

Simulation of the effects of non-Newtonian fluid on the behavior of a step hydraulic rod seal based on a power law fluid model

Key words: Non-Newtonian effect, Power law fluid, Step seal, Soft elastohydrodynamic lubrication (EHL)

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Geometric Model

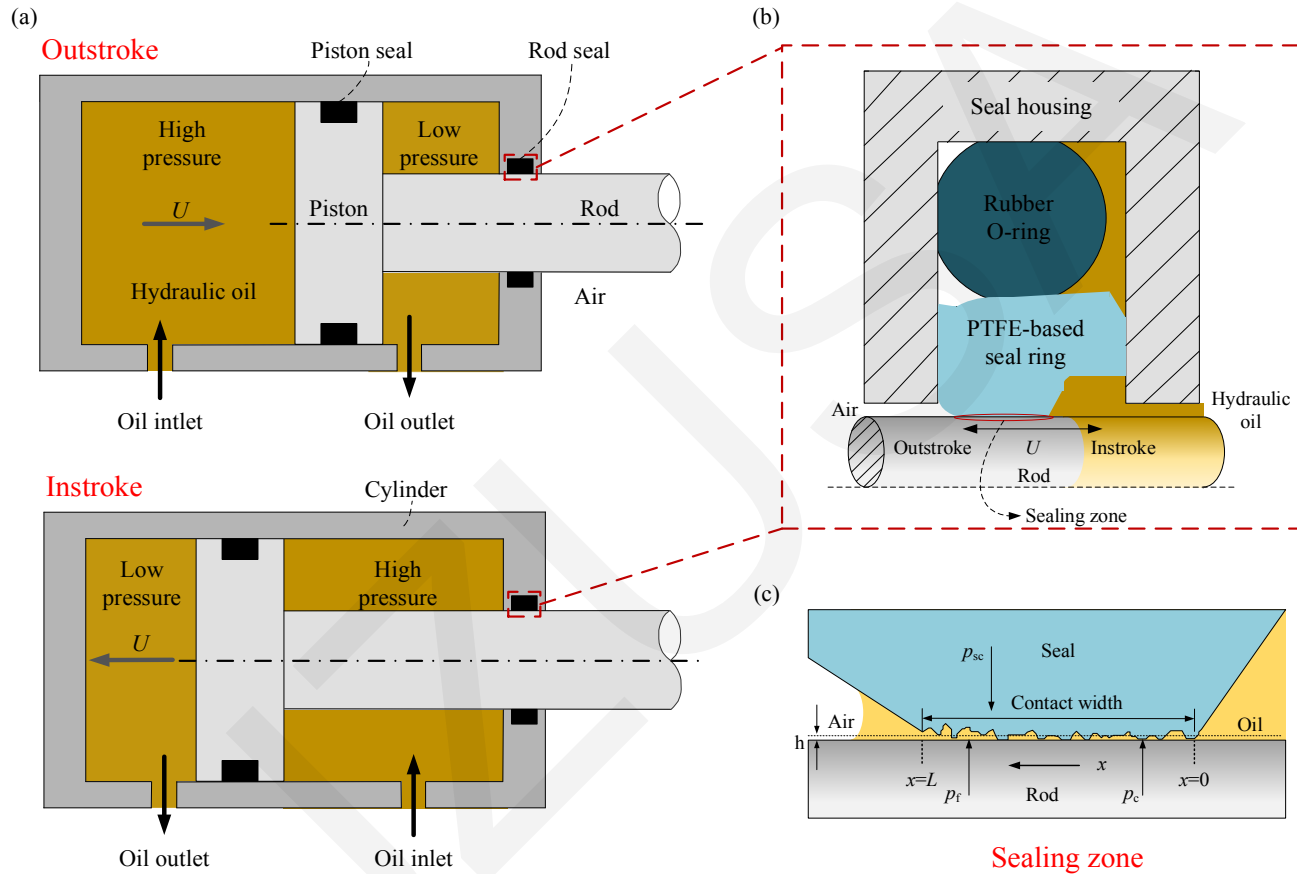


Fig. 1 The geometrical model. (a) Hydraulic seals in a linear hydraulic actuator, (b) schematic of the step seal, and (c) details of the sealing zone

