Entrainment of free water into hydraulic systems through the rod sealing

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Motivation

Oil ageing through hydrolysis and oxidation
\[ \text{Ester} + \text{H}_2\text{O} \leftrightarrow \text{Alcohol} + \text{Acid} \]

Compatibility on seals
- Swelling
- Decomposition

Oxidation of metals

Water entry into hydraulic systems

Dynamic Seals
\textit{(relative movement)}

Danger of steam cavitation
- \textit{Vapour pressure (50 °C)}
  - Oil: \(4.7 \cdot 10^{-8}\) bar
  - Water: 0.12 bar

Poor lubricity
- Hydrodynamic wear

\[ \eta(40 \, ^\circ\text{C}) \approx 0.65 \, \text{mPas} \]
\[ \eta(40 \, ^\circ\text{C}) \approx 39.1 \, \text{mPas} \]

Ice crystals at \( T < 0 \, ^\circ\text{C} \)

Tank lid (spray, breathing)
Entrainment potential of rod seals

- Film height greater during retraction than extension (when excessively lubricated)
- Difference can be filled up with water
- → Entrainment potential

Nißler, U., „Dichtheit von Hydraulikstangendichtringen aus Polyurethan”, 2015
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Test bench concept

- Prechambers for test fluid supply
- Entrained water increases fluid volume
- $\rightarrow$ Piston is displaced
- Pressure is set by hydro-accumulator
- Temperature sensors in front of seals
Entrainment sensor

Pressure [bar]

Displacement [mm]

Back pressure [bar]

Displacement [mm]

Hydro-accumulator

Back pressure

Pressure

Δx
Temperature impact

- Temperature rise during operation due to friction in sealing and guide rings
  - Volume expansion of oil leads to thermal induced stroke
- Determine the actual gradient through heating tests
- Used gradient $3.5 \frac{mm}{K}$ (Standard deviation: 3.9 %)

\[
\Delta V_{\text{thermal}} = V_0 \cdot \gamma \cdot (T - T_{\text{Start}}) = A_{\text{piston}} \cdot \Delta x_{\text{thermal}}
\]

\[
\Delta x_{\text{thermal}} = \left(\frac{dx}{dT}\right)_A (T - T_{\text{Start}})
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First odd measurement results

- Measurement carried out for oil and water supplied outside the seals
  - Oil: is entrained into the system through the sealing
  - Water: loss of fluid volume out of the chamber
- Possible explanation: Oil film on rod is detached while water is supplied
Design change

- Modified water supply
  - Water runs pressure free onto the rod in front of seals
  - Water flow is kept constant by maintaining a constant level height

\[
\text{const.}
\]
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Test results

- Velocity and Temperatur have only minor impact
- Main impact is pressure
- Higher pressure → seal is harder pressed against rod → water is better wiped off
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Conclusion and outlook

- Water entrainment potential of rod seals
- Test bench concept
- Thermal induced stroke
- Measurement results
  - Main impact on water entrainment is pressure
- Investigation of other sealing concepts
  - Double sealing concept
  - Groove ring
- Investigation of the impact of wipers on the water entrainment

\[ \frac{dx}{dT} = 3.31 \text{ mm/K} \]
Thank you for your attention!

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