CFD Simulation of a dry Scroll Vacuum Pump including Leakage Flows

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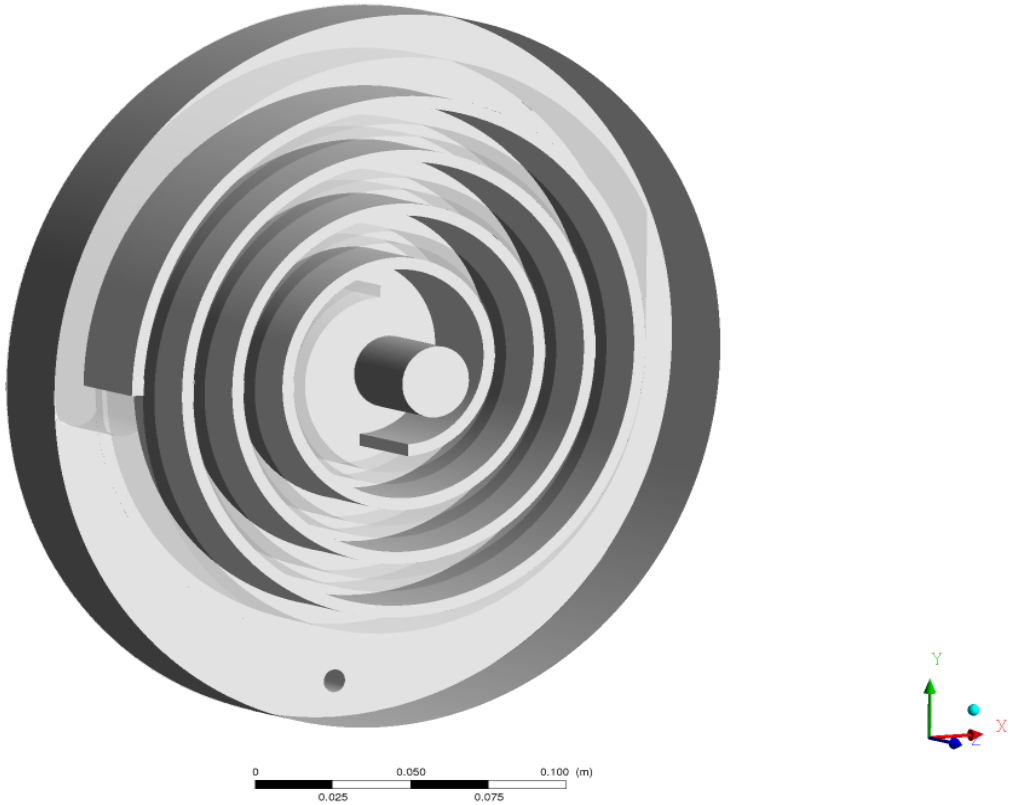
Introduction

- Numerical simulation results of a dry scroll vacuum pump (DSVP) in comparison to measurements of Li et al. (2010)
- Applications of a DSVP
  - In food industry for packing technology or freeze-drying
  - In metallurgy for degassing of melt or inside a coating line
  - In research vacuum technology is used for electron microscopes or mass spectrometer



