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CFD simulations of Tumbling Multi Chamber (TMC) pump

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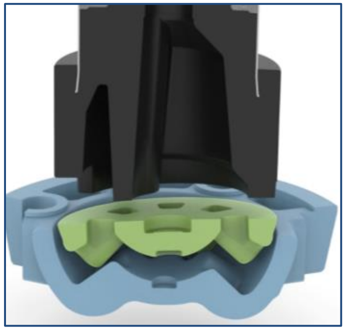
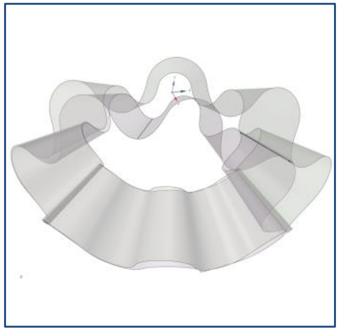
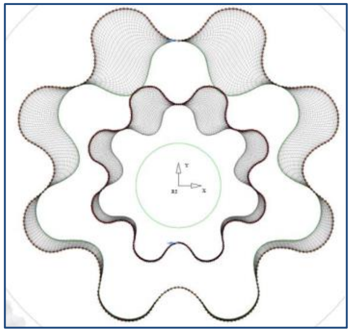
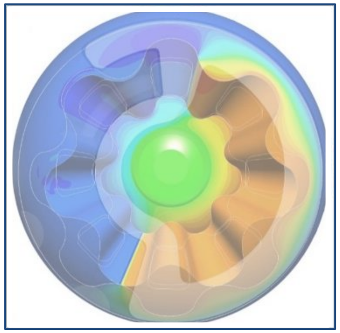
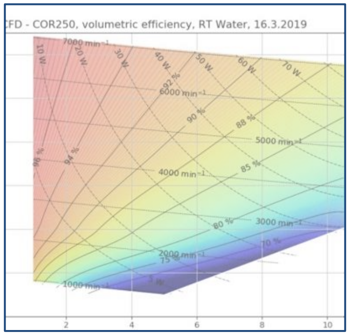
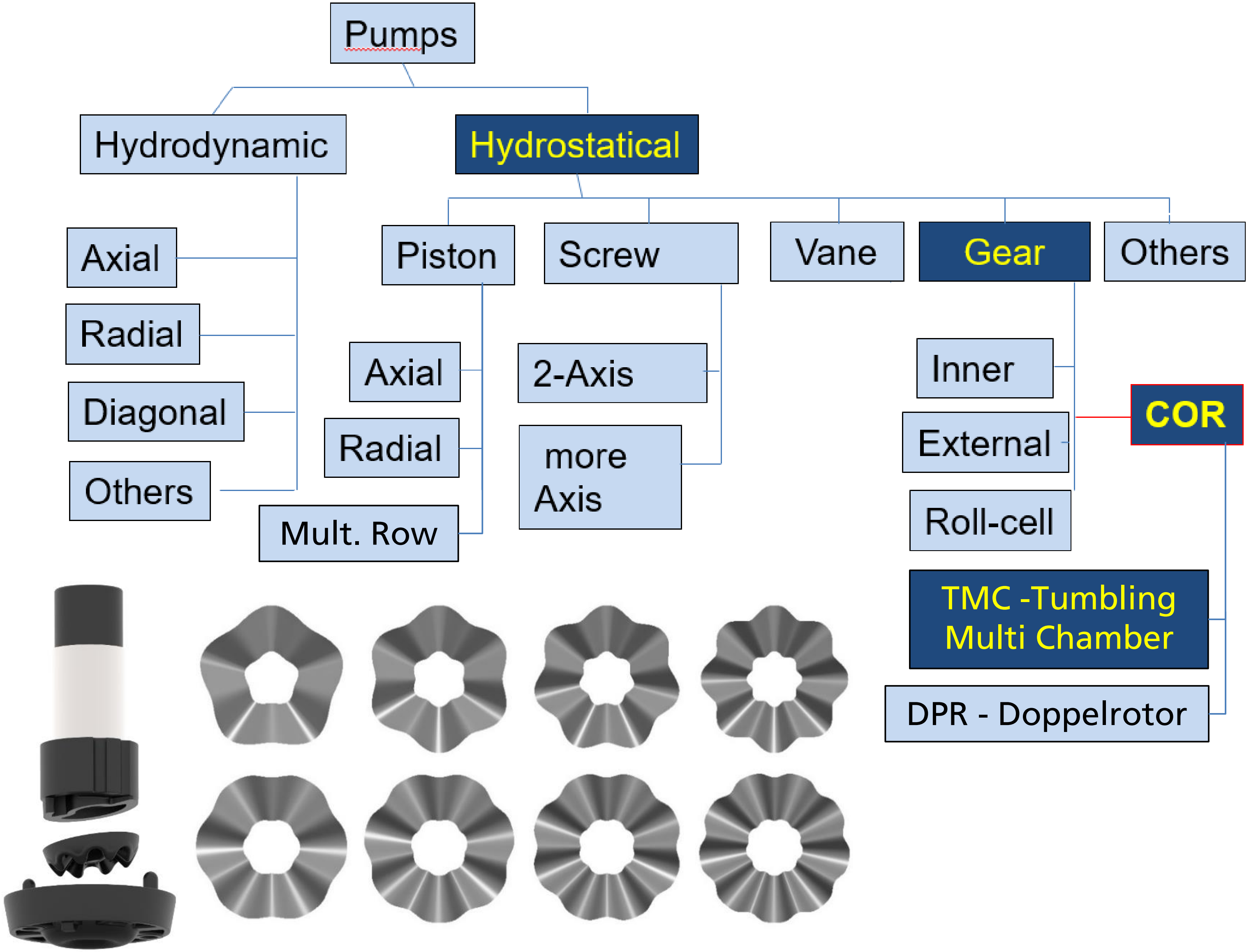
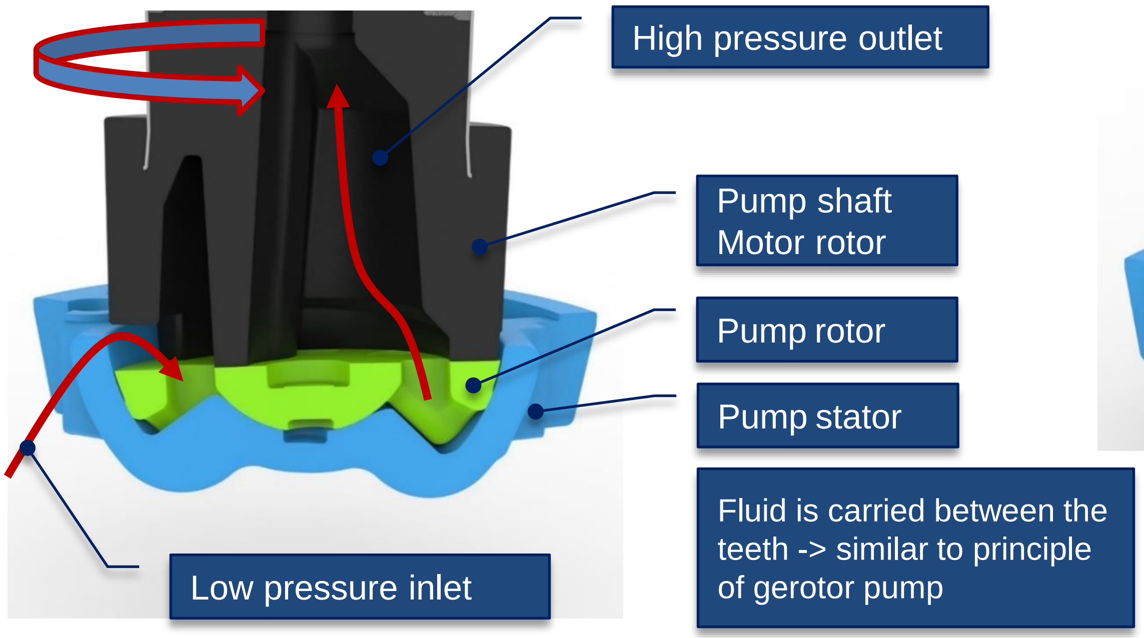






