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Simulating Cavitation Effects in High Performance Piston Pumps with iconCFD

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Agenda

Introduction

iconCFD: Cavitation Modelling

iconCFD: Layer Addition and Removal

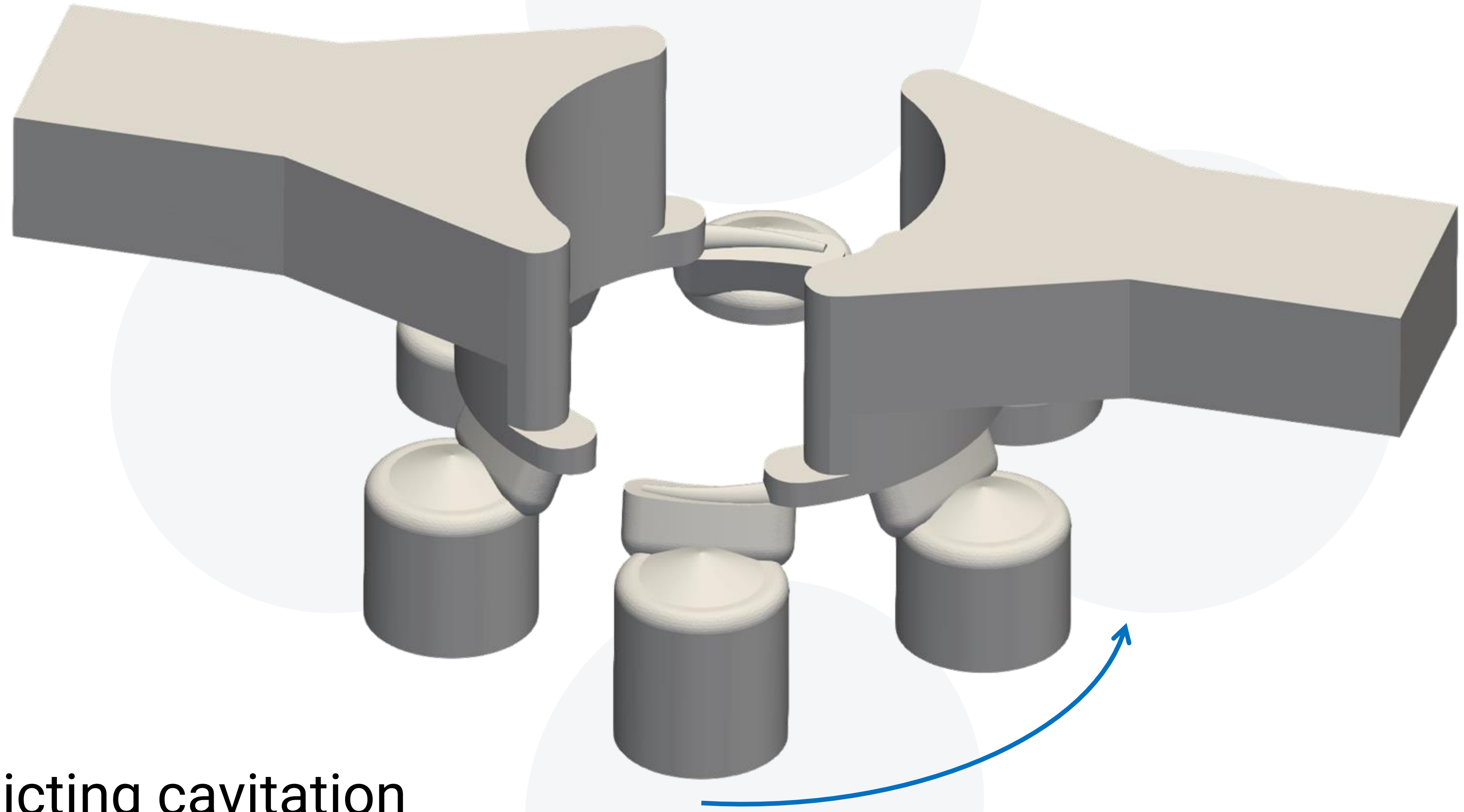
Results: Axial Piston Pump

Summary and Outlook

Introduction

High Performance Piston Pump Simulation

- Cavitation
  - Formation and collapse of vapor bubbles
  - Impacts pump performance, efficiency, and durability
- New advanced modelling tools in iconCFD V5 for simulating cavitating flows in pumps:
  - Dynamic mesh cavitation solver with different phase change models for predicting cavitation
  - Cell layer addition and removal for high mesh quality
- Simulation results shown on generic axial piston pump geometry



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Cavitation Solver

- Cavitation solver iconInterPhaseChangePisoFoam
  - 2 phase VOF solver with interface compression
  - Additional source terms for condensation and evaporation phase change effects
  - Dynamic mesh treatment supporting rigid movement, distortion and topological mesh changes

- Available cavitation models:
  - Schnerr-Sauer
  - Zwart
  - Singhal
  - Merkle
  - Kunz