Numerical Model

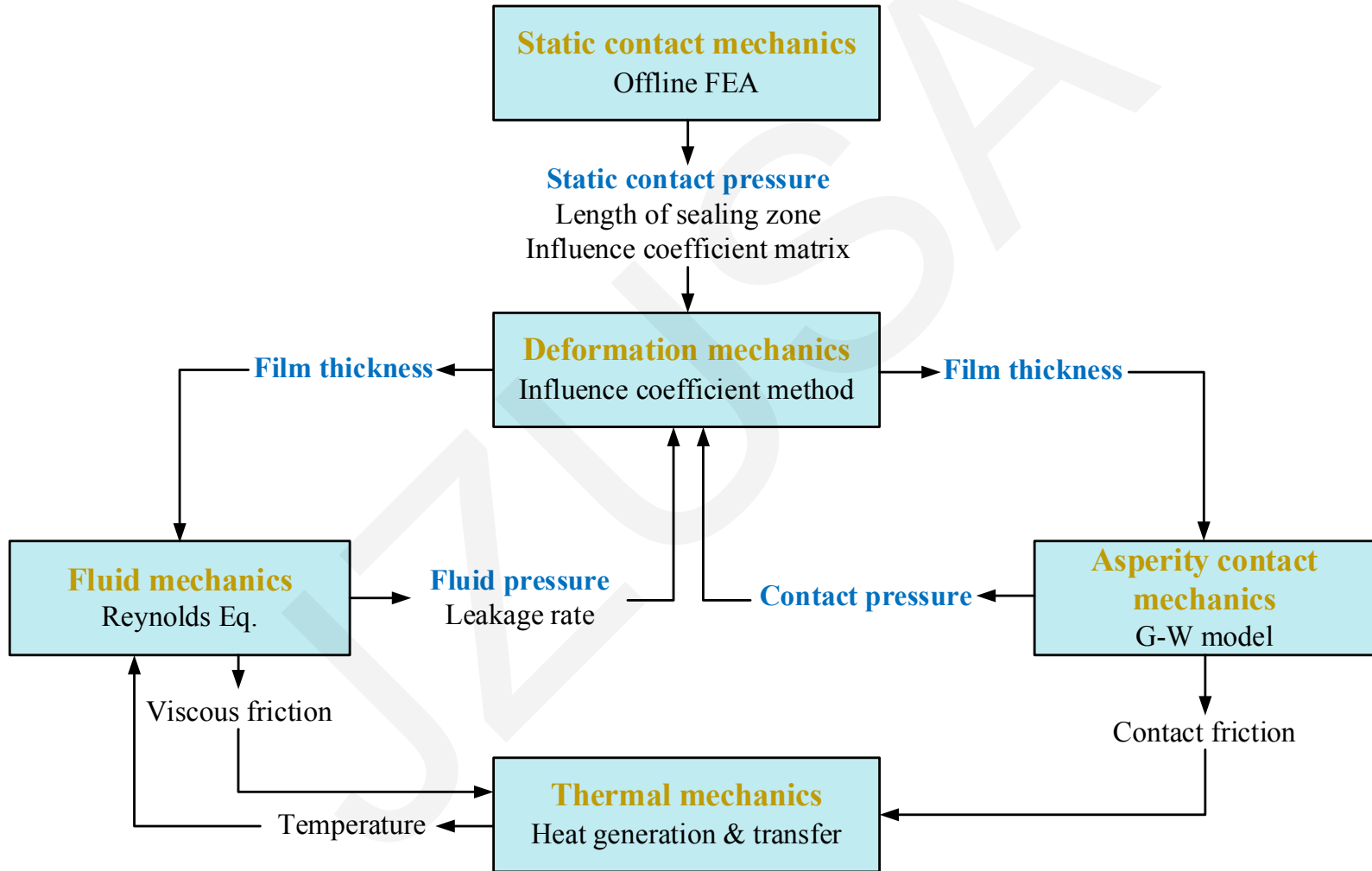
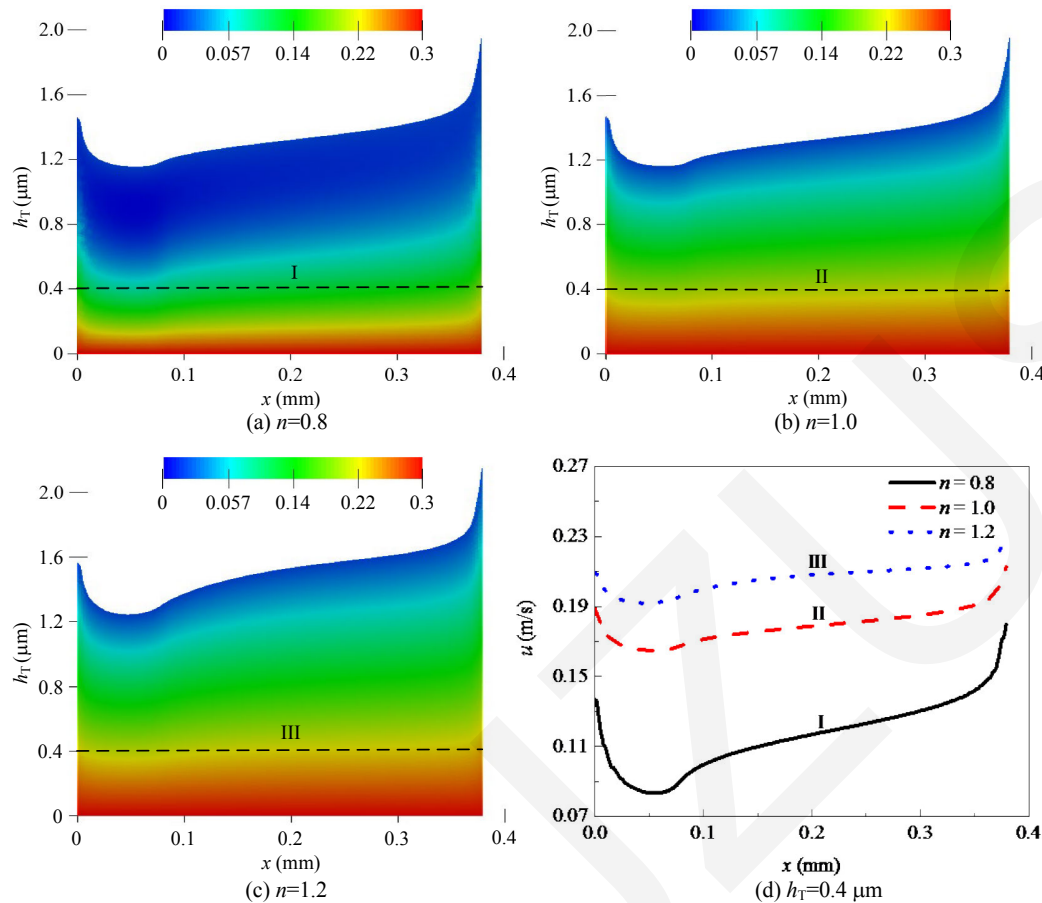


