# Influence of transient effects on the behaviour of translational hydraulic seals

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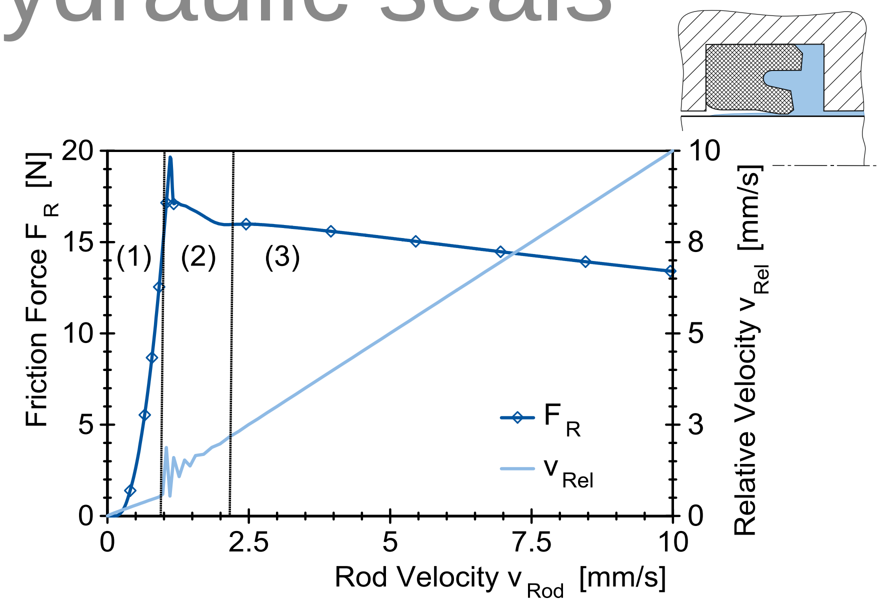
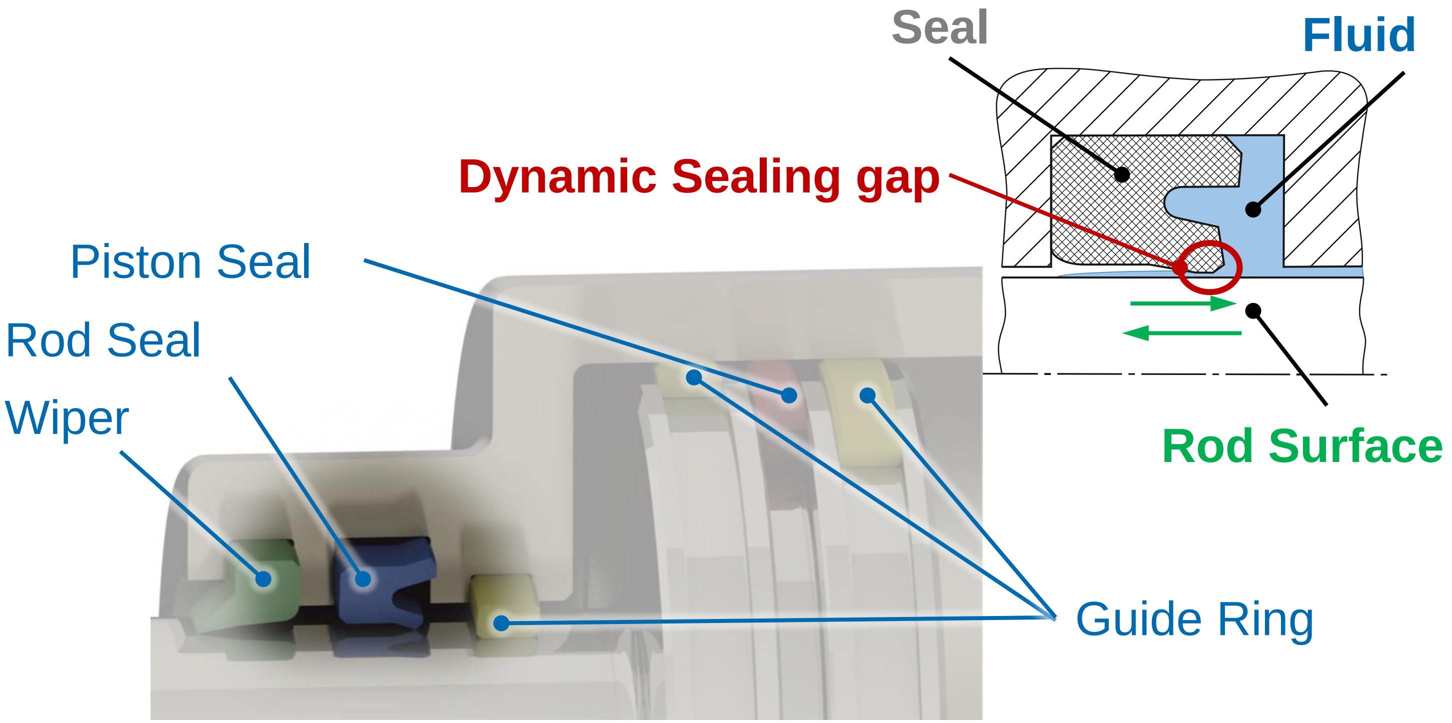


# Motivation and project aim

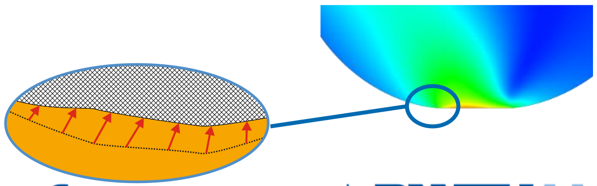



Physically motivated and experimentally validated model of translational hydraulic seals

