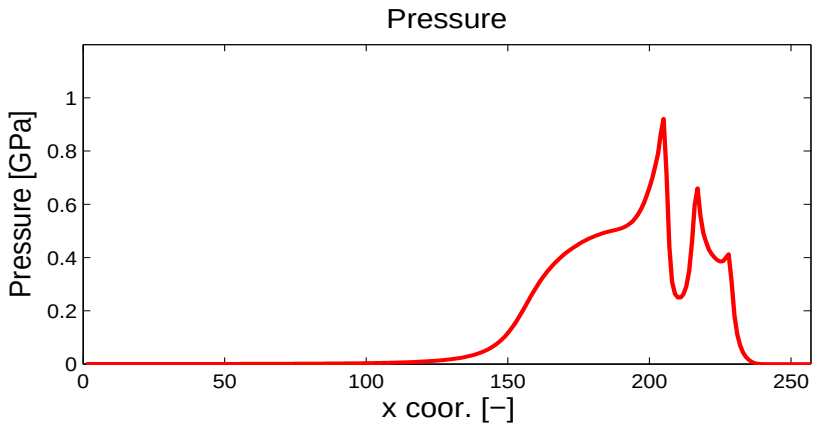


Surface feature type - Dent

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

$$r = \sqrt{\left(\frac{x - x_0 - \frac{u_1}{u_m}t}{l_x}\right)^2 + \left(\frac{y}{l_y}\right)^2}$$





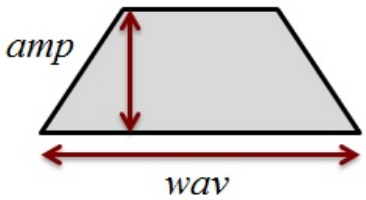
Dent

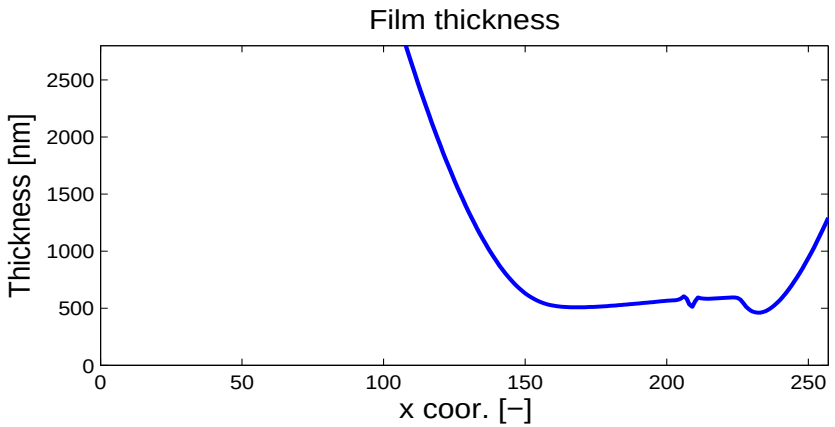
$w = 27N$, $u_m = 0.15m/s$, $\Sigma = 0$, $\alpha = 22GPa^{-1}$, $\eta_0 = 0.421Pas$, $E_r = 123.8GPa$, etc.