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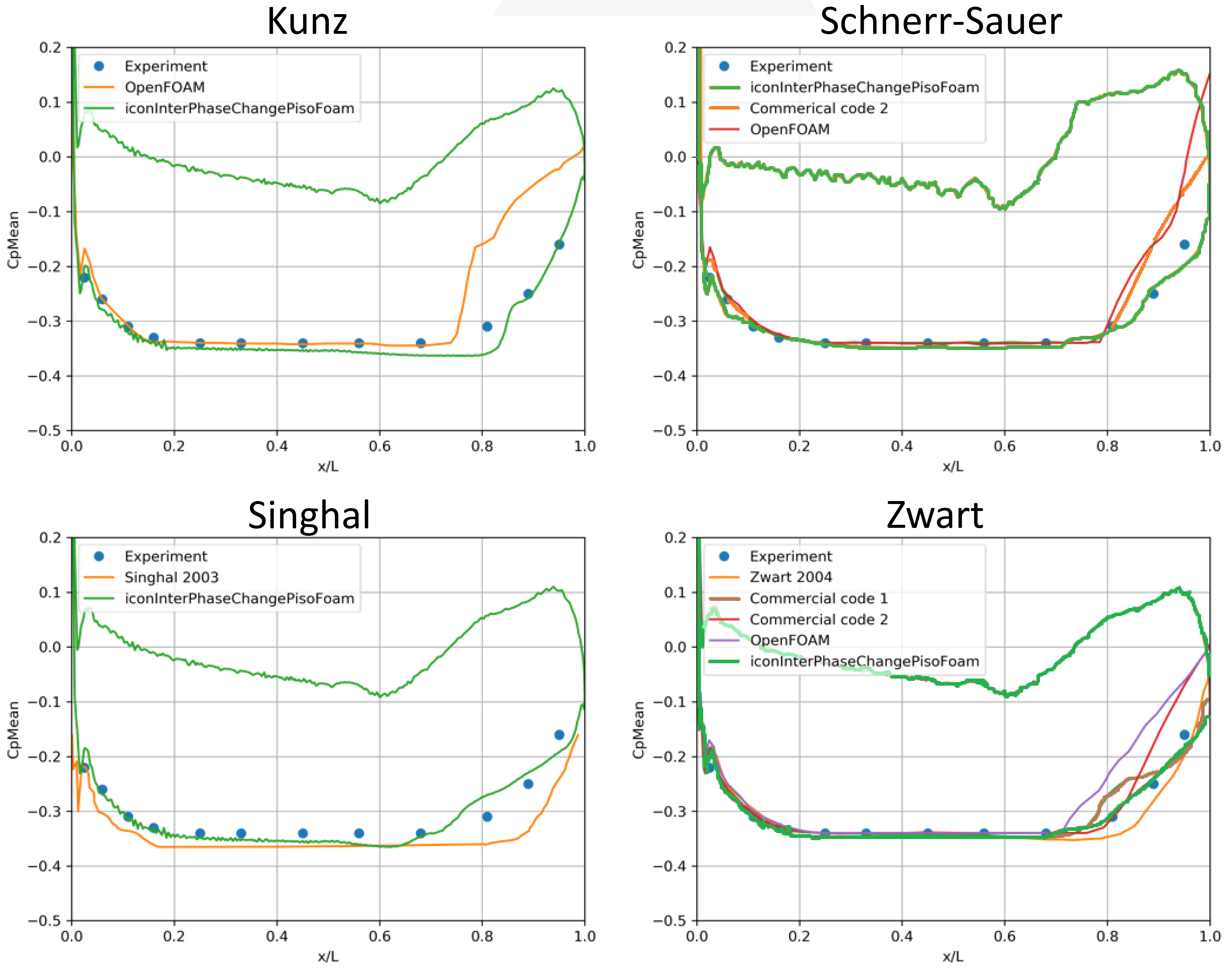
Cavitation Solver - Validation

- Validation on hydrofoil geometry
  - 2-D simulation of flow a NACA66(mod) hydrofoil
    (1º angle of attack, camber ratio: 0.02, mean line: 0.8, thickness ratio: 0.09)



"OpenFOAM", "Commercial code 1", and "Commercial code 2" from L. Hanimann et al., Cavitation modeling for steady-state CFD Simulations, 2016 *IOP Conf. Ser.: Earth Environ. Sci.* 49 092005
"Singhal 2003" denotes Singhal et al., Mathematical basis and validation of the full cavitation model, *JFE*, 2003.
"Zwart 2004" denotes Zwart et al., A two-phase flow model for predicting cavitation dynamics, *ICMF*, 2004.

