Effect of Piston Grooves in the Lubricating Performance of an Ultra-High Pressure Radial Piston Pump

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Outline

• Introduction to Radial Piston Pumps
• The Multi-Domain Simulation Tool
• The Solution Algorithm
• Exploring Grooved Piston Designs
• The Hydrodynamic Effect
• Results and Discussion
• Conclusions and Future Work
Radial Piston Pumps

Important Features:-

✓ Very high Pressures can be generated.
✓ Low noise level
✓ Can withstand very high loads at low speeds.
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Applications

- Wind turbines
- Injection Moulding
- Rock splitters
- Bolt Tensioners
Pump Parts:

Rotating Cam

Main functions of the gap:
+ Sealing
+ Bearing loads

Main source of power losses:
- Mechanical Losses
- Volumetric Losses
Multi Domain Simulation Tool

- Geometrical Model
  - C++, AMESim

- Global Fluid Dynamic Model
  - LMS.Imagine Lab AMESim®

- FSI Model for Lubricating Gaps
  - Piston Cylinder Interface
  - Cam Piston Interface
  - C++ OpenFoam®

Generic Hydraulic System
- LMS.Imagine Lab AMESim®
Multi Domain Simulation Tool

Geometrical Model
C++, AMESim

Global Fluid Dynamic Model
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Generic Hydraulic System
LMS.Imagine Lab AMESim®

Gap Length/mm vs. Angle/°

Velocity/ m/s vs. Angle/°
Multi Domain Simulation Tool

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Graph showing displacement chamber pressure and piston displacement vs. shaft angle.
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F = Friction between cam and piston
F = Normal contact force by cam on the piston
F = Normal force by fluid film
F = Viscous friction
F = Press. force from disp. chamber

All forces act along x-y plane
Fluid Film domain

**Piston micro-motion with 2 DOF**

\[ x_a \]
\[ l_{\text{gap}} \]
\[ x_b \]

**Boundary Conditions**

- **A**: \( P=0 \) (open to the drain)
- **B**: \( P=\text{Disp. chamber press.} \)
- **C, D**: Cyclic

- Discretized using finite volume method
- Reynolds equation solved to find pressure at each cell

\[
\nabla \cdot \left( \frac{\rho h^3}{12 \mu} \nabla p \right) + \left( \frac{\rho v_b}{2} \cdot \nabla h \right) + \rho v_b \cdot \nabla (h_b) + \rho \left( \frac{\partial h_t}{\partial t} - \frac{\partial h_b}{\partial t} \right) = 0
\]
Exploring Grooved Piston Designs

No Grooves  Case A  Case B  Case C
RESULTS
Variation of Leakage over one shaft revolution

![Graph showing the variation of leakage over one shaft revolution with and without grooves. The graph illustrates two curves: one for 'Without groove' with a blue line and one for 'With groove' with a red line. The x-axis represents the angle in degrees, ranging from 0 to 360 degrees, and the y-axis represents leakage in liters per minute, ranging from 0 to 0.04 liters per minute. The graph highlights the difference in leakage between the two conditions.]
Variation of Viscous Friction Power Loss over one shaft revolution
THANK YOU

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