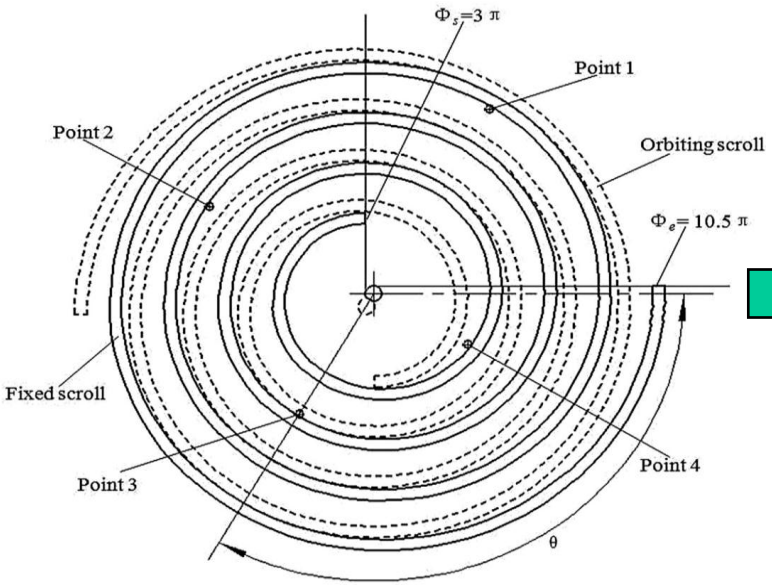
View into the working chamber of a DSVP

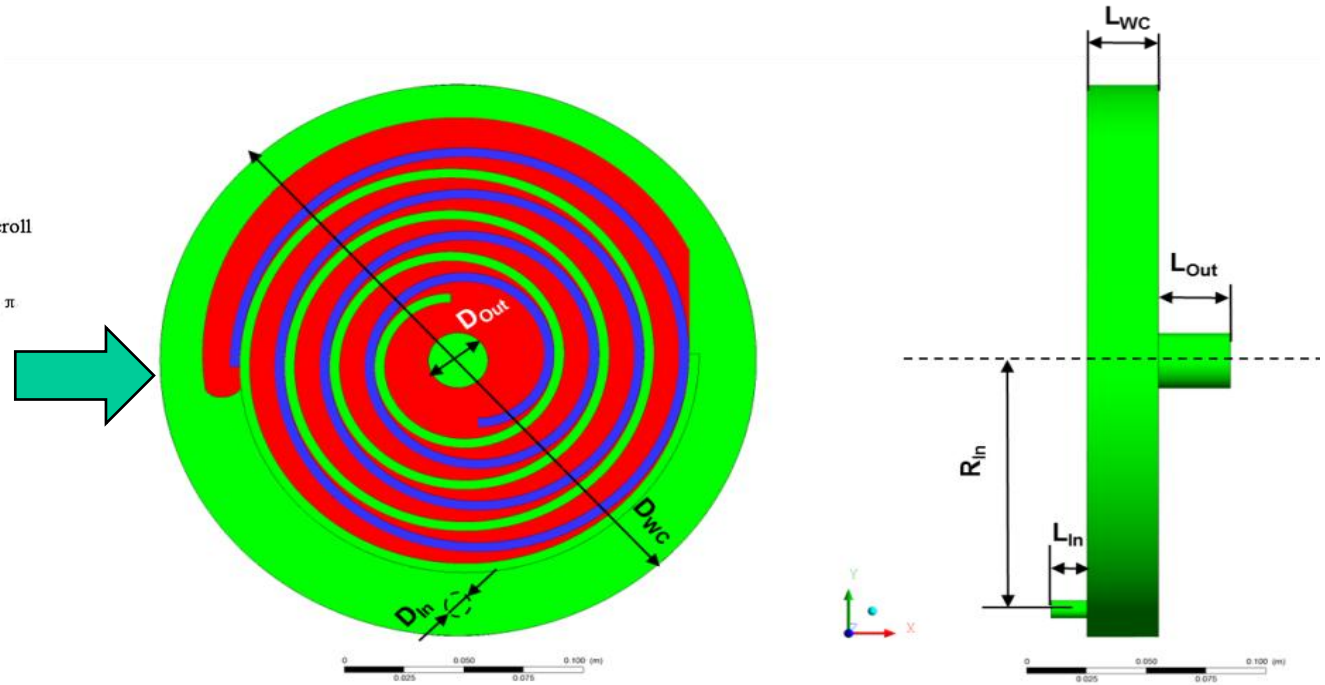
Introduction

- DSVP is complex from the fluid dynamics view
  - Orbiting scroll wrap relative to the fixed scroll wrap
    → time changing working chamber volume
  - Small radial gaps between the wraps and axial gaps between wraps and casing
  - Compressible fluid
  - Properties of the vacuum could
    have to be taken into account

Geometry

- The geometry is modelled as specified in (Yue et al., 2015)
  - In addition axial gaps are included (30 microns)



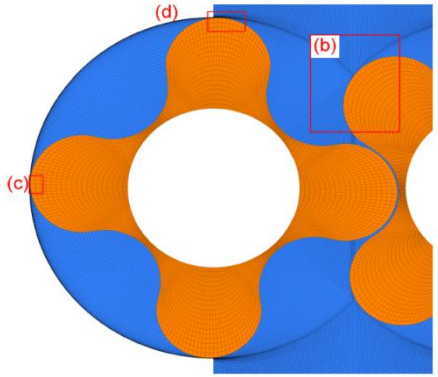


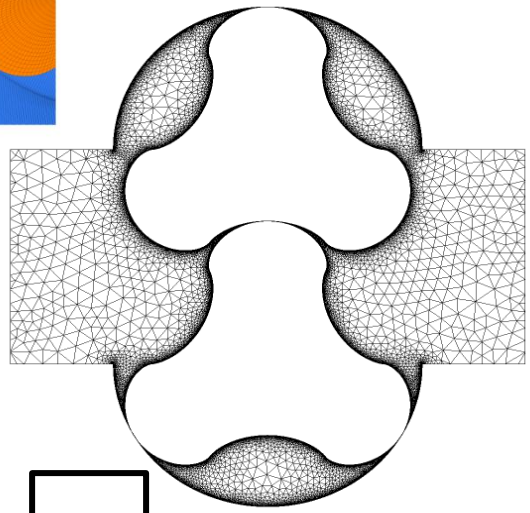
Geometry of the scroll wraps (Yue et al., 2015)

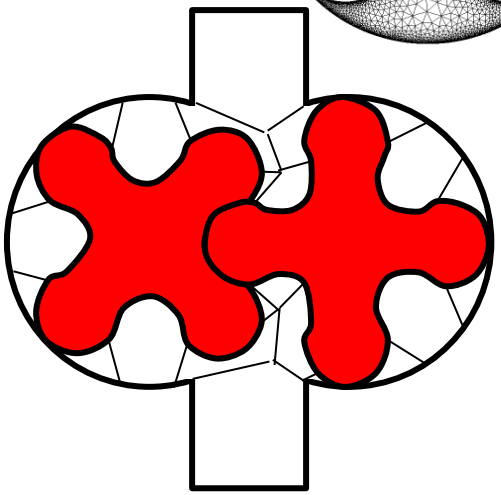
Simulation domain

Meshing

- Chamber modelling
  - Immersed solid
    - Simple mesh generation (+)
    - Many restrictions in solver modelling (-)
  - Remeshing
    - Automatic mesh generation (+)
    - High number of elements and mesh quality issues (-)
  - Manual generation
    - Best mesh and numerical quality (+)
    - High manual effort (-)