# Modelling of dynamic translational seals

## Macroscopic

- EHD-calculation
- Component experiments



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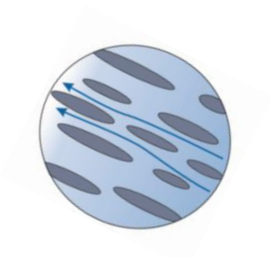
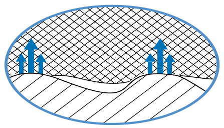
## Microscopic

- Physically motivated calculations
- Simplified model experiments





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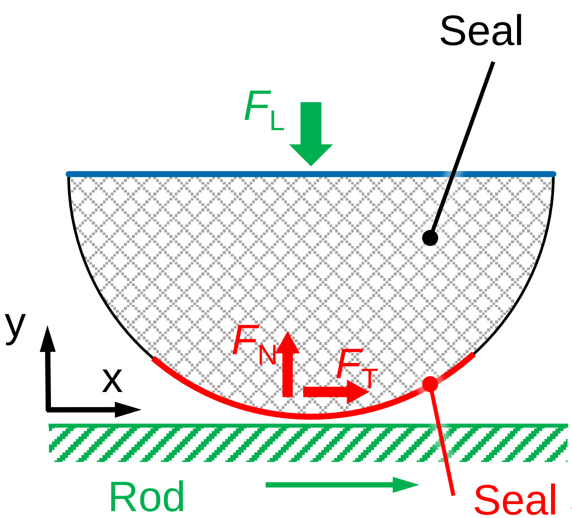
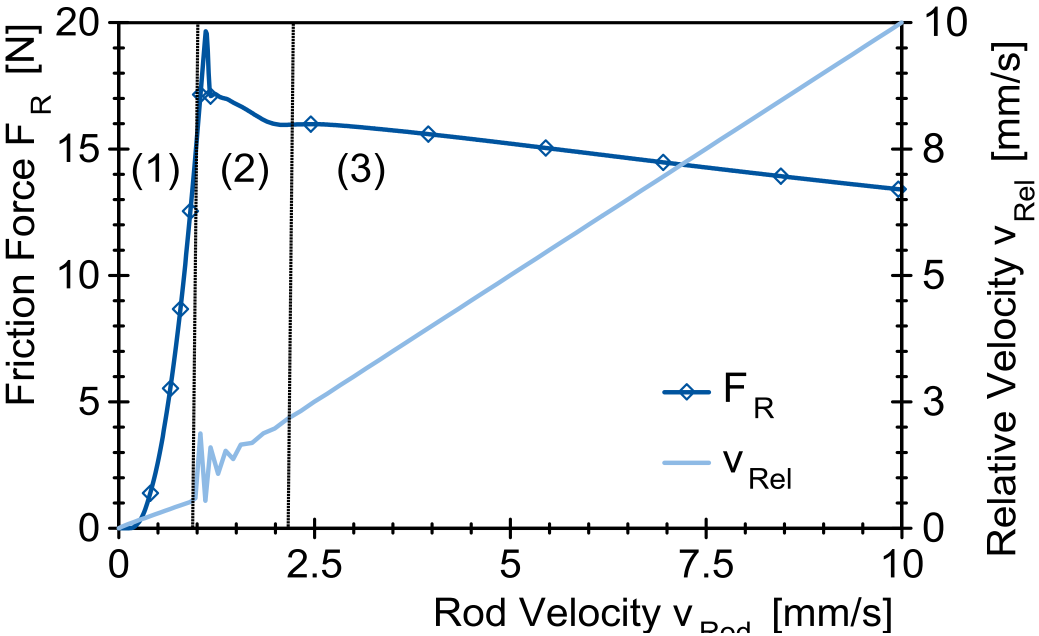
# Phases of friction during acceleration

- Phase (1): Seal sticks to the rod's surface, relative velocity < rod velocity
  - Critical stress $\tau^{\text{crit}}$ exceeded locally -> Minor slip
- Phase (2): Breakaway of the seal
  - Critical stress $\tau^{\text{crit}}$ exceeded on macroscopic scale
- Phase (3): Relative velocity equals rod velocity