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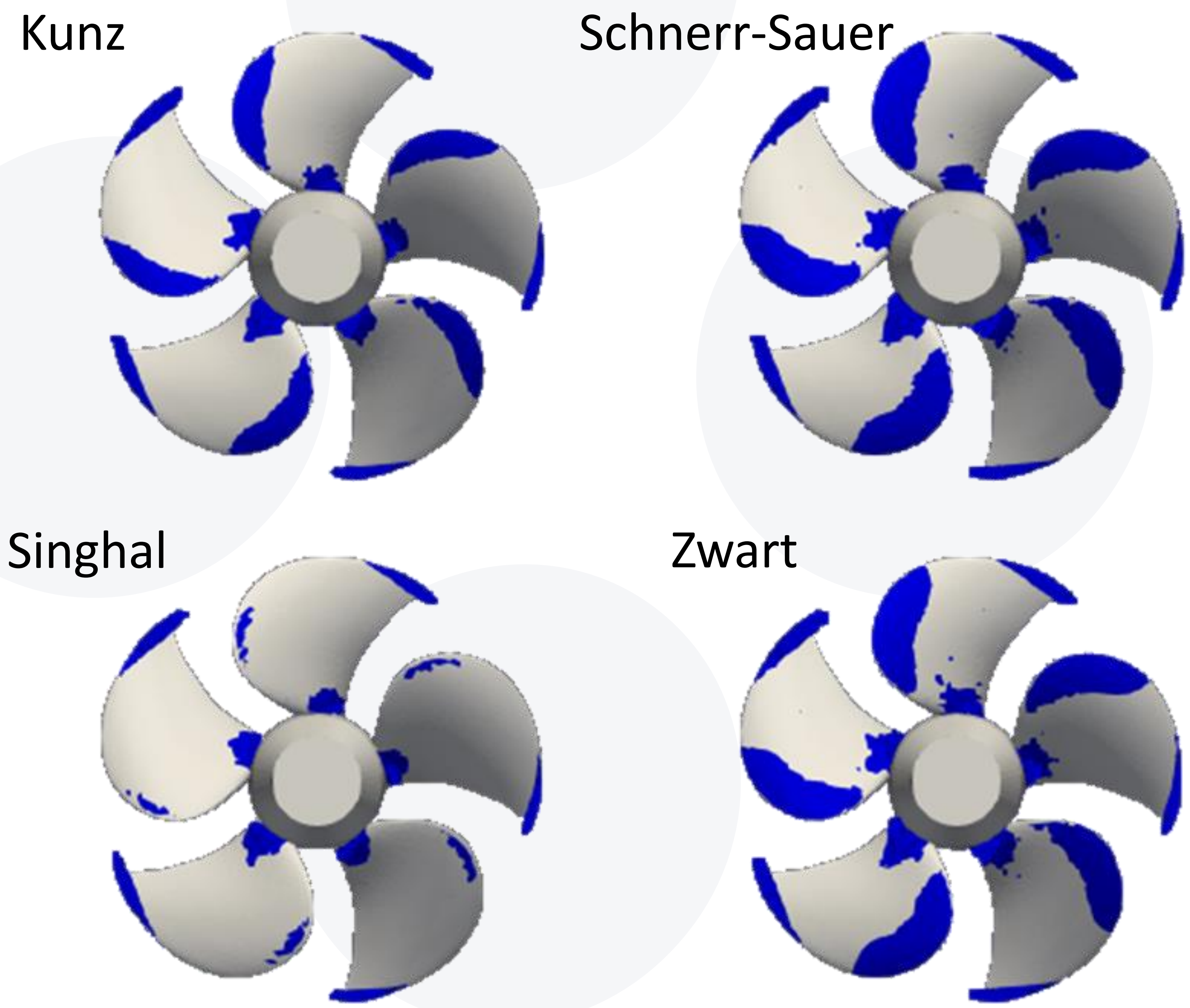
Cavitation Solver - Validation

- Validation on Potsdam Propeller Test Case (PPTC)
  - 5 blade generic controllable pitch propeller geometry used for validation and comparison

Experiment (left) and simulation (right) from L. Hanimann et al., Steady-state cavitation modeling in an open source framework: Theory and applied cases, 16th Int. Symp. on Transport Phenomena and Dynamics of Rotating Machinery, 2016



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Dynamic Mesh Treatment

- Axial piston pump motion
  - Rotating cylinders
  - Sinusoidal piston movement in cylinders
  - Variable displacement depending on swash plate angle