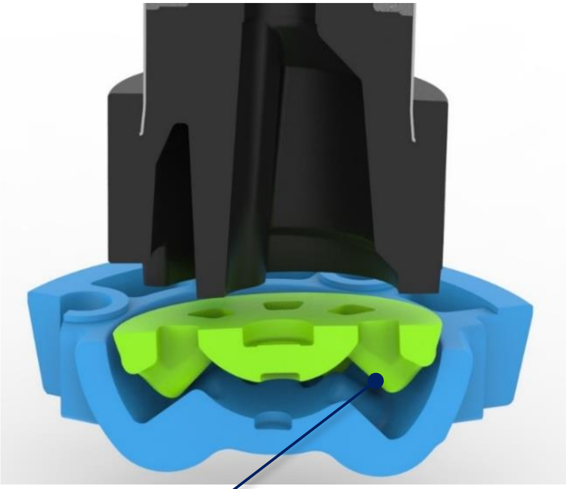
Tumbling Multi chamber pump | Classification

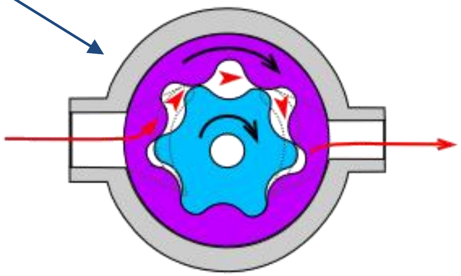


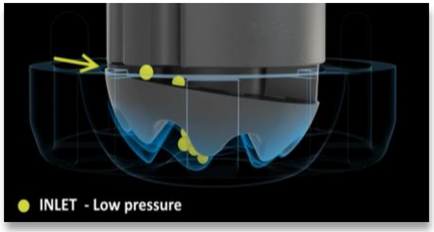
Tumbling Multi chamber pump | Working principle

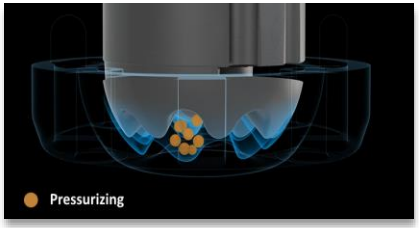
- 2 working parts with 3d trochoidal gear -> pump stator & rotor
- Number of teeth -> stator N, rotor N+1
- Transfer of the torque from the shaft via tilted sliding surface / valve plate
- Tumbling motion of the rotor causes compression / suction of the fluid

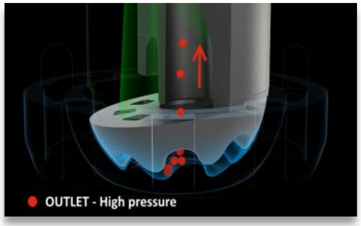












TMC pump | Motivation & goals

Pump 1 - COR200

Medium: **Water**
Displacement: 781 mm^3/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.

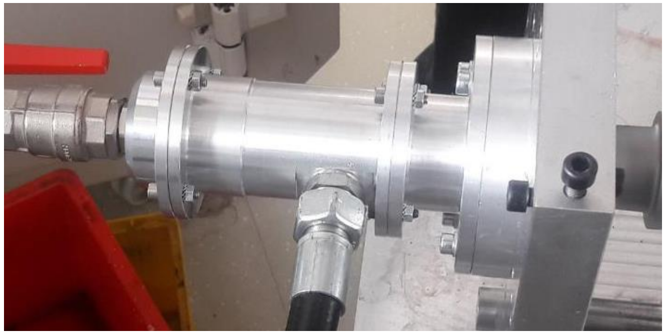
Pump 2 – COR600

Medium: **Transmission oil**
Displacement: 3000 mm^3/rev
Flow: more than **600 l/h**
Possible applications:

- Transmission / actuation / oil pump

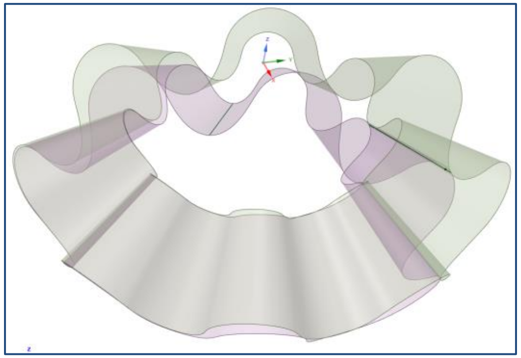
Simulation goals:

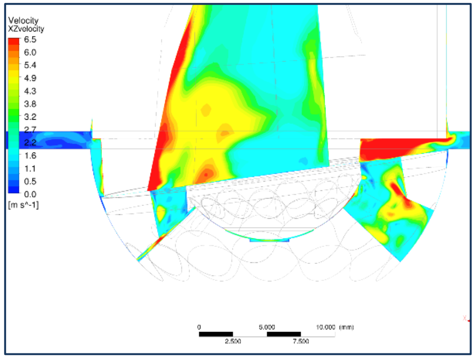
1. torque calculation,
2. viscous loss calculation,
3. efficiencies –> volumetric, mechanical, total.