$$v_{\text{rel}} = v_{\text{Rod}} - \overline{v_{\text{Seal}}}$$



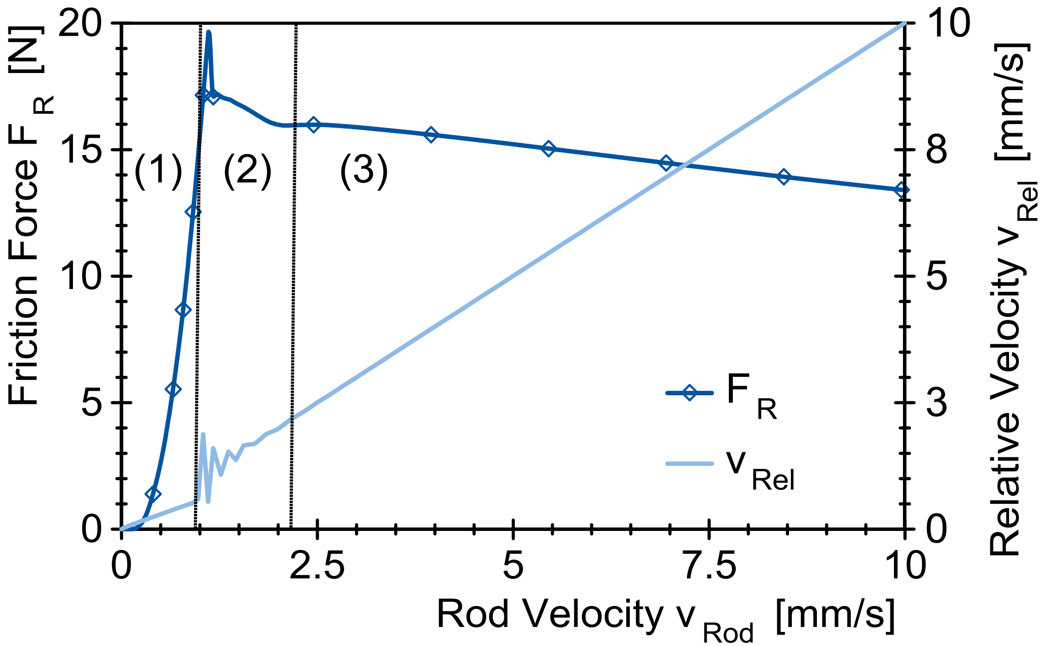



# Transient influences

I. Influence of the actual relative velocity in the contact

II. Influence of the non-constant coefficient of solid friction

III. Influence of the time dependent change of the sealing height



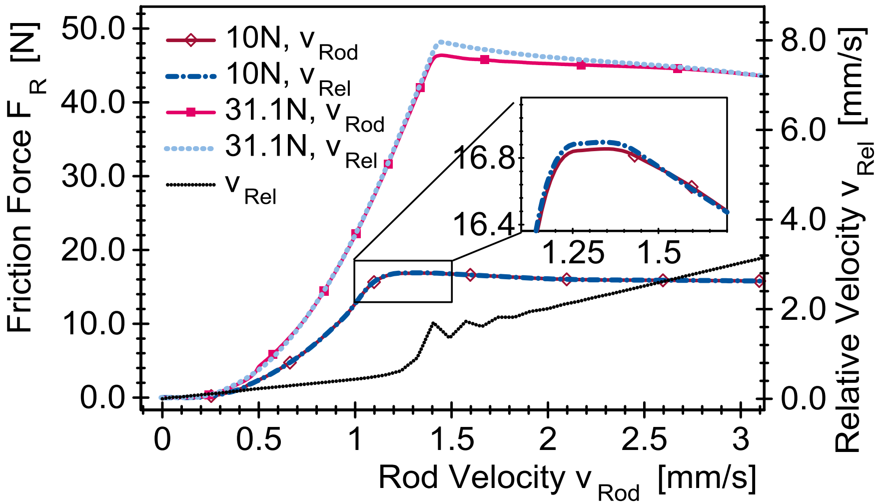
# I. Influence of the actual relative velocity

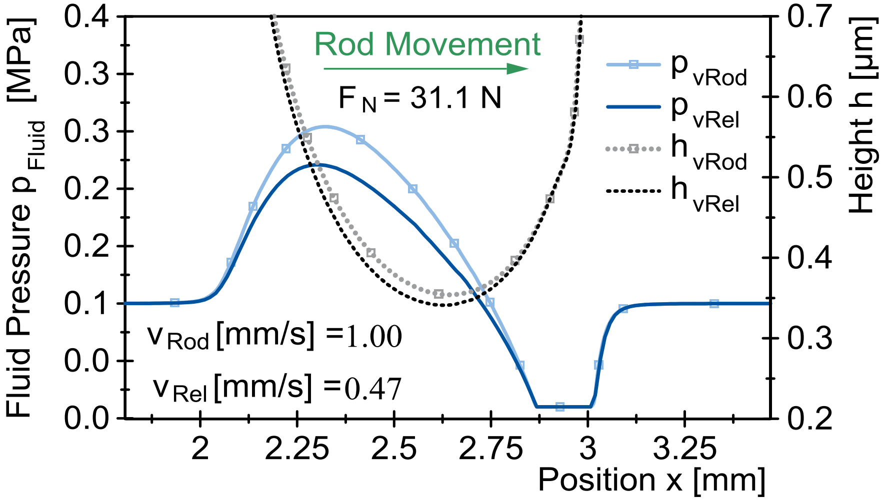
- Phase (1): Relative velocity < rod velocity

$$\frac{\partial}{\partial x}\left(\frac{h^3}{12\eta}\frac{\partial p}{\partial x}\right) = \frac{\partial}{\partial x}\left(\frac{h\, v_x}{2}\right)$$