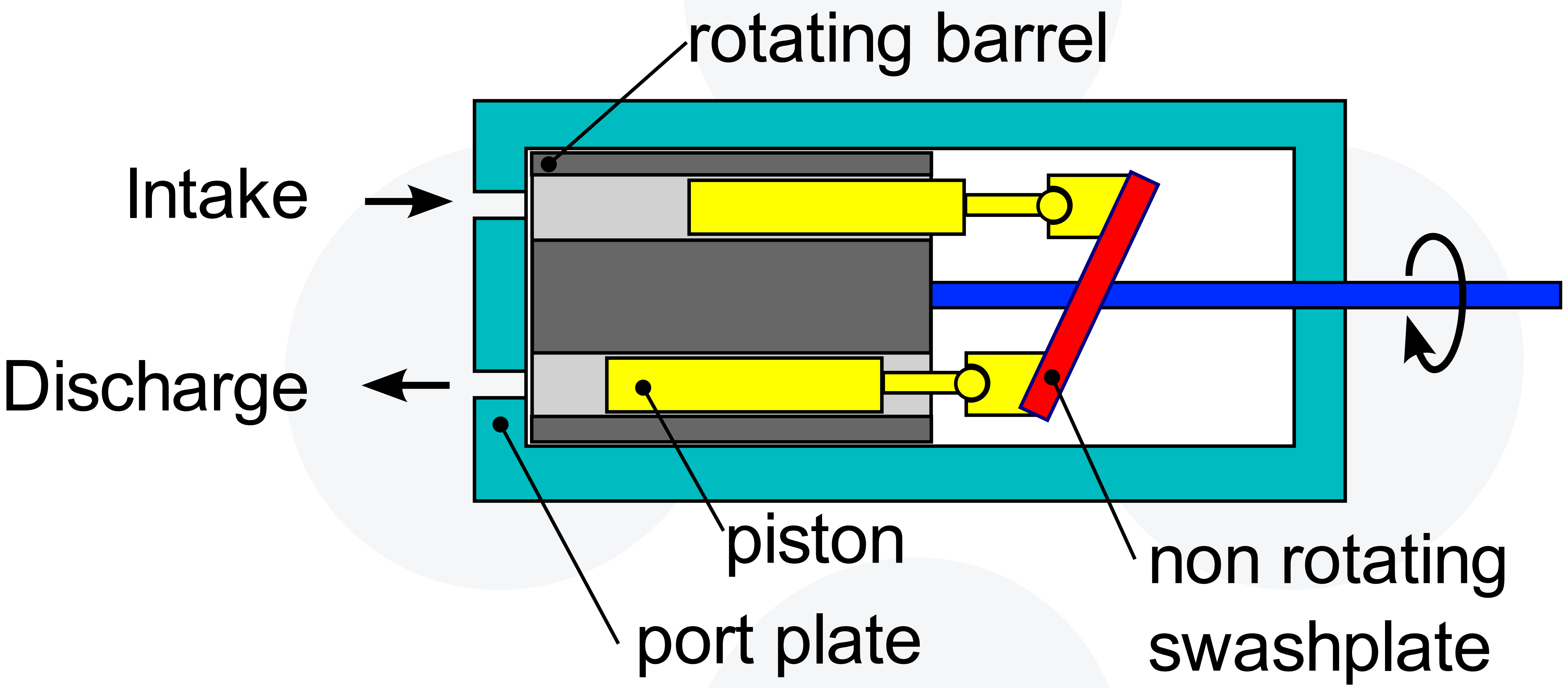
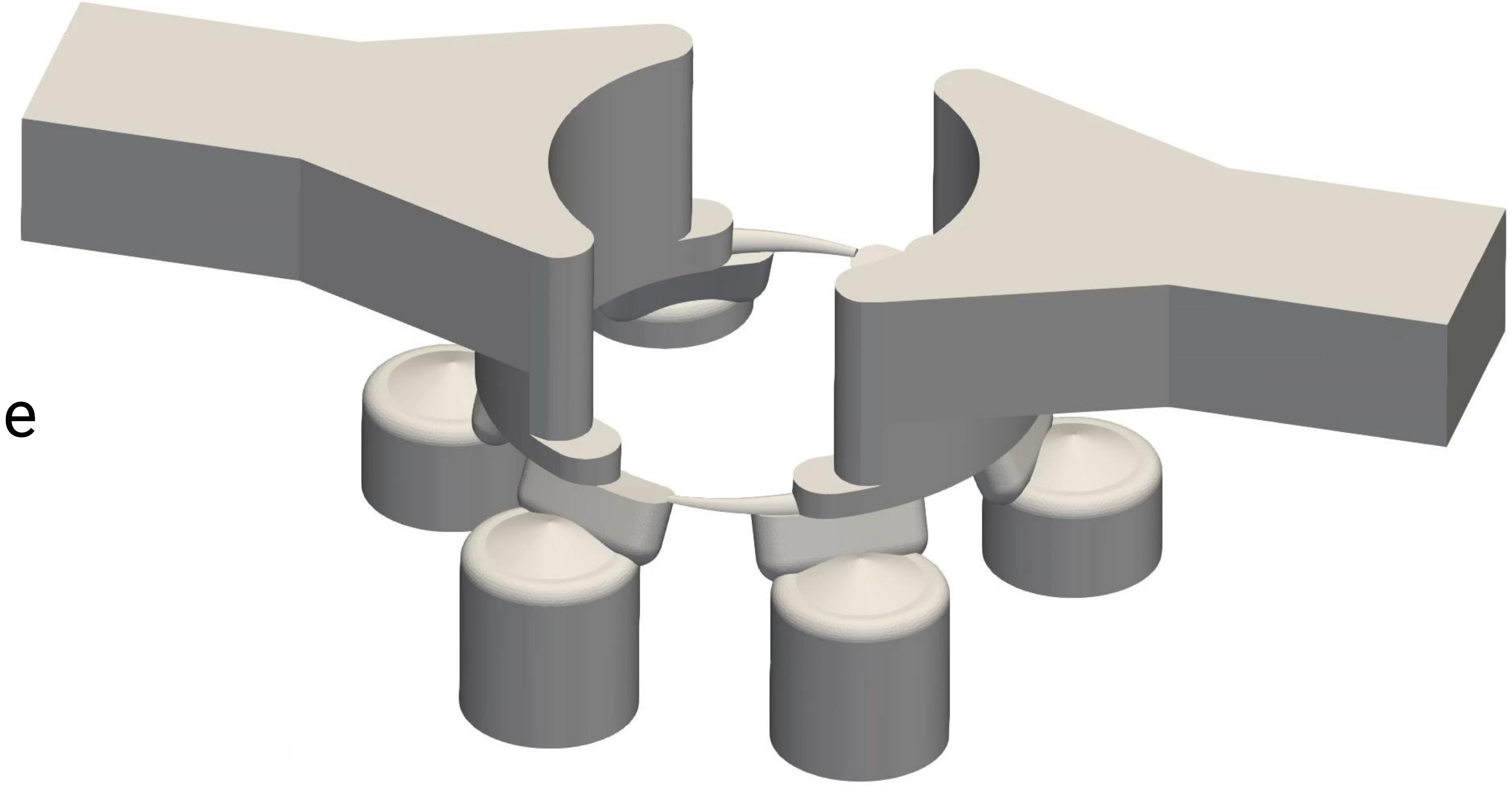