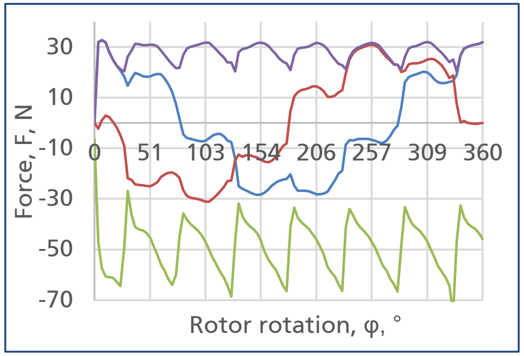


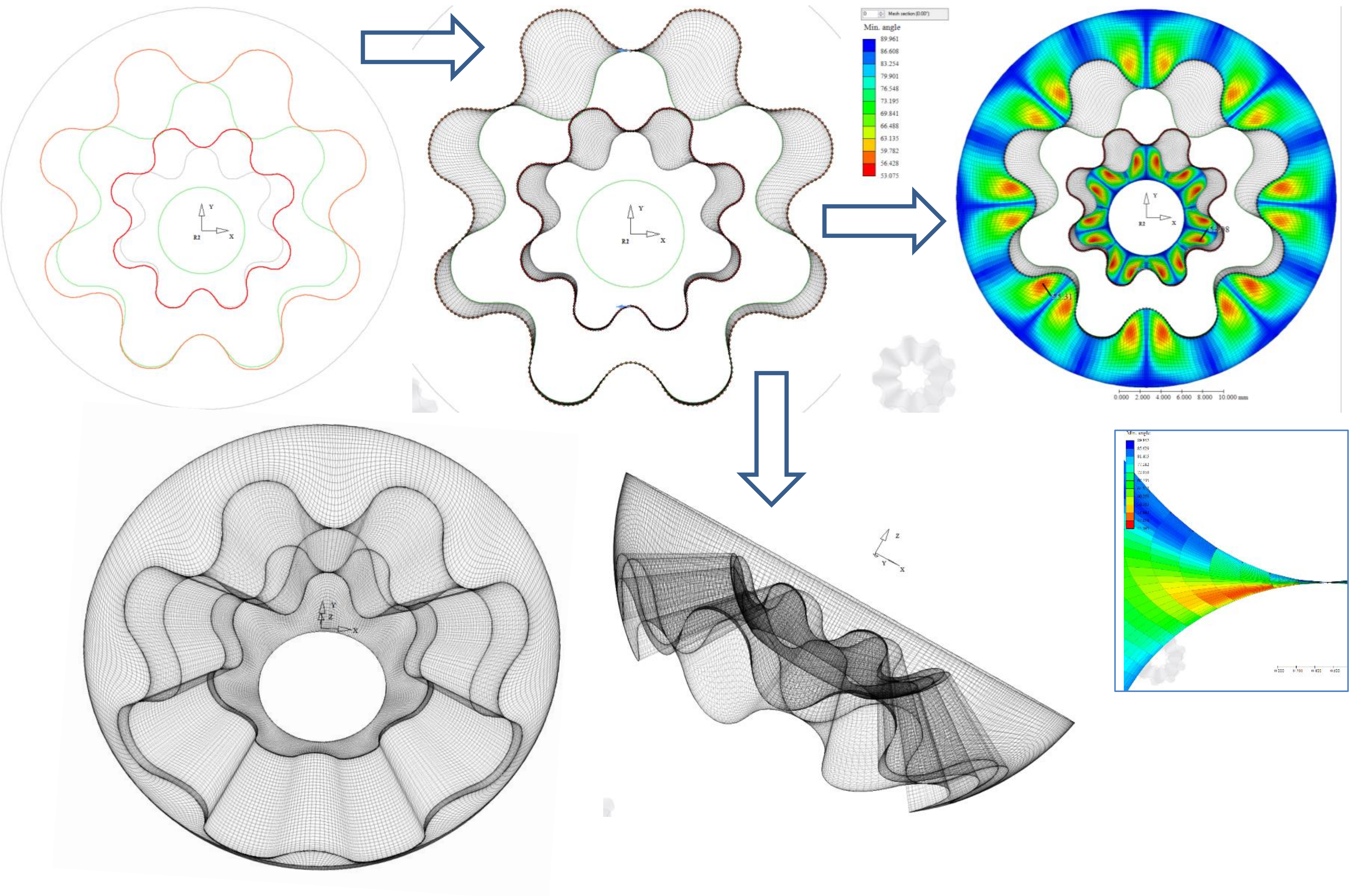
TMC pump | Analysis steps

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








Min. angle
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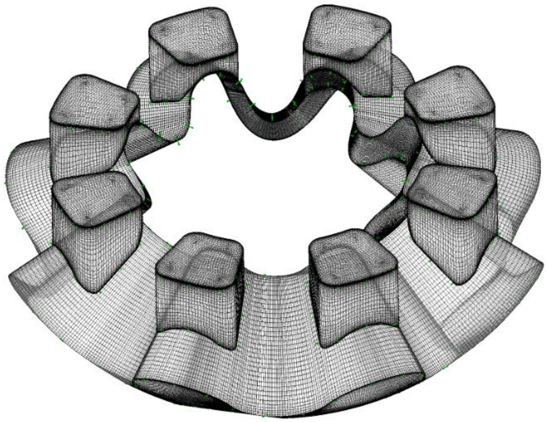
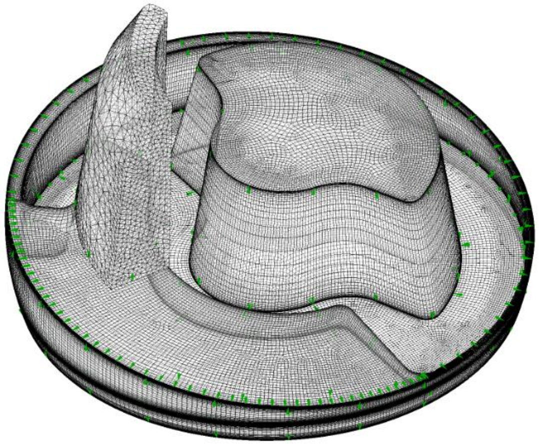
86.608
83.254
79.901
76.548
73.195
69.841
66.488
63.135
59.782
56.428
53.075
0.000 2.000 4.000 6.000 8.000 10.000 mm

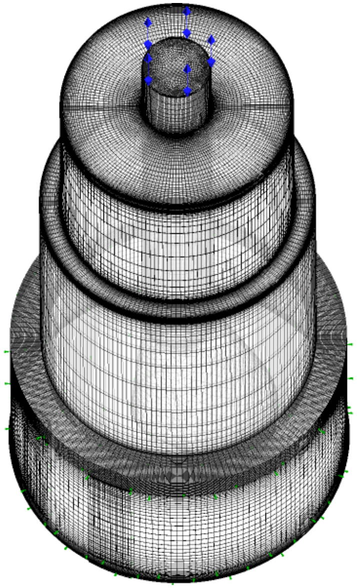
Pump 1 | Mesh components



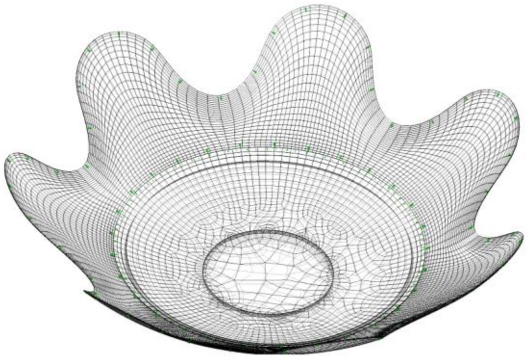
- Volume between 3d surfaces
- Holes in pump rotor



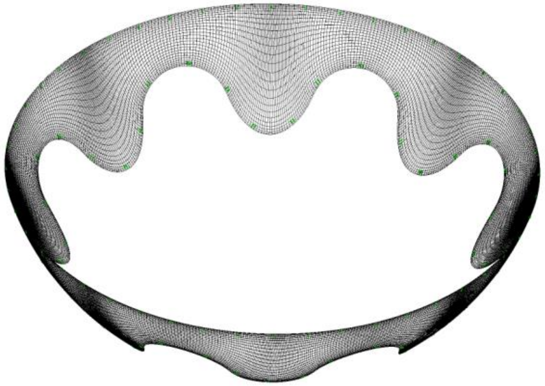
- Rotating geometry (part 1)



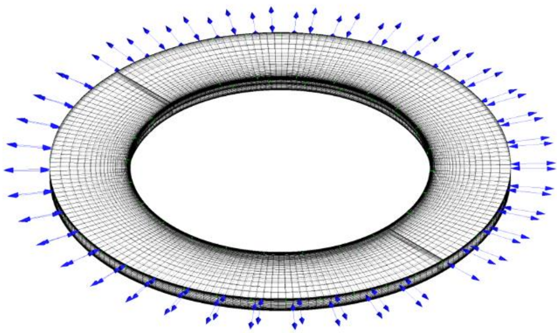
- Rotating geometry (part 2)