$v_x$ → $v_{\mathrm{Rod}}$

$v_x$ → $v_{\mathrm{rel}} = v_{\mathrm{Rod}} - \overline{v_{\mathrm{Seal}}}$



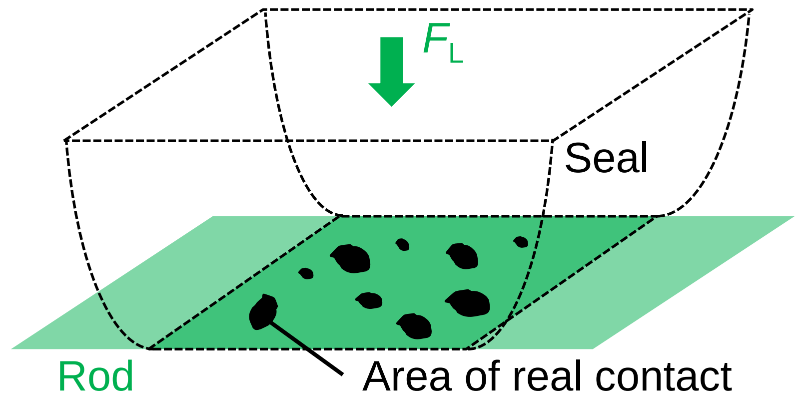

**Slightly higher breakaway friction force due to lower fluid pressure**

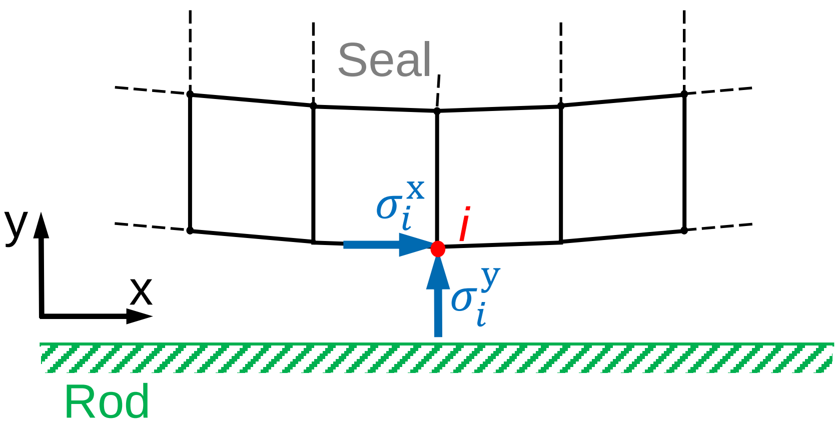
# II. Non-constant coefficient of solid friction

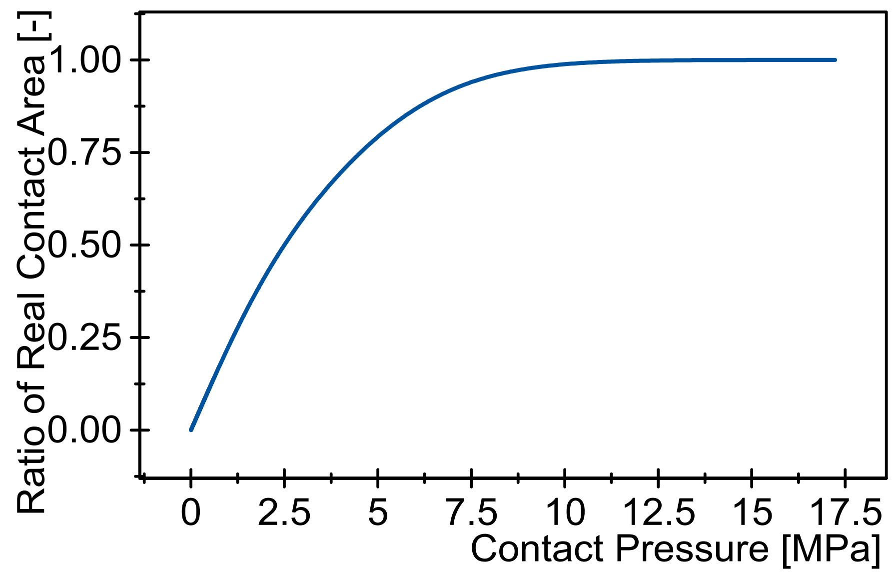
- Amonton's law of friction

$$F_i^{\mathrm{x}} = \mathrm{sign}\,(\delta_i) \cdot \mu \cdot \sigma_i^{\mathrm{y}} \cdot A_i^{\mathrm{Apparent}}$$

- Reality
  - $F_i^{\mathrm{x}} = sign\,(\delta_i) \cdot \tau^{\mathrm{cont}} \cdot A_i^{\mathrm{Real}}$
  - $\tau^{\mathrm{cont}} \approx const.$
  - $\mu \neq const.$



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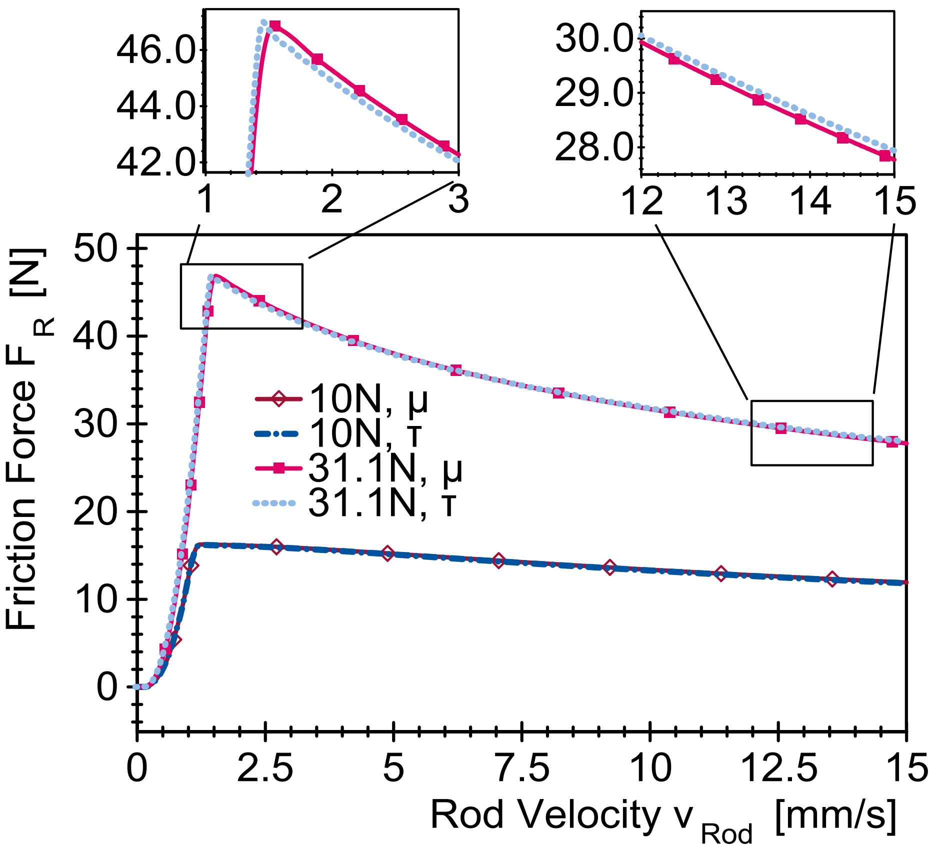
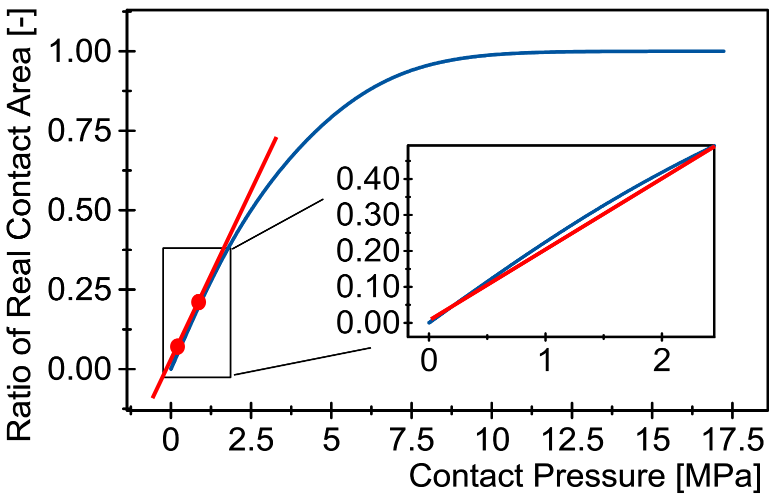