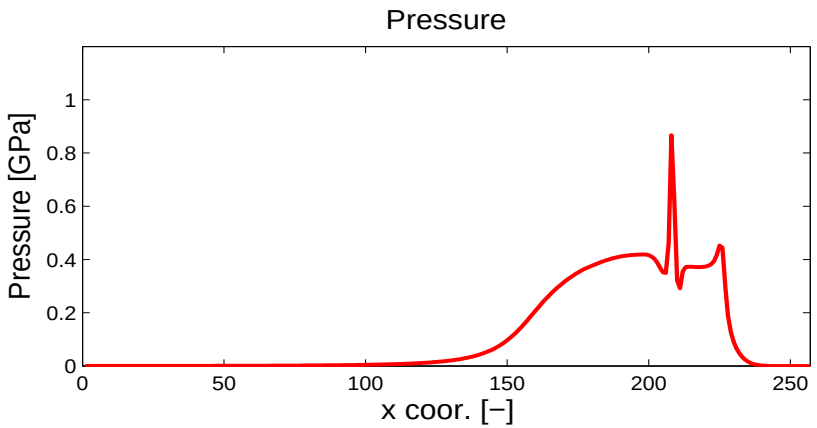
Surface feature - transverse ridge

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

$$r = x - x_0 - \frac{u_1}{u_m}t$$







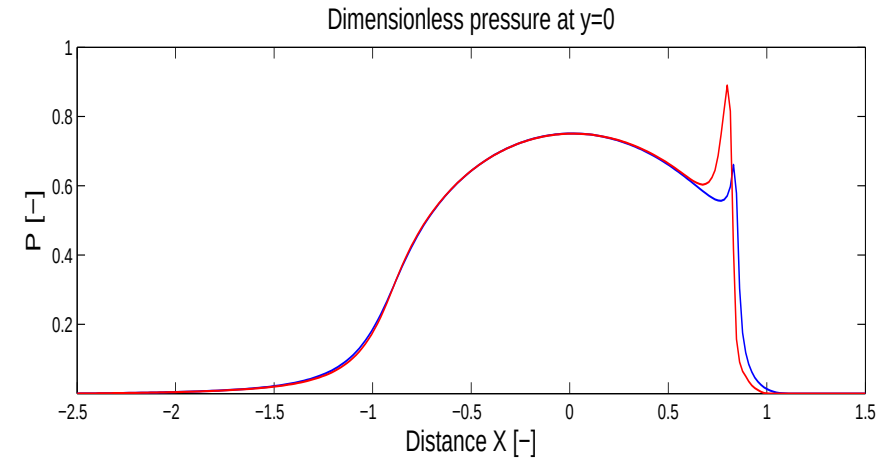
Transverse ridge

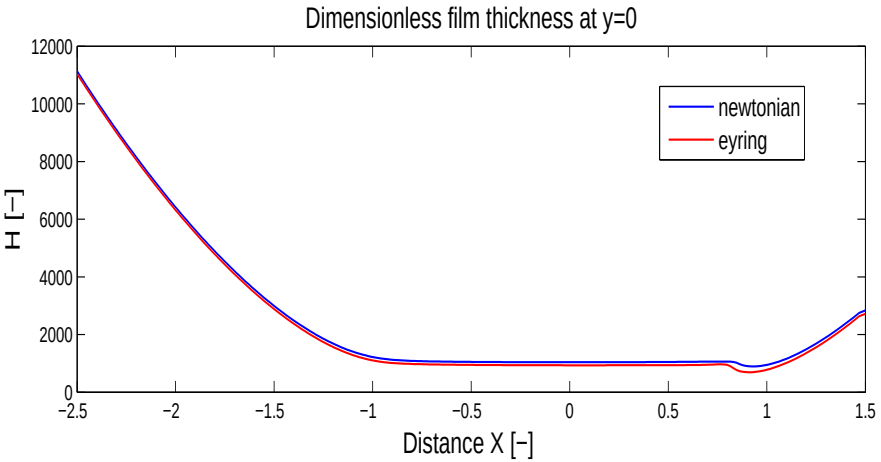
$w = 49.9N$, $u_m = 0.2m/s$, $\Sigma = 1$, $\alpha = 23.6GPa^{-1}$, $\eta_0 = 0.2016Pas$, $E_r = 123.8GPa$, etc.

Newtonian vs. Eyring fluid model

- incorporating variables η_x and η_y into Reynolds equation
- rheological function

$$f\left(\frac{\tau}{\tau_0}\right) = \frac{\tau_0}{\tau}\sinh\left(\frac{\tau}{\tau_0}\right)$$





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.