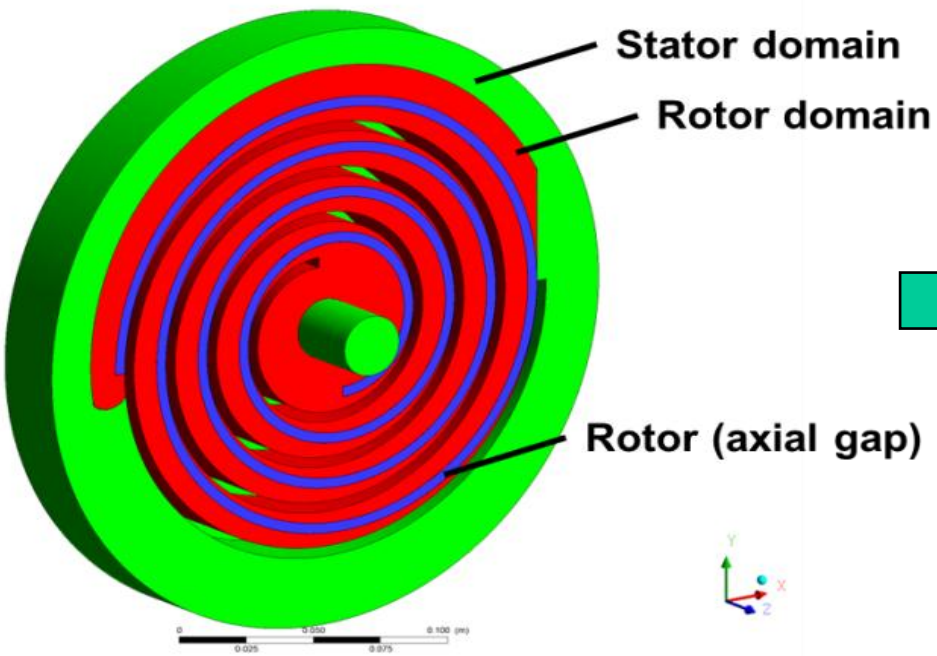


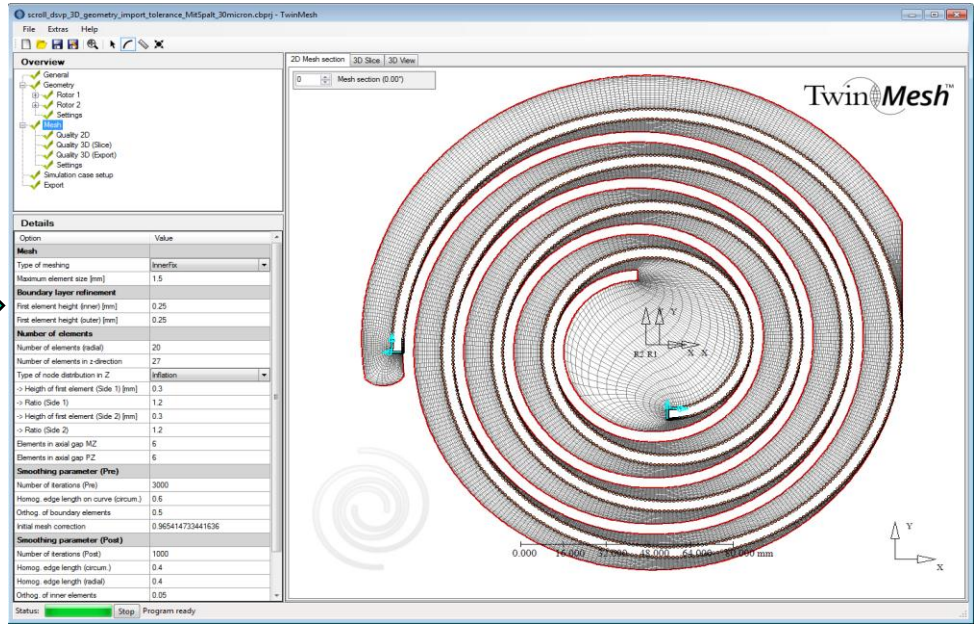




Meshing

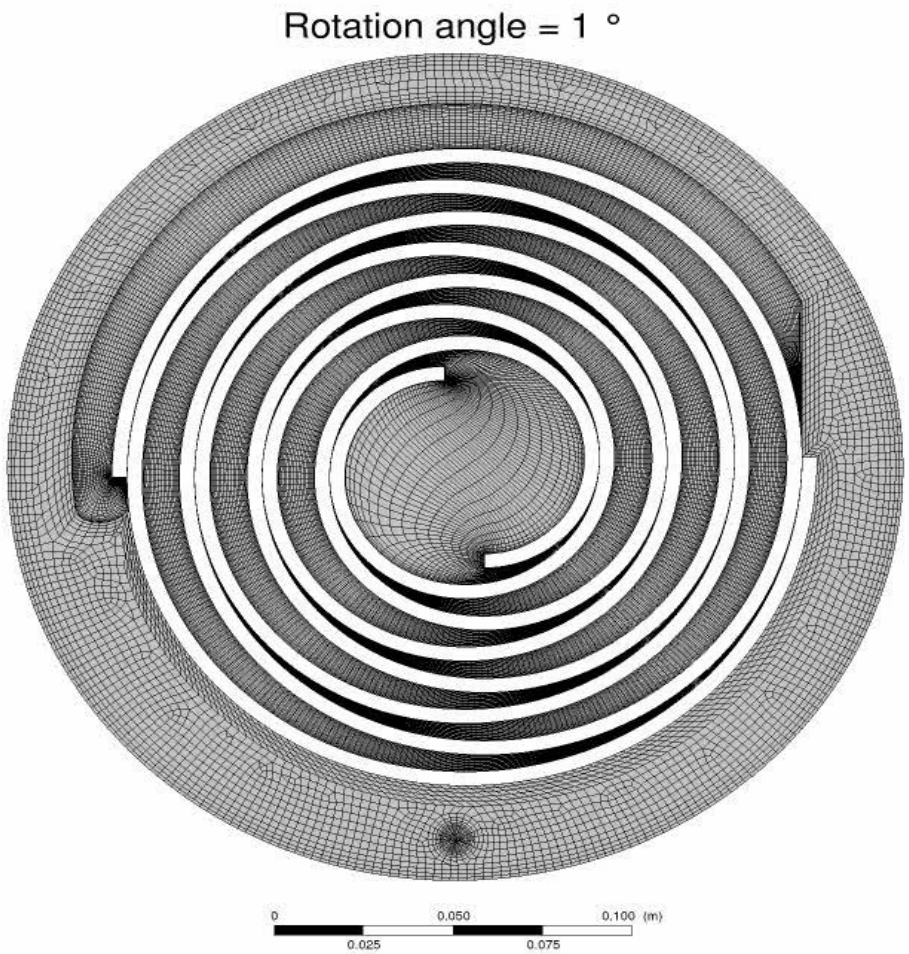
- Stator domain meshed with **ANSYS Meshing**
  - Number of elements: 360 000
- Rotor domain meshed with **TwinMesh**
  - Number of elements: 1.6 Mio.