Influence is negligible for small contact pressures

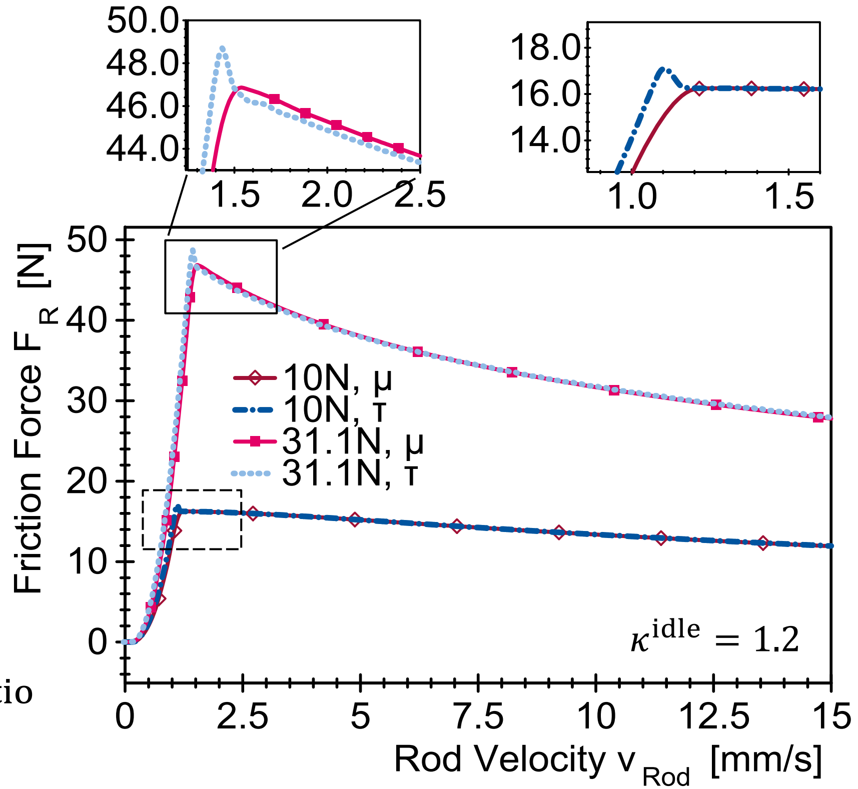
# Idle time dependent breakaway force

- Idle time
  - Elastomer creeps into the rod's surface
  - Area of real contact increases
  - Higher critical contact shear stress

$$\tau_i^{\text{crit,idle}} = \tau^{\text{cont}} \cdot A_i^{\text{Ratio,idle}}$$
$$= \tau^{\text{cont}} \cdot \kappa^{\text{idle}} \cdot A_i^{\text{Ratio}}$$