Image by Egmason (talk) (original image). Michael Frey (talk) (Labeling of the parts, changed color coding) - File:Axial piston pump.svg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=61619713

iconCFD V5

Layering Addition and Removal

- Axial piston pump motion
  - Rotating cylinders
  - Sinusoidal piston movement in cylinders
  - Variable displacement depending on swash plate angle
- Dynamic mesh model
  - Main rotation: rigid motion
  - Piston movement: rigid motion
  - Volume change: cell layer addition and removal
  - Connection to static inlet and outlet manifolds: ACMI interface



iconCFD V5

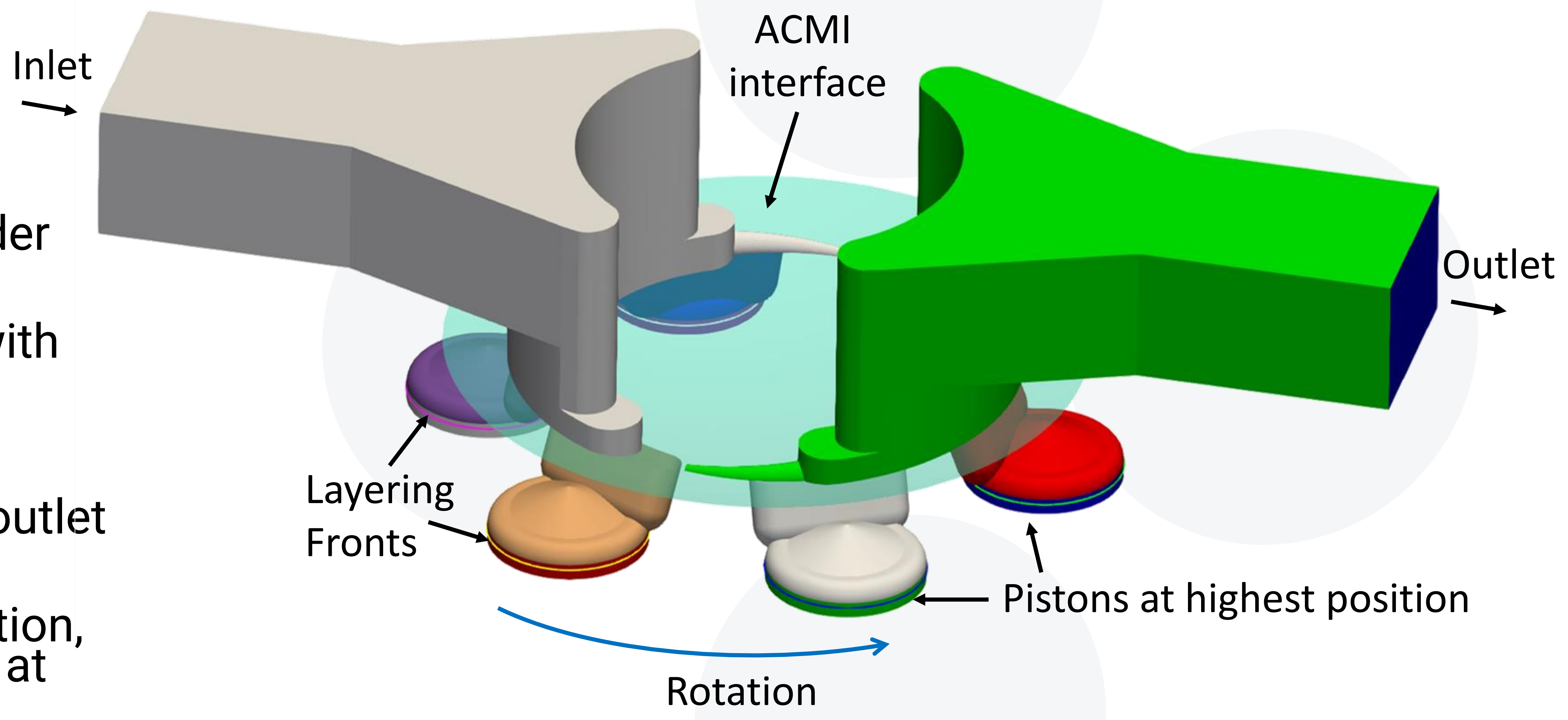
Layering Addition and Removal

- Layering Addition and Removal Set-up:
  - Define a layering front (group of connected faces at which cell layers will be added)
  - Minimum and maximum layer thickness control layer spacing
  - Provide initial mesh at smallest expected position
    - Will be moved to starting position at initialization
    - To ensure only cell layers are removed, which have been created by the layering model itself
- Layer spacing
  - Smallest position: no additional layers
  - First layer added: evens out any differences in total layer thickness
  - Next layers: uniform thickness between min and max thickness
  - Layer adjacent to front: only layer changing in thickness
    - Will be split into two layers if thickness goes above max thickness
    - Will be removed if thickness goes below min thickness