- Inner gap



- Outer gap



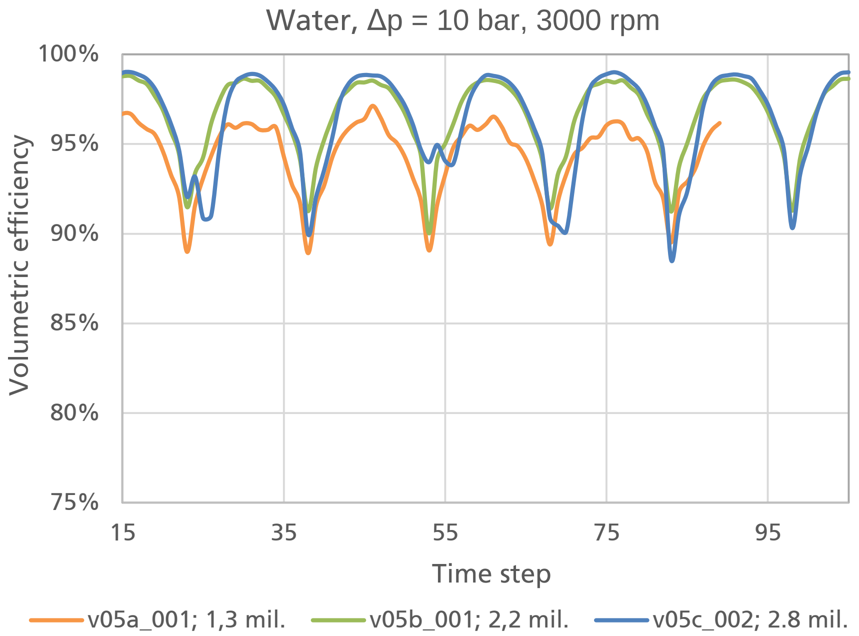
- Static inlet

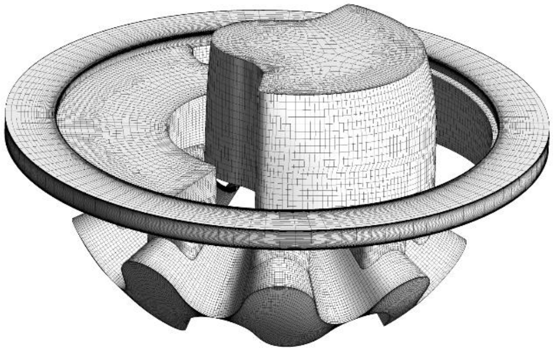
Pump 1 | Mesh independance check

Test of different mesh refinements in Twinmesh
-> finding of optimal mesh density.

Final results:

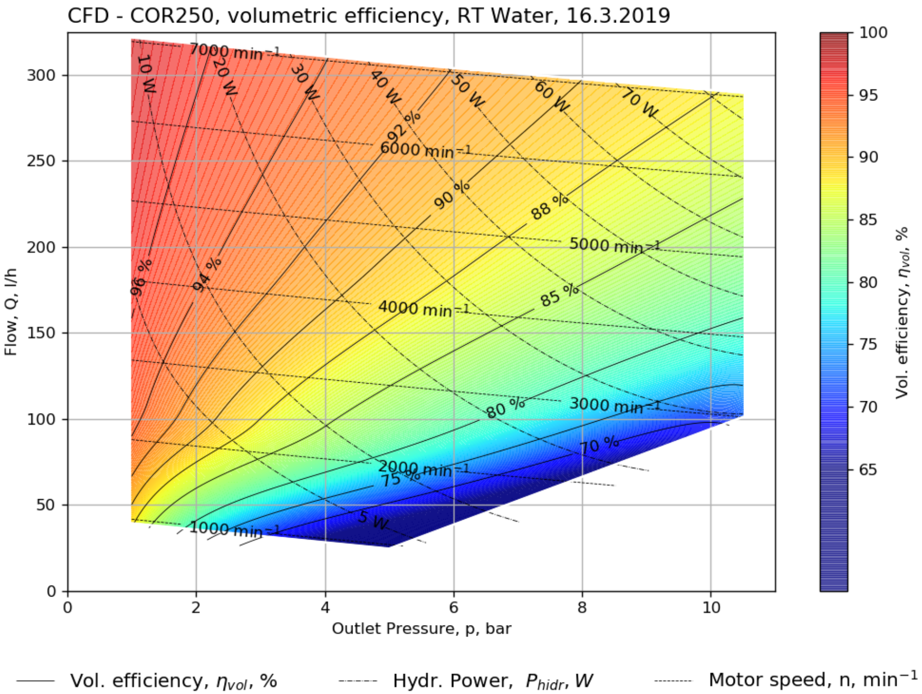
- Theoretical flow:
  - $n_{teor}(3000\, rpm) = 140,6 \frac{l}{h}$.
- Simulated flow (withouth small gaps):
  - $n_{sim}(3000 \text{ rpm}, 0 \text{ bar}) \approx 140{,}0 \frac{\text{l}}{\text{h}}$.
  - $n_{sim}(3000 \text{ rpm}, 10 \text{ bar}) \approx 135{,}7 \frac{\text{l}}{\text{h}}$.
- Simulated flow ripple:
  - 0 bar: 8 l/h (5,8 %)
  - 10 bar: 9,2 l/h (7,3 %)

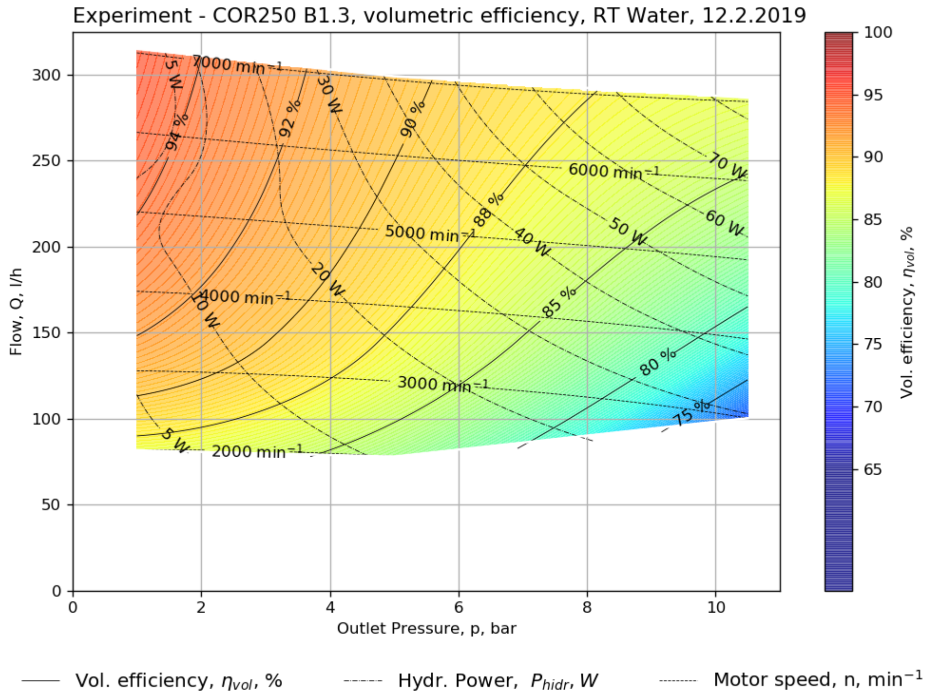




Run	Nr. of elements	Nr. of elements (R1.cfx5)	Avg. η_vol	Flow Q, l/h
1	1,3 mil.	780k	0,94	132,6
2	2,2 mil.	1,7 mil.	0,97	135,7
3	2,8 mil.	2,4 mil.	0,96	135,3

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.