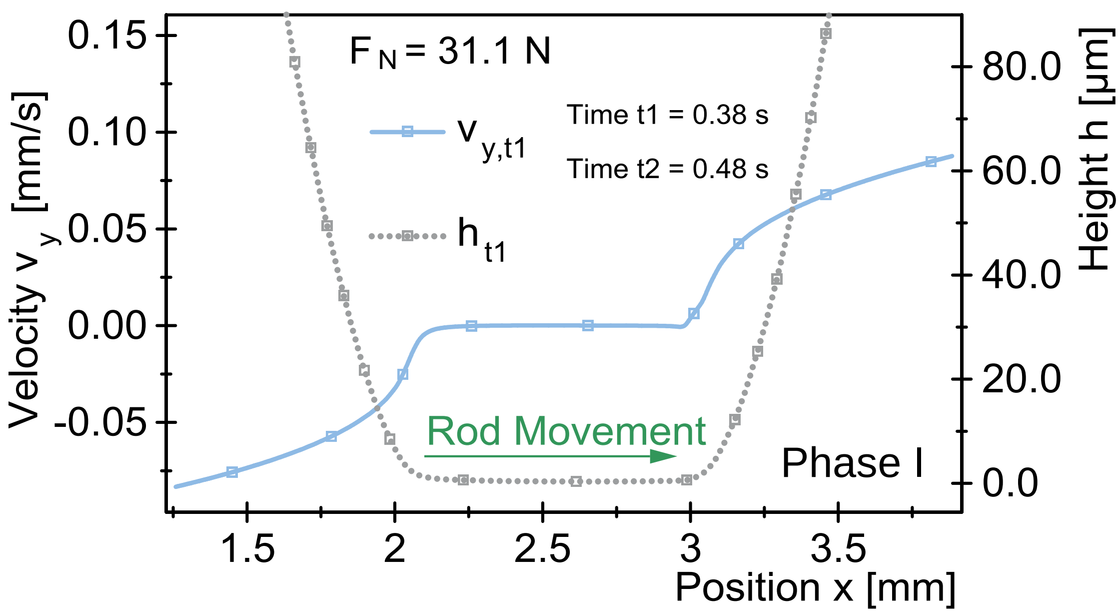
- Condition for breakaway

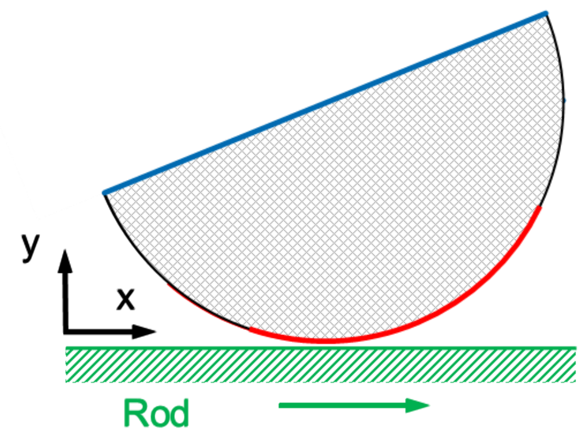
$$\tau_i > \tau_i^{\text{crit}} = \tau^{\text{cont}} \cdot \frac{A_i^{\text{Real}}}{A_i^{\text{Apparent}}} = \tau^{\text{cont}} \cdot A_i^{\text{Ratio}}$$



# III. Time dependent change of the sealing height

$$\frac{\partial}{\partial x}\left(\frac{h^3}{12\eta}\frac{\partial p}{\partial x}\right) = \frac{\partial}{\partial x}\left(\frac{h \cdot v_x}{2}\right) + \frac{\partial h}{\partial t}$$



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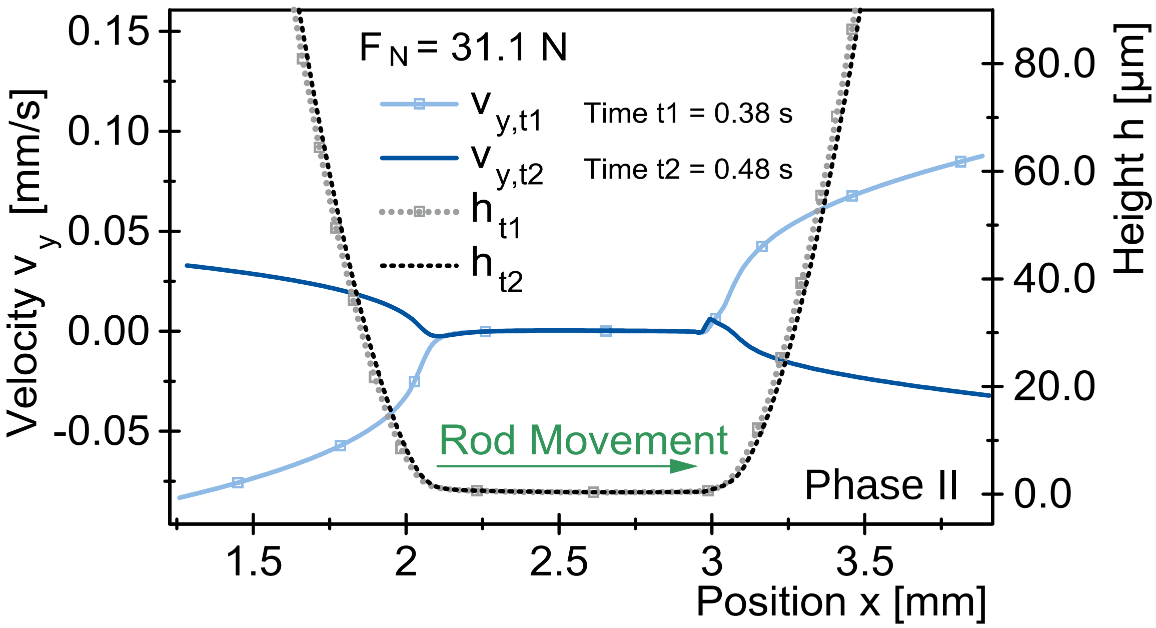