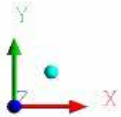




Meshing

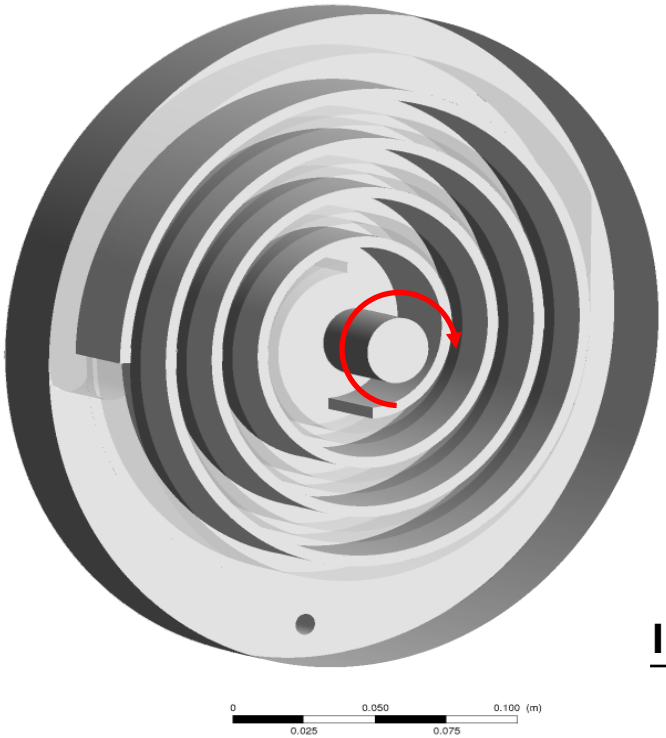
- Animation of the mesh movement

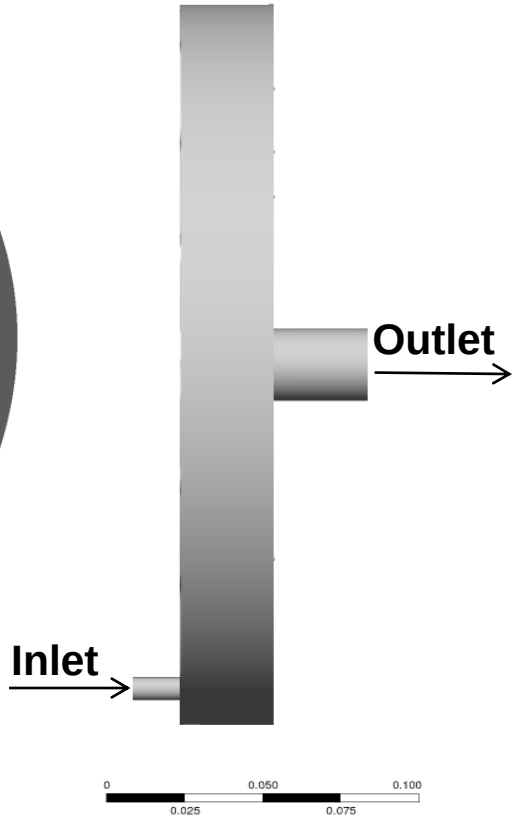




Simulation Setup

- Commercial CFD solver ANSYS CFX
  - Stator-rotor connection GGI (Generalized Grid Interface)
  - Fluid: Air ideal gas
  - Turbulence model: SST (Shear Stress Transport)
- Inlet
  - Absolute Pressure (17 kPa)
  - Temperature (20°)
- Outlet
  - Absolute Pressure (95 kPa)
- Rotational speed (1704 rpm)





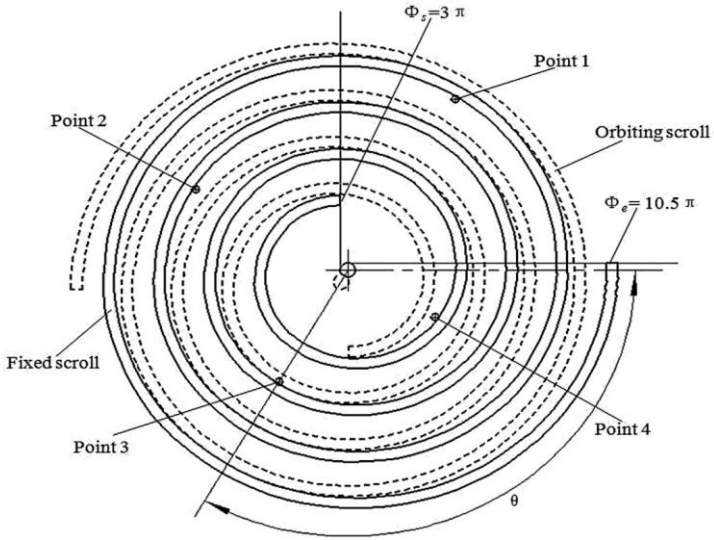
Simulation Setup

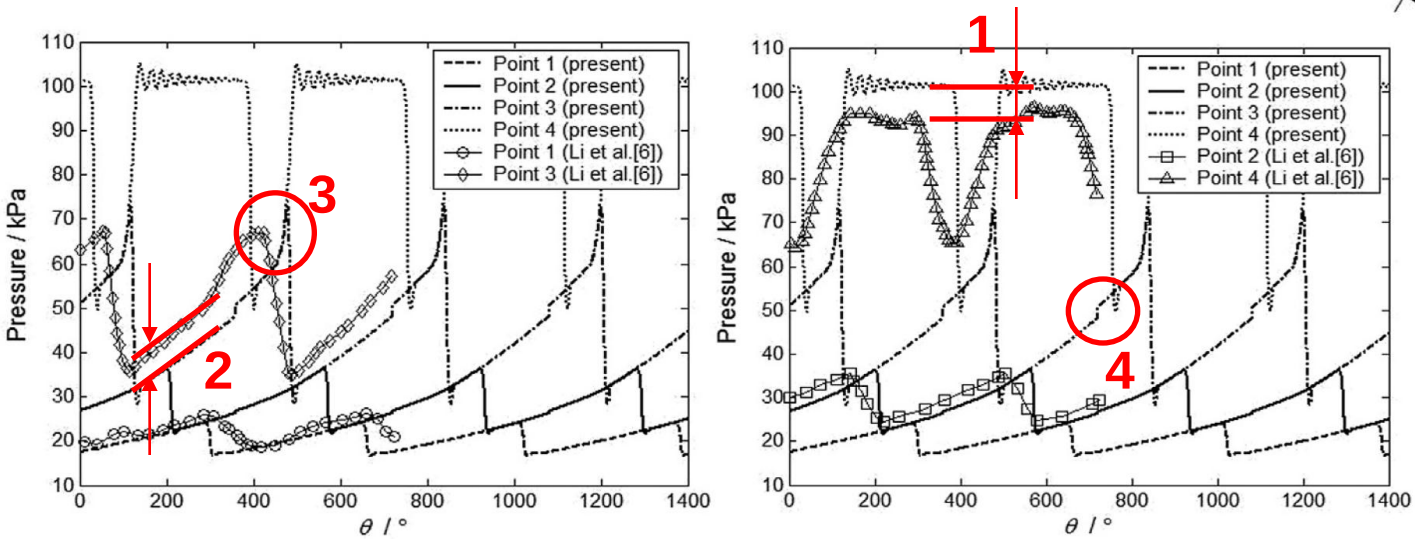
CFX Berlin

- Time step
  - Calculated from the rotational speed and the angle step
  - Angle step is 1 degree
- Flow regime
  - Boundary condition set to no slip wall (Knudsen < 0.01)
- Discretization
  - Advection scheme: high resolution
  - Transient scheme: second order backward Euler
- Simulation wall clock time
  - 1 day per rotation on 8 core computer (Intel(R) Xeon(R) CPU E5-2637 v2)

Simulation Results

- Reference data
  - CFD vs. measurement
  - Comparison between Yue's CFD and Li's measurement results