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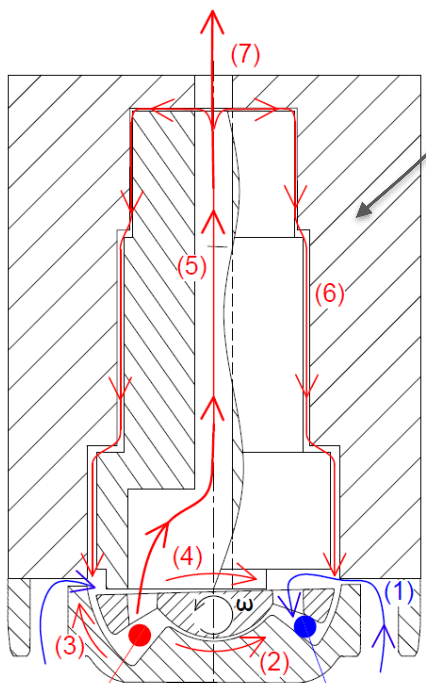
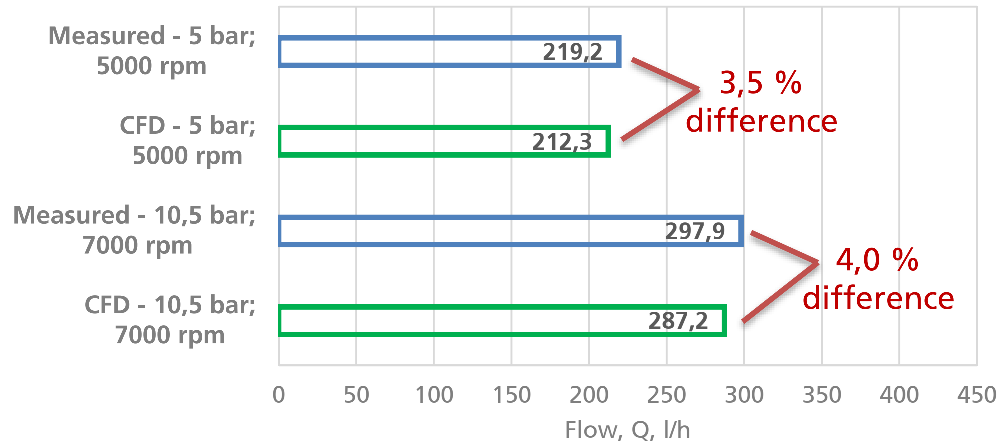
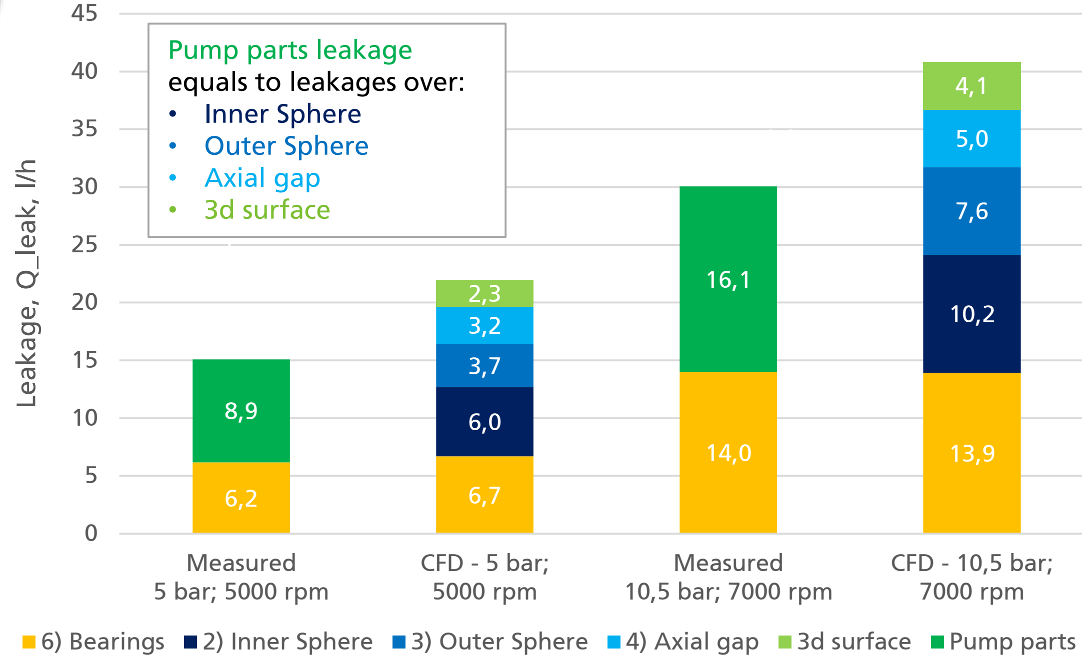
Pump 1 | Flow - CFD & experiment

- **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.

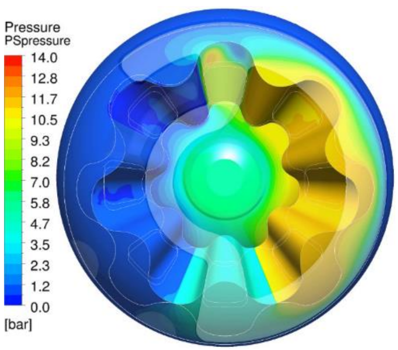


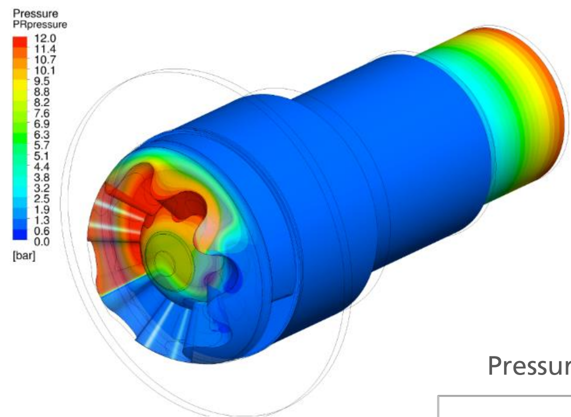


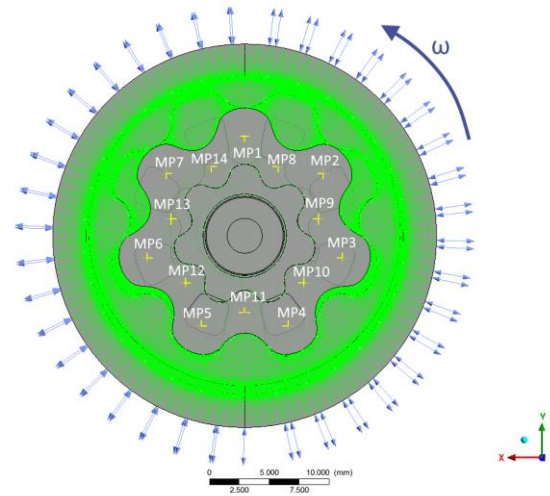


Pump 1 | Pressure – CFD

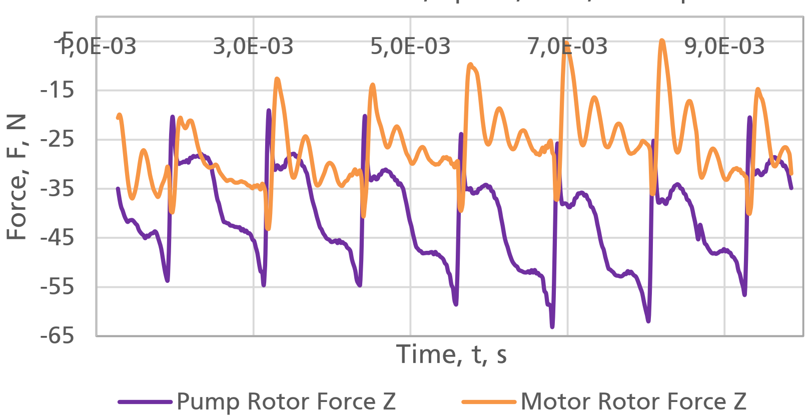
- **Motivation:**
  - pressure pulsations -> source of noise, flow ripple, cause mechanical fatigue.
  - Vacuum pressure in inlet -> can cause cavitation (low temp. oil).
  - CFD allow to analyze some causes of pressure pulsations.