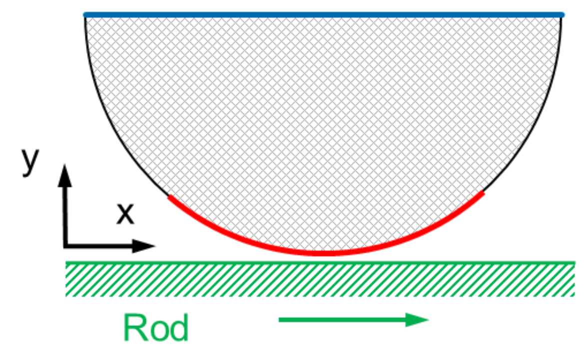

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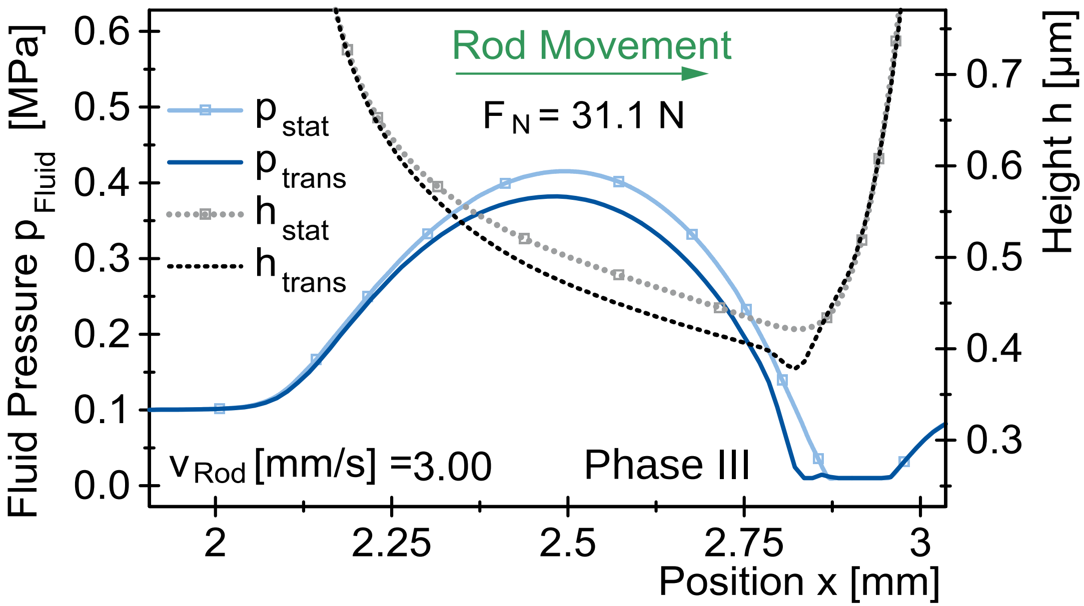


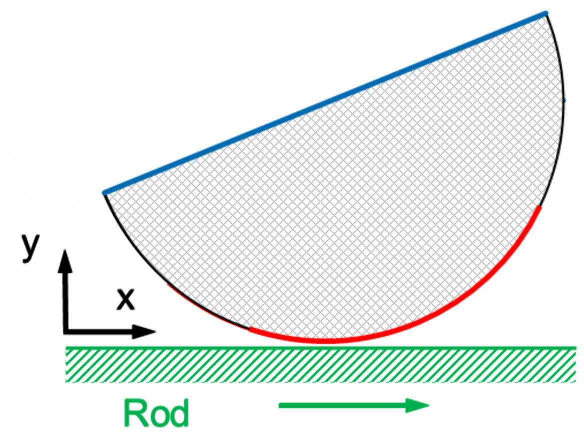

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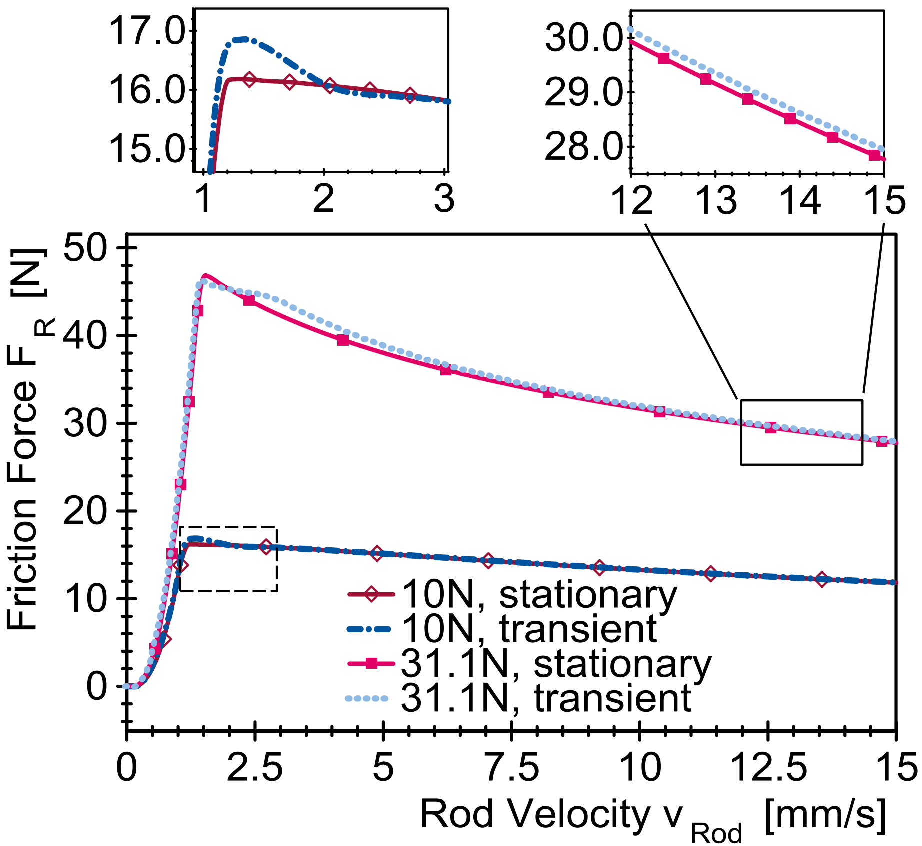
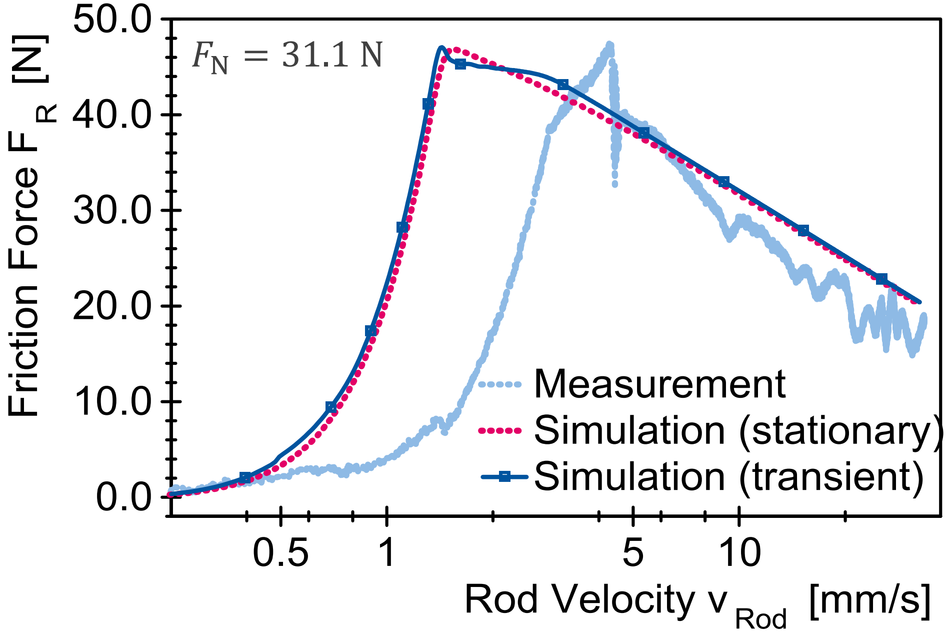
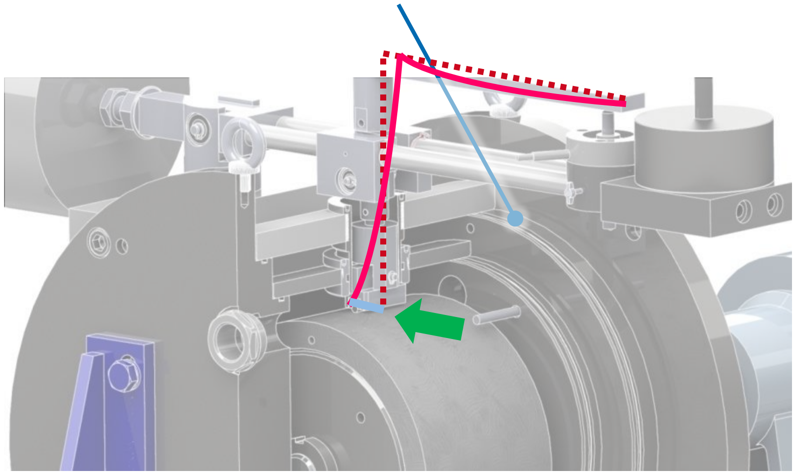