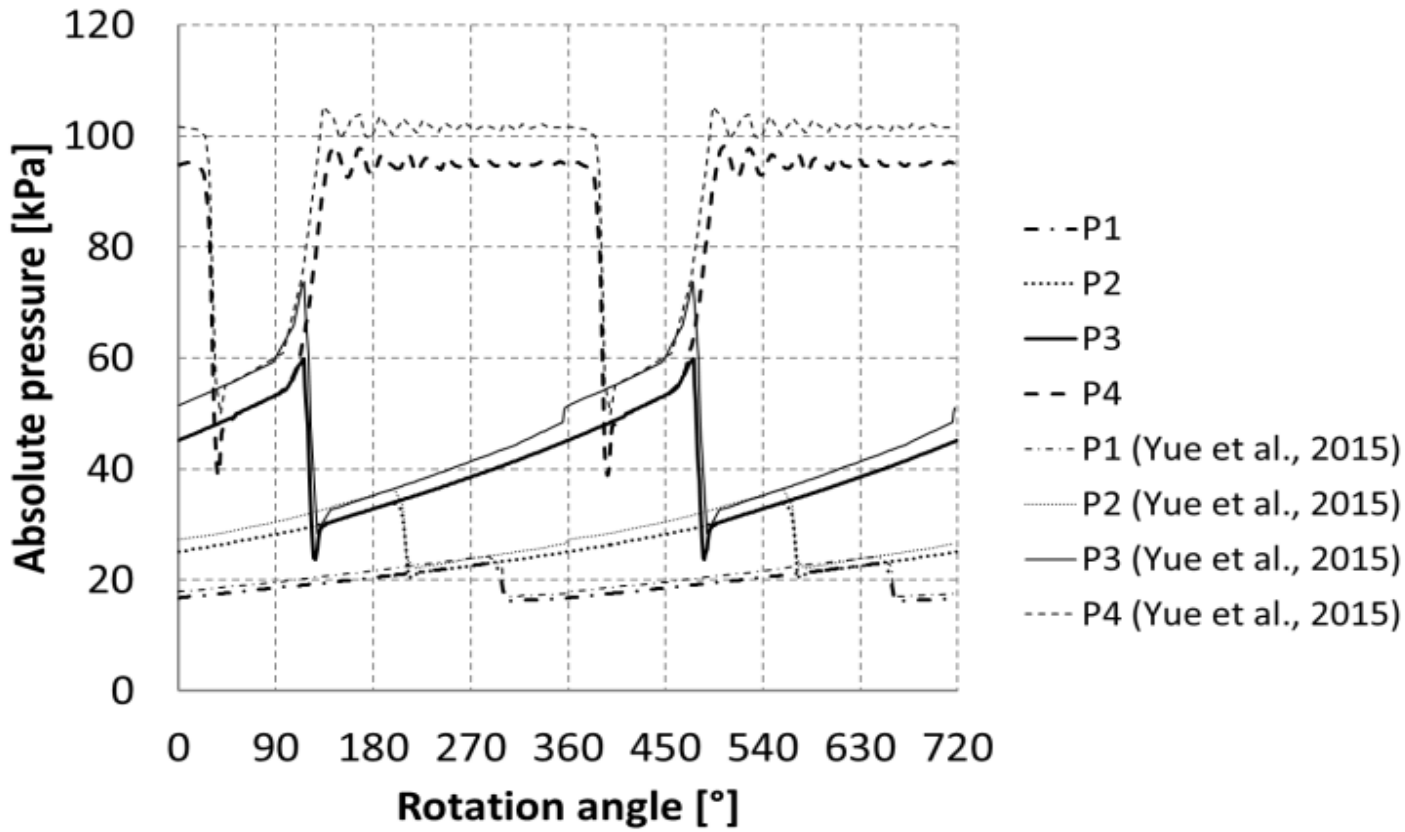
Working process (suction pressure 17kPa, 1704 rpm) (Yue et al., 2015)

Remarks:

1. **Different outlet pressure**
2. **Pressure offset in working chamber**
3. **Angle shift in pressure drop location**
4. **Discontinuity in pressure curve**

Simulation Results

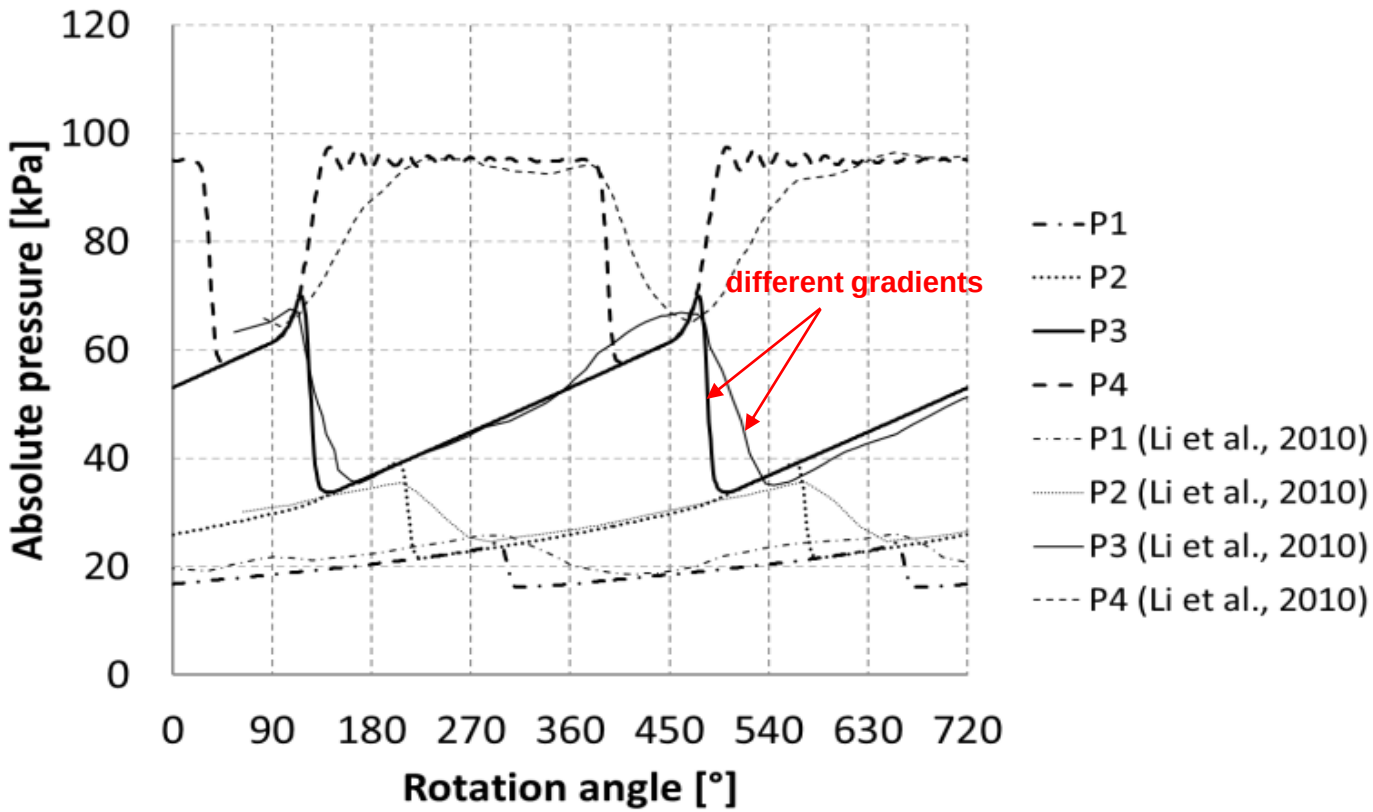
- Our CFD results in comparison with Yue's CFD results
  - Same setup except the outlet pressure