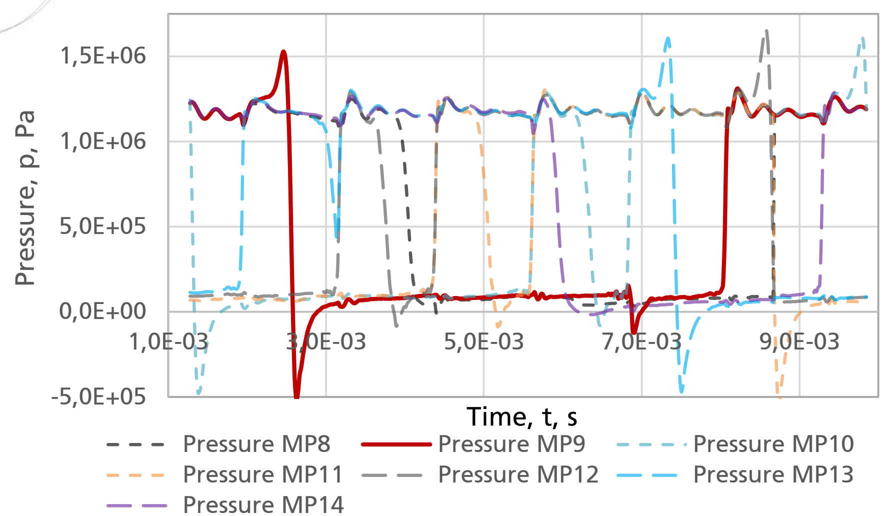




Z-Force - PR and MR, Δp=10,5 bar, 7000 rpm



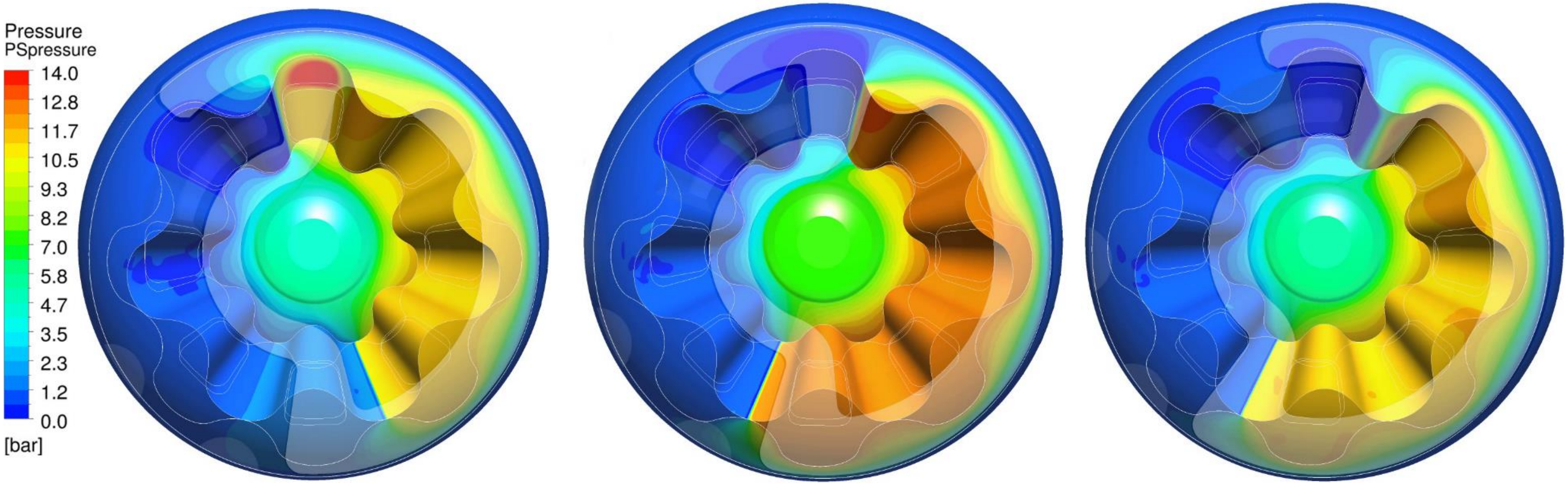
Pressure - points on PS, Δp=10,5 bar, 7000 rpm