Friction force is slightly increased

# Comparison with experimental data

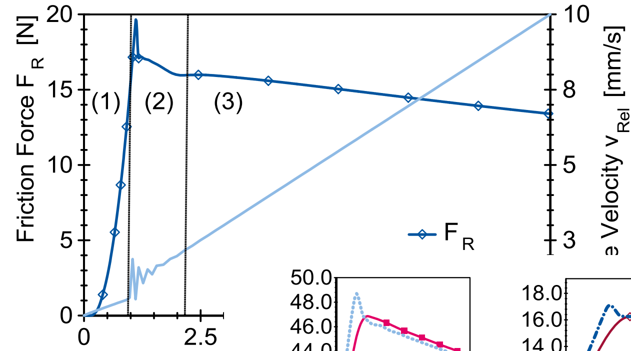
- Linear contact: Seal (d = 5 mm) and rotating cylinder (D = 200 mm)
- Measurement: Travel distance of approximately 1.2 mm until breakaway



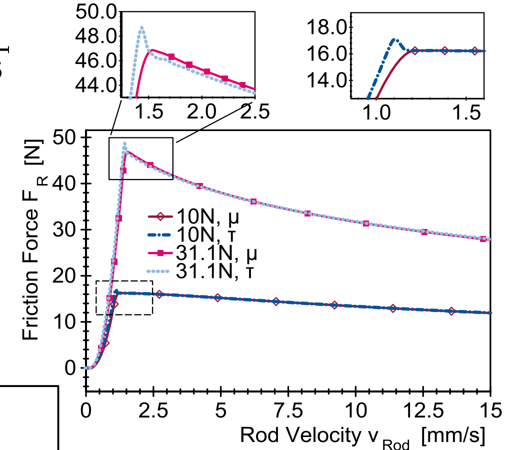



# Conclusion

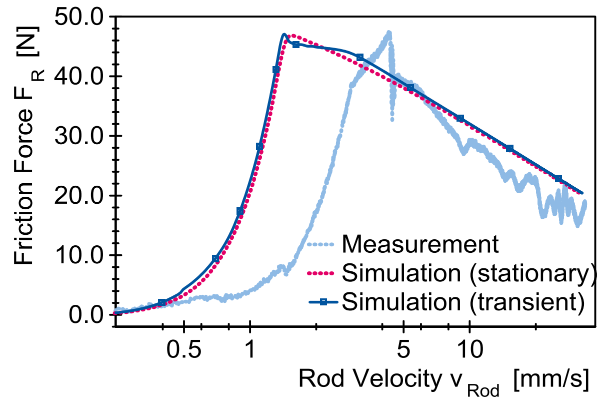
- Three phases of friction during acceleration




- Transient influences
  – Small influence for investigated conditions
  – Influence rises with higher contact pressure




- Comparison with experimental data
  – Higher travel distance until breakaway in measurement
  – Otherwise good comparability



# Thank you for your attention!

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