Comparison of our simulation results with the CFD results of Yue et al. (2015)

Simulation Results

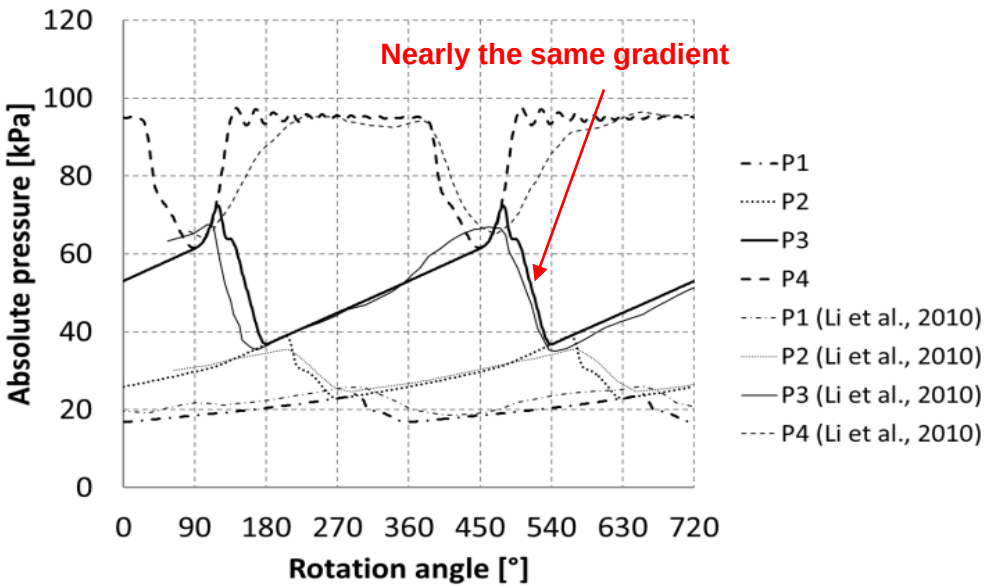
- Our CFD results in comparison with Li's measurement results
  - Measurement data is shifted to get the correct pressure drop position

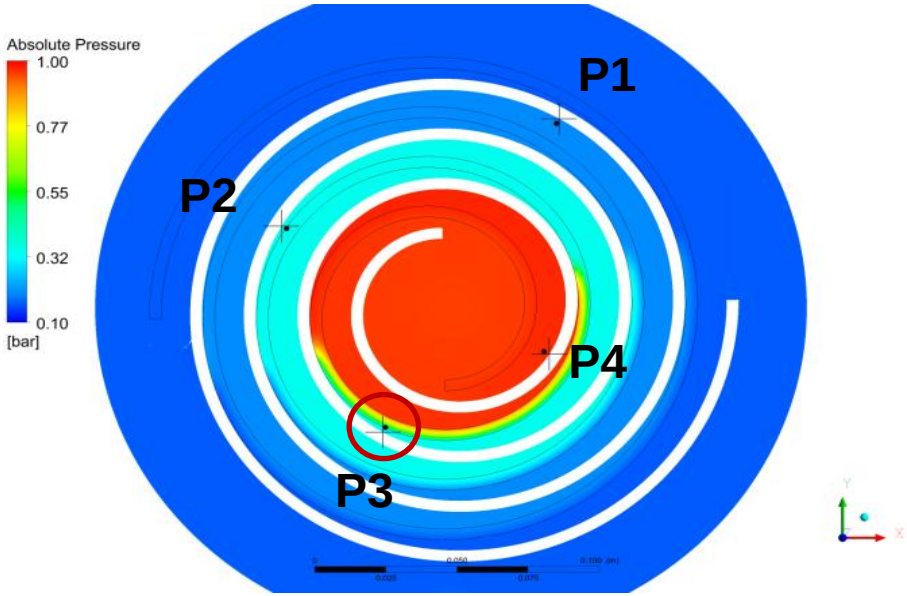


Comparison of our CFD results with measurements of Li et al. (2010, Vacuum 85)

Simulation Results

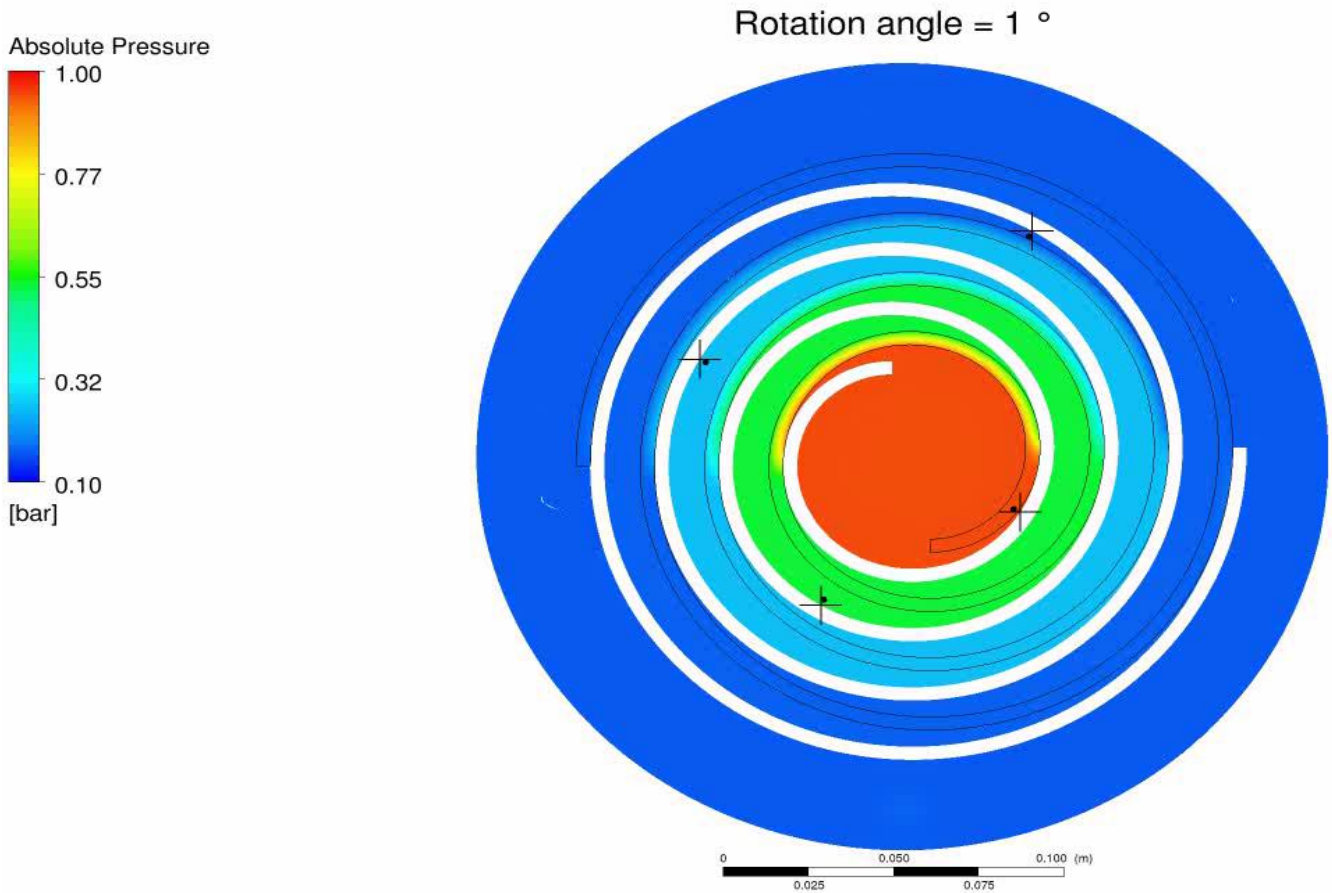
- Our CFD results in comparison with Li's measurement results
  - Change the post-processing method from measurement point to measurement circle with a location away from the wrap





