CFD simulations of Tumbling Multi Chamber (TMC) pump

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Overview

1. Classification
2. Working principle
3. Motivation & goals
4. Analysis steps
5. Meshing – Twinmesh
6. Mesh components
7. Mesh independance check
8. Results – flow and pressure (Pump 1)
9. Results – torque, pressure, wall shear (Pump 2)
10. Conclusions
Tumbling Multi chamber pump | Classification

Pumps

Hydrodynamic

Axial

Radial

Diagonal

Others

Hydrostatical

Piston

Screw

Vane

Gear

Others

Axial

Radial

2-Axis

more Axis

Inner

External

Roll-cell

TMC - Tumbling Multi Chamber

DPR - Doppelrotor

COR
Tumbling Multi chamber pump | Working principle

- 2 working parts with 3d trochoidal gear -> pump stator & rotor
- Number of teeth -> stator N, rotor N+1
- Transfer of the torque from the shaft via tilted sliding surface / valve plate
- Tumbling motion of the rotor causes compression / suction of the fluid

Fluid is carried between the teeth -> similar to principle of gerotor pump
TMC pump | Motivation & goals

Pump 1 - COR200

Medium: Water
Displacement: 781 mm³/rev
Flow: up to 250 l/h
Possible applications:
• Water injection pump
• Transmission / actuation / oil pump
• Household appliances

Simulation goals:
1. flow & flow ripple calculation,
2. pressure field & pulsations analysis,
3. volumetric loss calculation,
4. volumetric efficiency.

Pump 2 – COR600

Medium: Transmission oil
Displacement: 3000 mm³/rev
Flow: more than 600 l/h
Possible applications:
• Transmission / actuation / oil pump

Simulation goals:
1. torque calculation,
2. viscous loss calculation,
3. efficiencies -> volumetric, mechanical, total.
TMC pump | Analysis steps

1. Modification of the geometry.
2. Mesh generation
   - Pump parts
   - Static and rotating geometry
3. Setting of initial & boundary conditions (pressure, speed,..)
4. Solving + monitoring the solution.
5. Results analysis
Pump 1 | Meshing - Twinmesh
Pump 1 | Mesh components

- Volume between 3d surfaces
- Holes in pump rotor
- Rotating geometry (part 1)
- Rotating geometry (part 2)
- Inner gap
- Outer gap
- Static inlet
Test of different mesh refinements in Twinmesh -> finding of optimal mesh density.

Final results:
- Theoretical flow:
  - \( n_{teor}(3000 \text{ rpm}) = 140,6 \frac{l}{h} \).
- Simulated flow (without small gaps):
  - \( n_{sim}(3000 \text{ rpm, 0 bar}) \approx 140,0 \frac{l}{h} \).
  - \( n_{sim}(3000 \text{ rpm, 10 bar}) \approx 135,7 \frac{l}{h} \).
- Simulated flow ripple:
  - 0 bar: 8 l/h (5,8 %)
  - 10 bar: 9,2 l/h (7,3 %)

<table>
<thead>
<tr>
<th>Run</th>
<th>Nr. of elements</th>
<th>Nr. of elements (R1.cfx5)</th>
<th>Avg. ( \eta_{vol} )</th>
<th>Flow Q, l/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,3 mil.</td>
<td>780k</td>
<td>0.94</td>
<td>132,6</td>
</tr>
<tr>
<td>2</td>
<td>2,2 mil.</td>
<td>1,7 mil.</td>
<td>0.97</td>
<td>135,7</td>
</tr>
<tr>
<td>3</td>
<td>2,8 mil.</td>
<td>2,4 mil.</td>
<td>0.96</td>
<td>135,3</td>
</tr>
</tbody>
</table>
Comparison of volumetric efficiencies – CFD vs. Experiment

- High pressure, high flow region – good alignment.
- Low pressure, low flow region – some differences in shape of efficiency contours.
- Possible reasons for difference -> alignment of the parts (static, dynamic), geometry differences, non-linear phenomena.
• **Less then 5 % difference** in flow between CFD and experiment (two analyzed OPs).

• **Good info. about geometry is important!**

• **Pump splitted to 5 leakage paths** -> analysis of contributions.

![Diagram of pump parts leakage](image)

**Pump 1 | Flow - CFD & experiment**

<table>
<thead>
<tr>
<th>Flow, Q, l/h</th>
<th>Measured - 5 bar; 5000 rpm</th>
<th>CFD - 5 bar; 5000 rpm</th>
<th>Measured - 10,5 bar; 7000 rpm</th>
<th>CFD - 10,5 bar; 7000 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>219,2</td>
<td>212,3</td>
<td>297,9</td>
<td>287,2</td>
</tr>
</tbody>
</table>

- **3,5 % difference**
- **4,0 % difference**

**Pump parts leakage equals to leakages over:**
- Inner Sphere
- Outer Sphere
- Axial gap
- 3d surface

**Leakage, Q_Leak, l/h**

- **Measured 5 bar; 5000 rpm**
  - 8,9
  - 6,2
- **CFD - 5 bar; 5000 rpm**
  - 3,2
  - 6,7
- **Measured 10,5 bar; 7000 rpm**
  - 16,1
  - 14,0
- **CFD - 10,5 bar; 7000 rpm**
  - 4,1
  - 10,2

**Notes:**
- Less than 5 % difference in flow between CFD and experiment (two analyzed OPs).
- Good info. about geometry is important!
- Pump splitted to 5 leakage paths -> analysis of contributions.
Motivation:

- Pressure pulsations -> source of noise, flow ripple, cause mechanical fatigue.
- Vacuum pressure in inlet -> can cause cavitation (low temp. oil).
- CFD allow to analyze some causes of pressure pulsations.
Pump 1 | Pressure – CFD

Contact / sealing lines

Pressure

Pressure

PSp Pressure

14.0
12.8
11.7
10.5
9.3
8.2
7.0
5.8
4.7
3.5
2.3
1.2
0.0

[bar]
6 regions with significant viscous losses.
Pump 2 | Measurements

Measured parameters:
- Inlet and outlet temperature
- Inlet and outlet pressure
- Flow
- Torque
- Rotational speed

Calculated parameters:
- Mechanical and hydraulic power
- Total, volumetric, mechanical efficiency
Pump 2 | Pressure, Wall shear - CFD

Time Step = 210
Shaft Angle = -360 [degree]
• CFD -> linear dependancy between wall speed and $\tau = \frac{F}{A} = \mu \frac{du}{dy}$

• Good alignment at low pressure (3 bar) over complete range of shaft speed.

• Higher pressures (10 and 20 bar) -> measured torques are higher especially at low rpm.
Conclusion / ideas for future studies

Pump 1 (COR200):
• Clearance in CFD model -> based on experience and some assumptions.
• Comparable values with measured flow / volumetric efficiency.
• Leakages over different regions were evaluated.
• Pulsations of the pressure field were analyzed – optimizations possible.

Pump 2 (COR600):
• Comparable volumetric efficiency (oil temp 30°C).
• Good alignment between CFD / experiment only for low pressures.

Main challenges:
• Complex model -> time consuming in comparison with other pump types (gerotor / ext. gear pump).
• Different geometry assumptions have to be used for different viscosities (water, high / low temp. oil)