Results

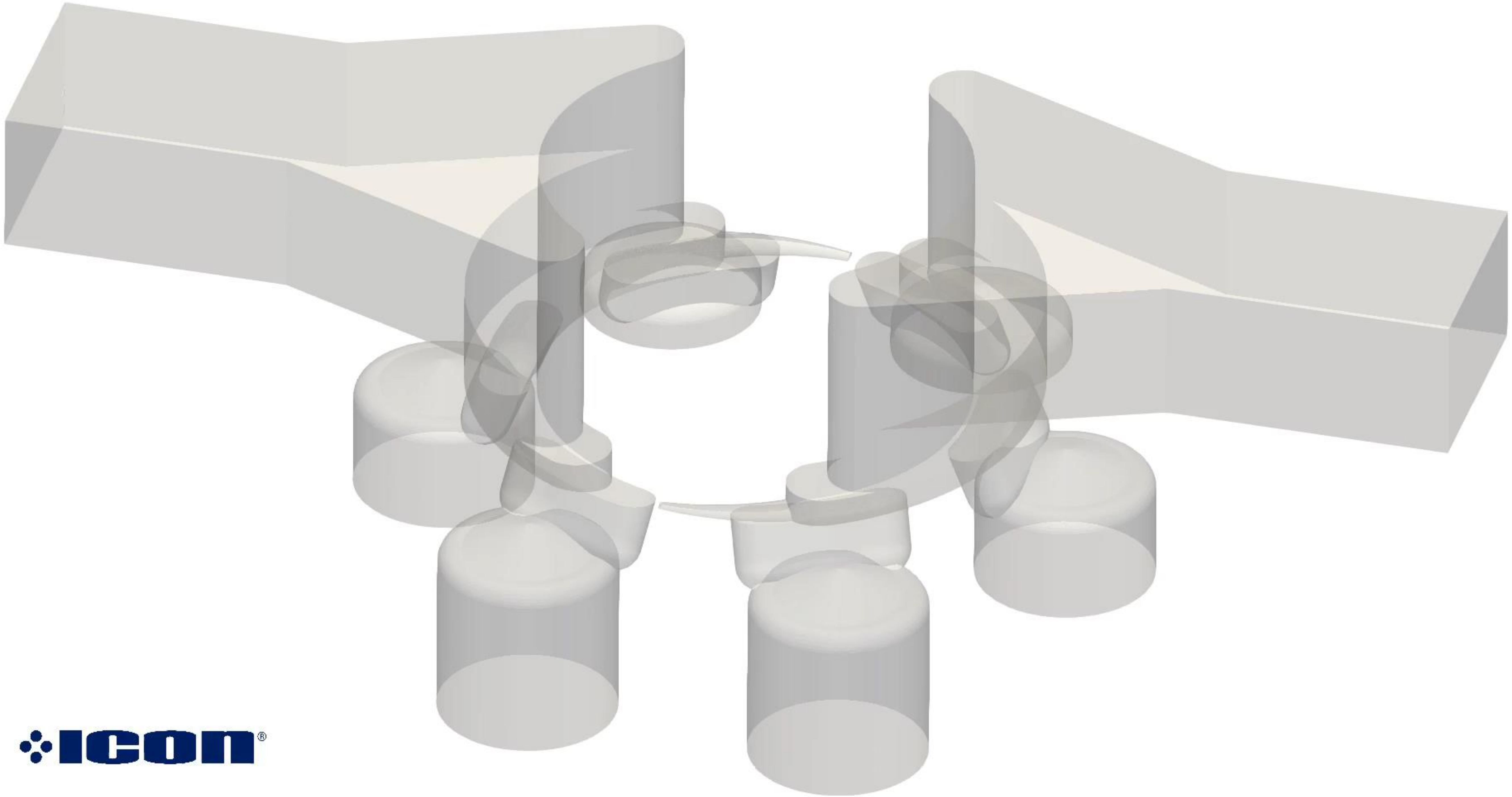
Axial Piston Pump – Geometry & Setup

- Generic axial piston pump with 6 cylinders rotating at 2000 RPM
- Single ACMI interface
- All pistons at top position
- Layering fronts between top of cylinder and piston
- 1.6 million cell initial mesh created with iconHexMesh
- Up to 27 layers per cylinder
- Total pressure BCs inlet (3 bar) and outlet (320 bar)
- Motion ramping during first half rotation, then simulating 2 more full rotations at speed
- Fluid: Oil
    - Density = 870kg/m^3
    - Kinematic viscosity = 0.6e-5m^2/s
    - Surface tension = 0.036 kg/s^2
- Zwart cavitation model