Simulation Results

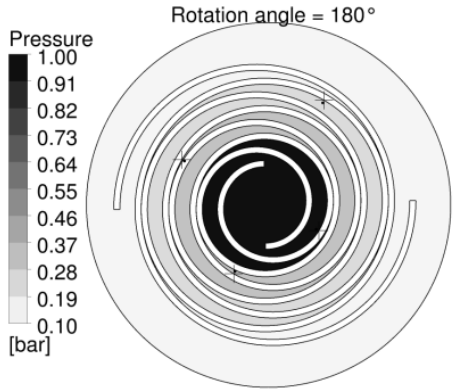
- Animation of the pressure on a slice plane in the axial gap on discharge side

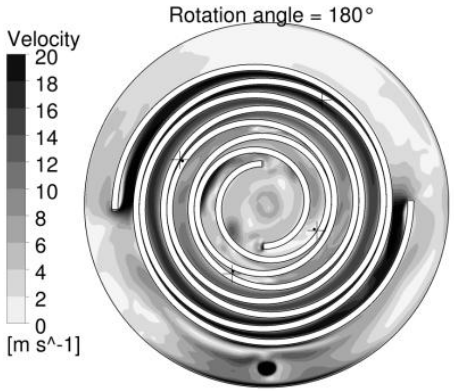


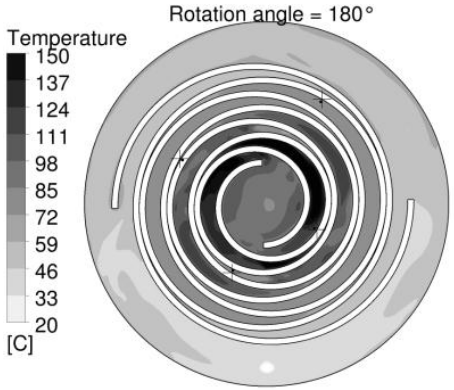
Simulation Results

- Cross-sectional view of the pressure, velocity and temperature with suction pressure of 17 kPa and rotational speed of 1704 rpm