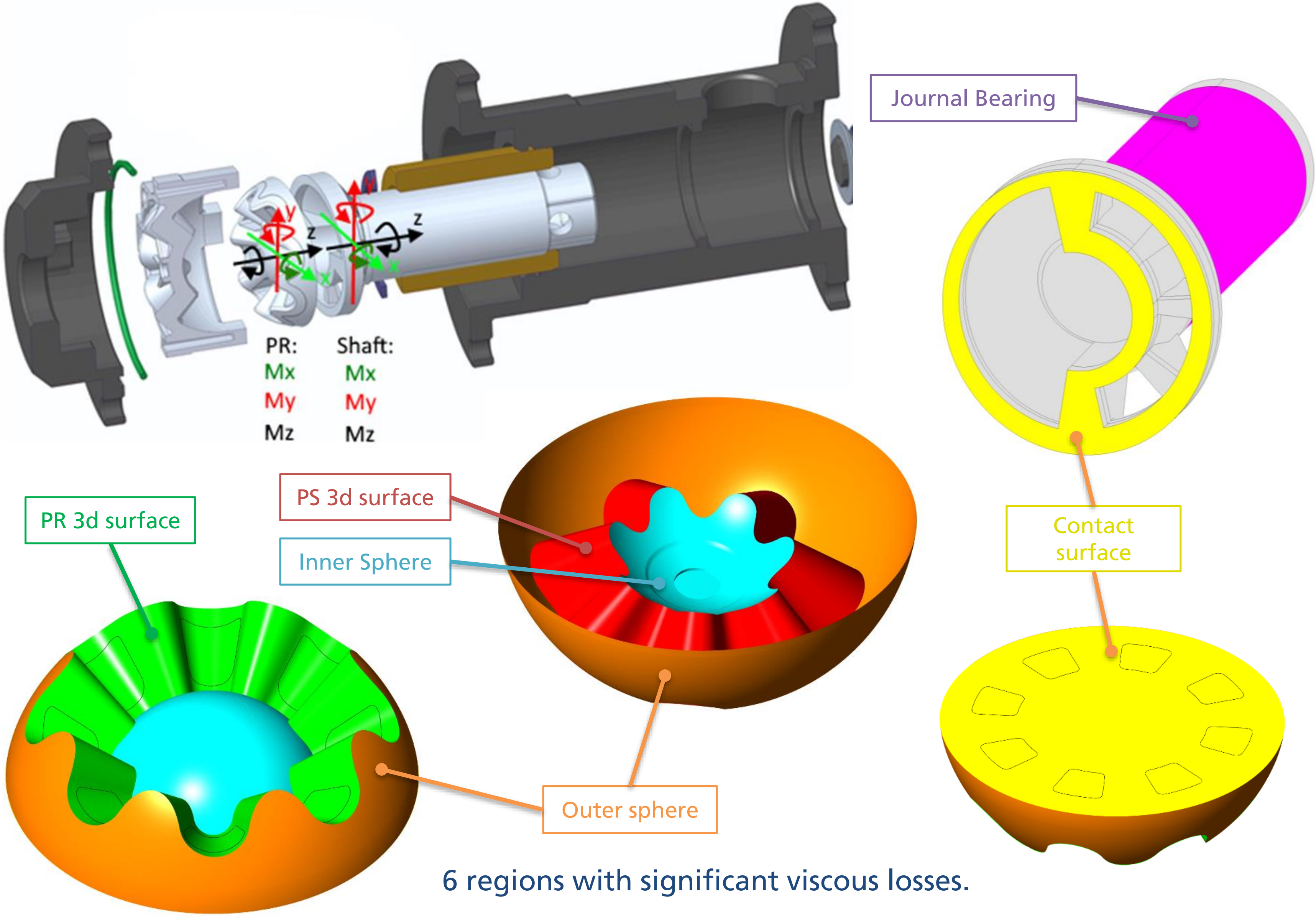
Pump 1 | Pressure – CFD

Contact / sealing lines

Pressure



Pump 2 | Overview



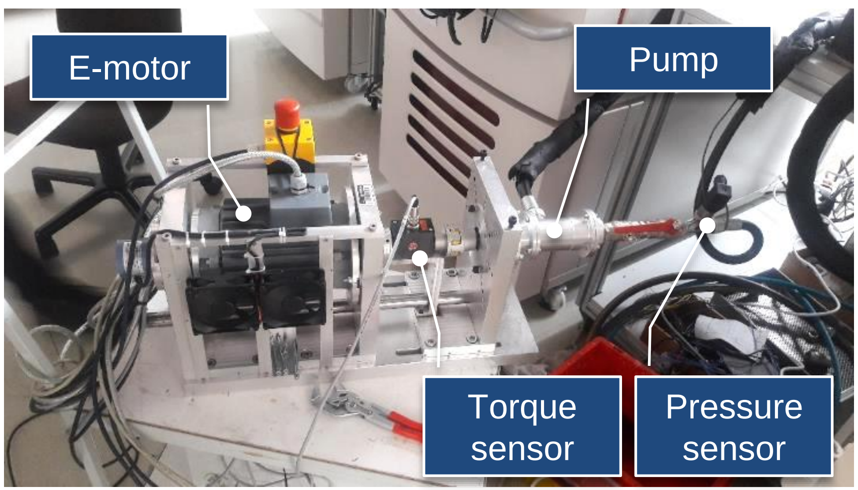
6 regions with significant viscous losses.

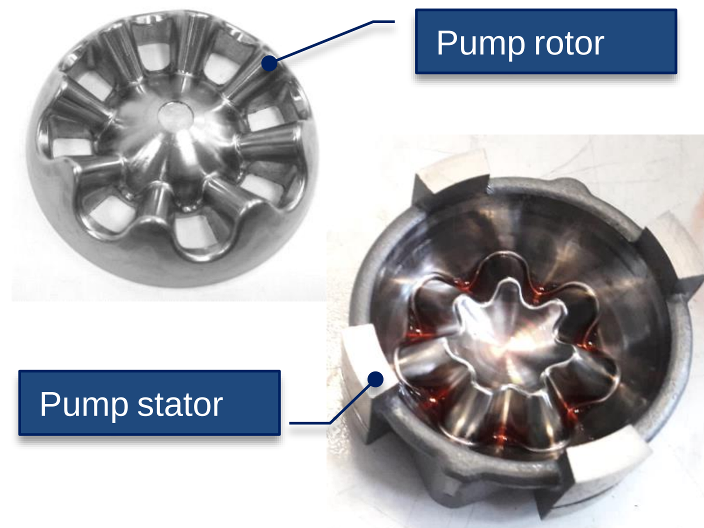
Measured parameters:

- Inlet and outlet temperature
- Inlet and outlet pressure
- Flow
- Torque
- Rotational speed

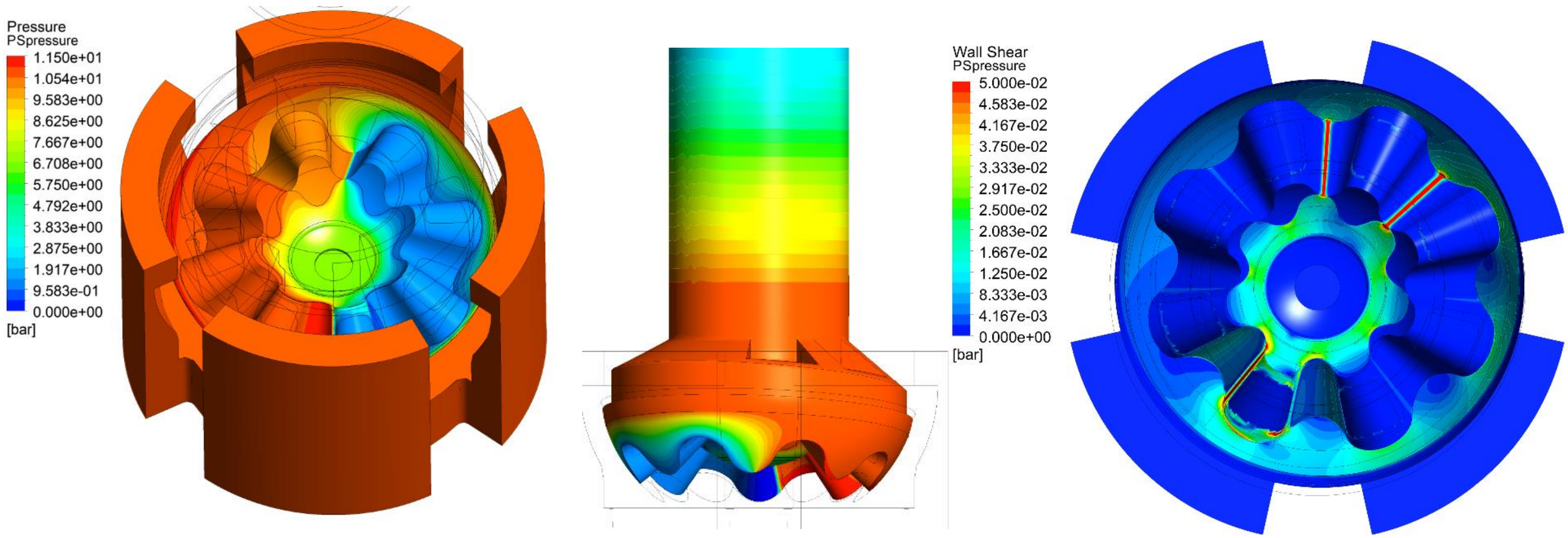
Calculated parameters:

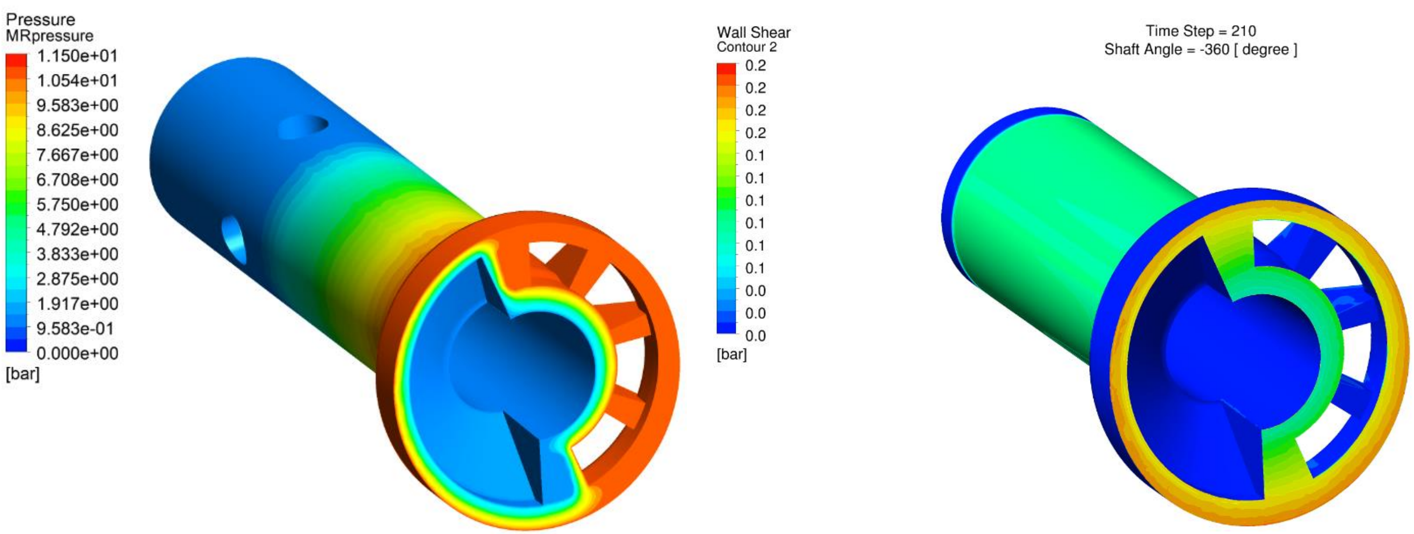
- Mechanical and hydraulic power
- Total, volumetric, mechanical efficiency



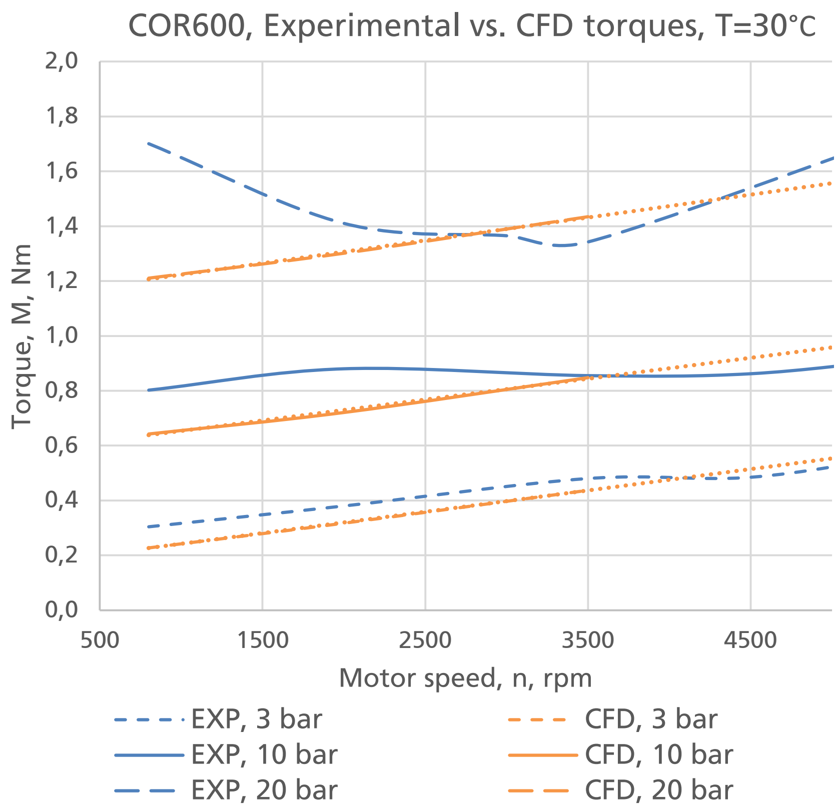


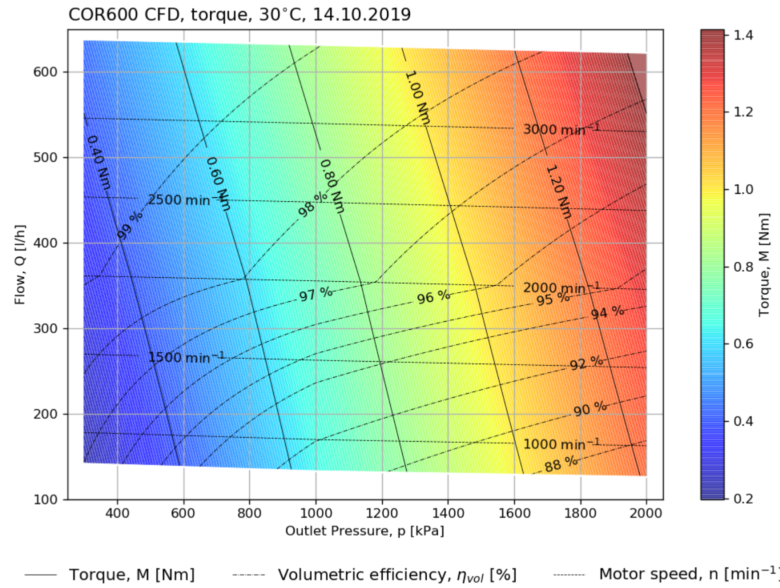
Pump 2 | Pressure, Wall shear - CFD

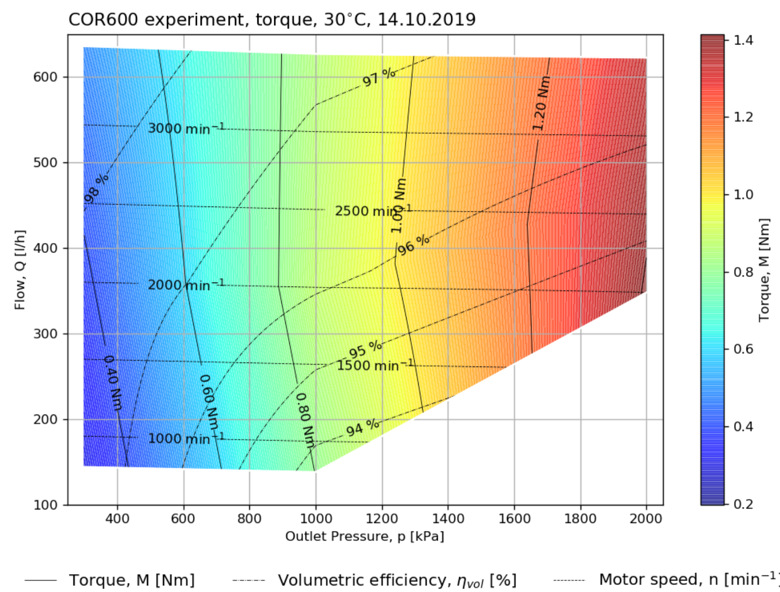




Pump 2 | - CFD & experiment







- CFD -> linear dependancy between wall speed and viscous losses.

$$\tau = \frac{F}{A} = \mu \frac{du}{dy}$$

- Good alignment at low pressure (3 bar) over complete range of shaft speed.
- Higher pressures (10 and 20 bar) -> measured torques are higher especcialy 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)