Fig. 2 Components of the numerical model

Sealing mechanisms



- Power law model

$$\tau = m \left| \frac{\partial u}{\partial z} \right|^{n-1} \frac{\partial u}{\partial z} = \mu \frac{\partial u}{\partial z}$$

➤ Variation in the power law index of non-Newtonian fluids or the fluid rheological property alters the flow behavior of the lubricant, especially the fluid film velocity profile, which is responsible for generating the fluid hydrodynamic pressure.

Fig. 8 Fluid film velocity distribution with different power law indexes (instroke, $|U| = 0.3 \text{ m/s}$, $\sigma = 0.5 \mu\text{m}$ and $p_s = 5.0 \text{ MPa}$)

Conclusions

- A mathematical model was developed for a hydraulic reciprocating rod seal to analyze the effect of non-Newtonian fluids on the seal behavior.
- The non-Newtonian fluid effect of hydraulic oil on a reciprocating seal is not negligible, which has a significant influence on the film forming between the sealing interfaces, and on the sealing performance.
- The rheological properties of the hydraulic oil influence the viscous shearing stress of the fluid, resulting in a change in the hydrodynamic pressure.
- For a dilatant fluid, the hydrodynamic effect is strong due to the shear thickening rheological property, resulting in a seal with low friction and zero leakage. But for a pseudoplastic fluid, the lubrication condition in the sealing zone is relatively poor, and it is very difficult for the seal to achieve zero leakage under the conditions simulated.