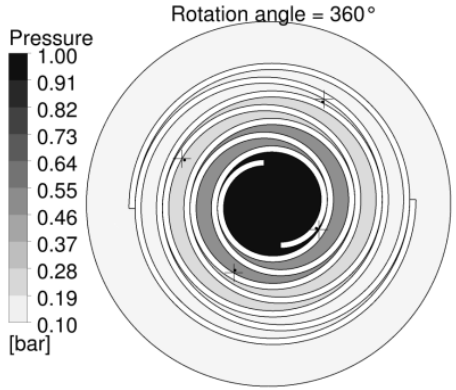
180°

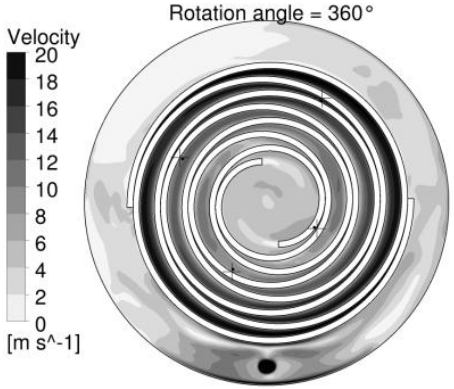


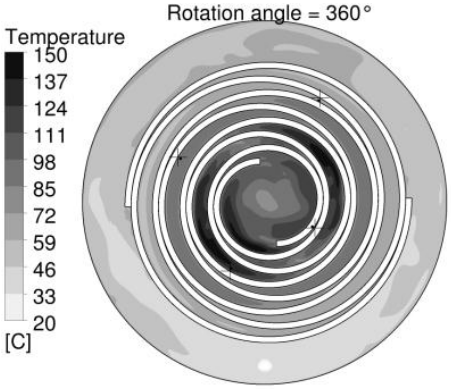




360°



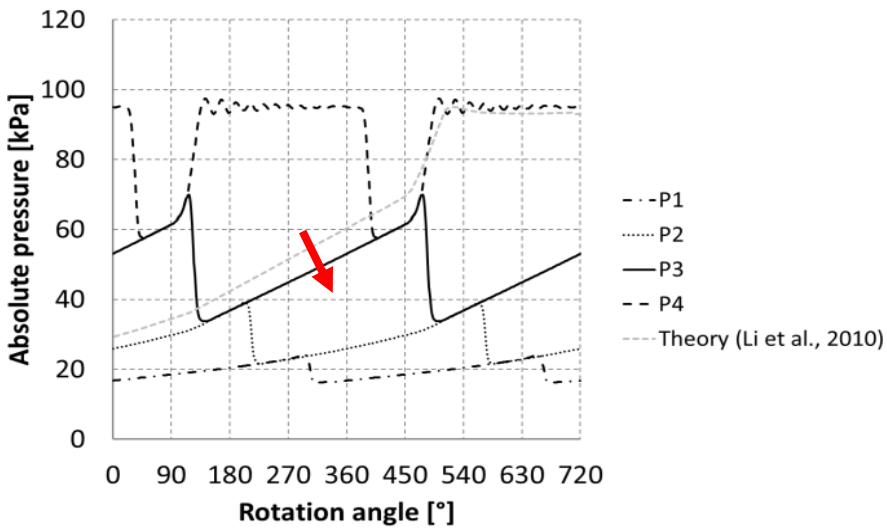




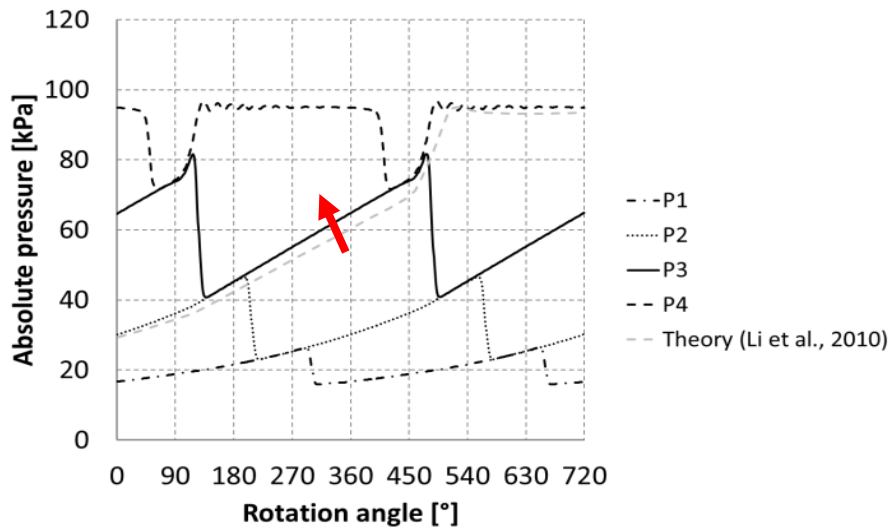
Pressure **Velocity** **Temperature**

Simulation Results

- Comparison of theoretical approach of Li et al. (2010, Vacuum 85) with our CFD results using a wall temperature of 65°C and an adiabatic wall
  - The effects of wall heat transfer have a strong influence on the working process



Temperature of 65°C

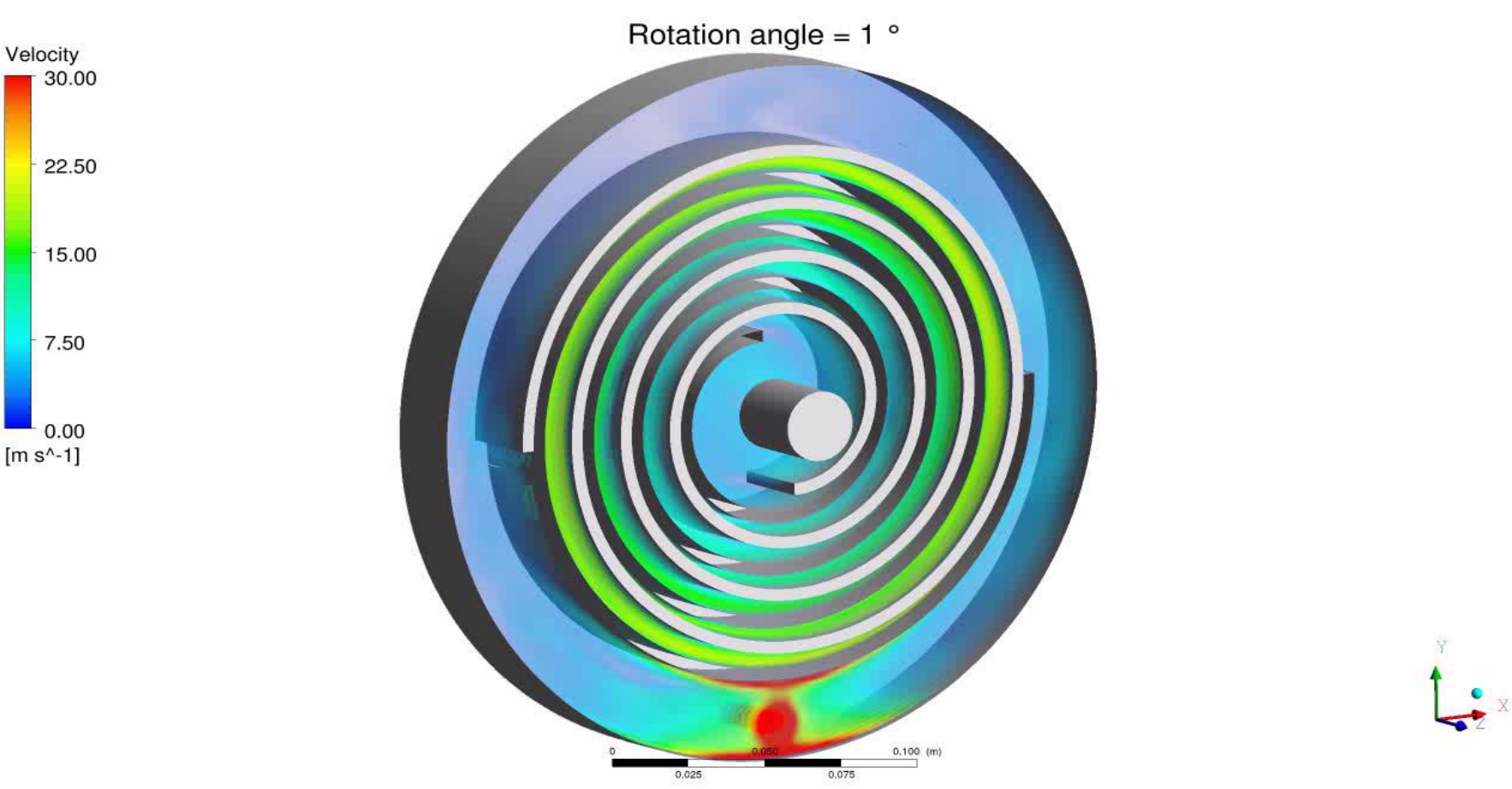


Adiabatic

Simulation Results

CFX Berlin

- Animation of the flow velocity



Summary

- This presentation shows
  - Presentation includes CFD results of a dry scroll vacuum pump calculated with ANSYS CFX
  - CFD results are compared with measurement data and other CFD results
  - TwinMesh is used to realize the mesh movement
  - The CFD results are in good agreement with the measurements
  - The effects of wall heat transfer have a strong influence on the working process

Outlook

- Possible next steps
  - Perform CFD simulations with realistic temperature boundary conditions or CHT solid
  - Get more detailed measurement data and compare it with CFD results
  - Perform FSI simulation to see the influence of the temperature on the casing deformation

Thank you for your attention!

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