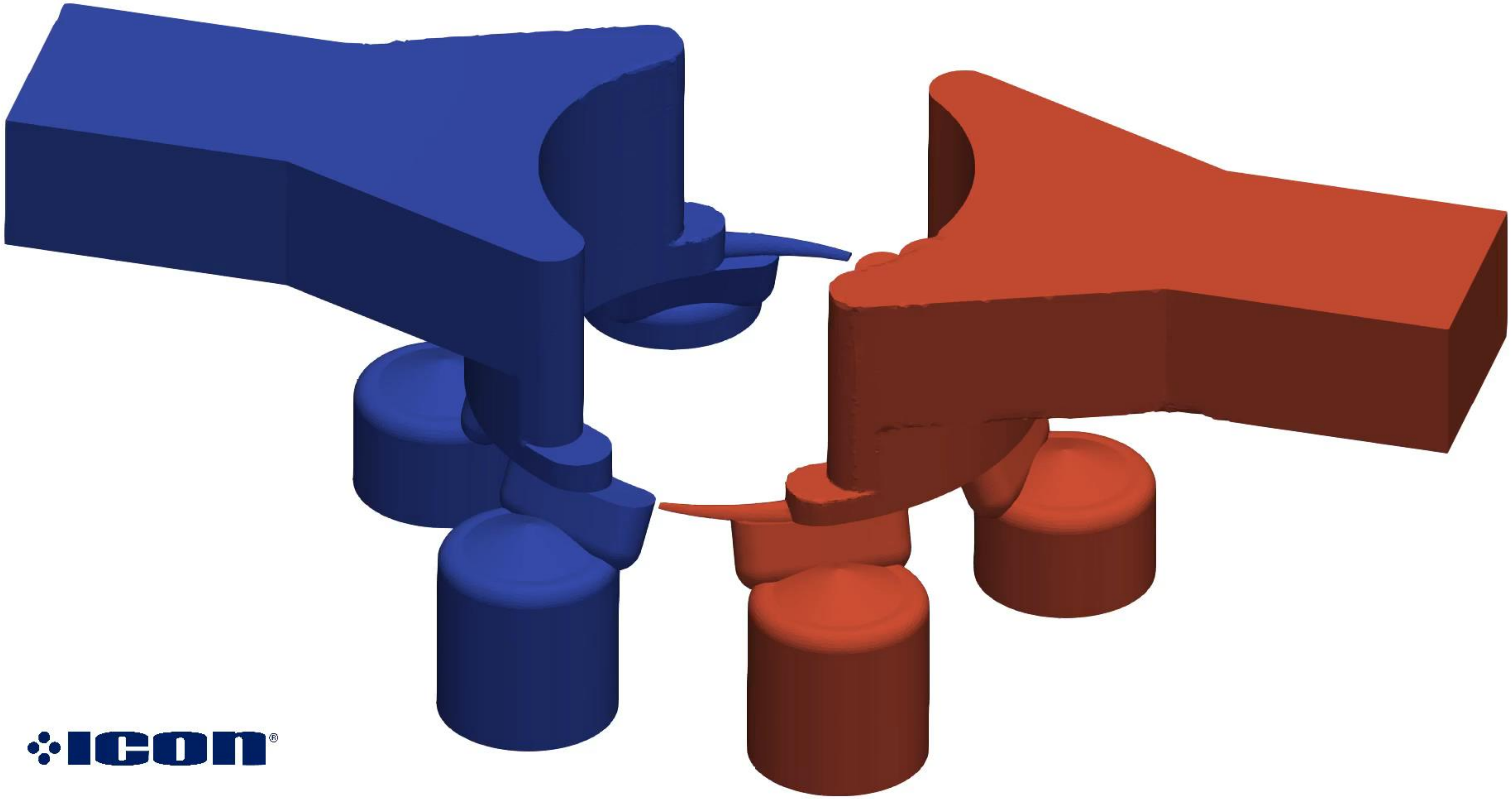
Results

Axial Piston Pump – Cavitation Bubbles



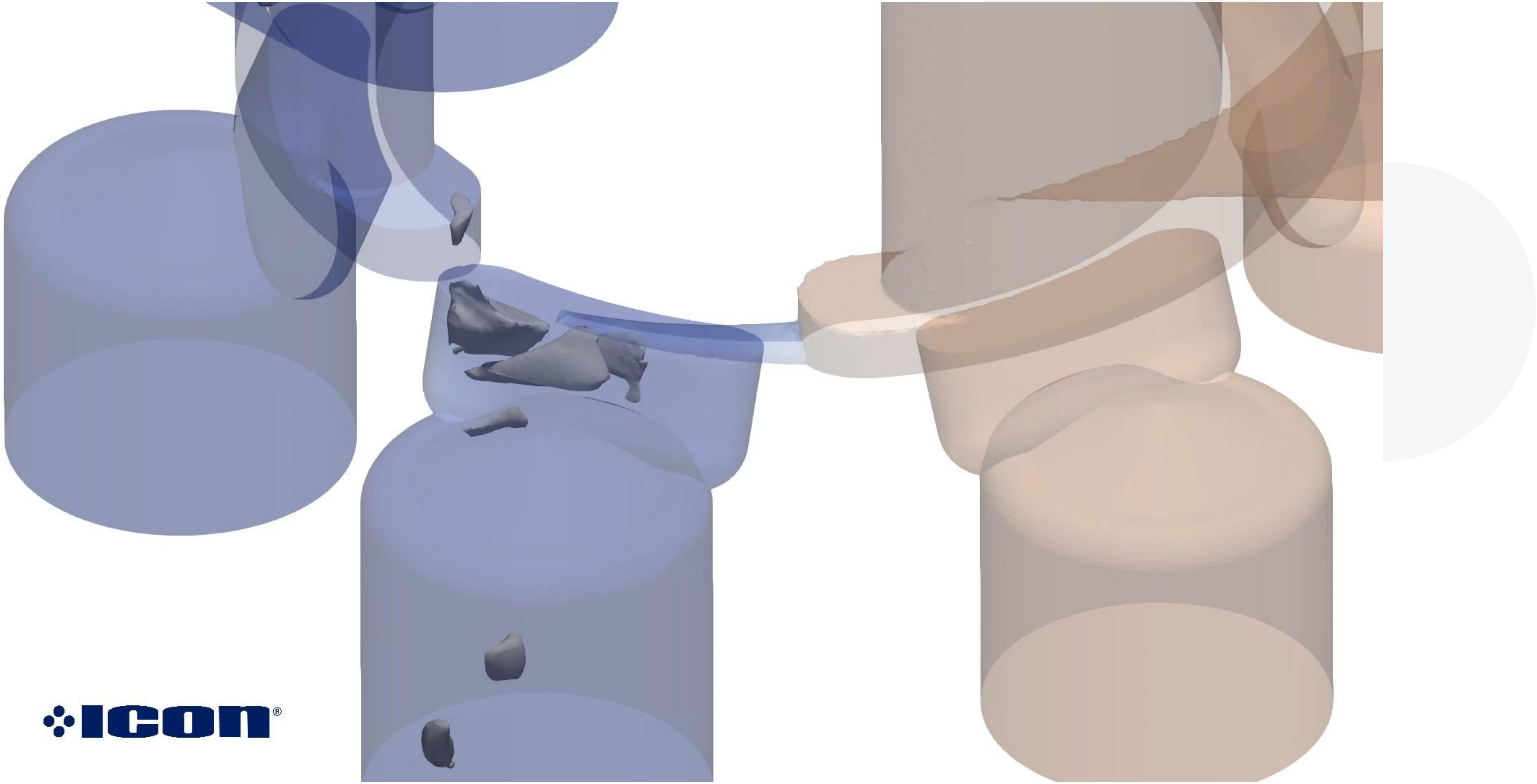
Results

Axial Piston Pump – Pressure Distribution



Results

Axial Piston Pump – Bubble Collapse



Summary & Outlook

- Summary
  - Simulation of cavitating flows in piston pumps using iconCFD v5.0
    - VOF cavitation solver to capture phase change effects
    - Layer addition and removal to model the deforming fluid space in the cylinders
    - Demonstrated by predicting cavitation bubbles in generic piston pump geometry

- Outlook
  - Stability improvements and fine tuning of cavitation models
  - Extending solver to consider aeration and gaseous cavitation effects
  - Erosion prediction model

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