Herrick Laboratories PURDUE UNIVERSITY

2016 Purdue Conferences
Compressor Engineering
Refrigeration and Air Conditioning
High Performance Buildings

CFD SIMULATION OF A DRY SCROLL VACUUM PUMP INCLUDING LEAKAGE FLOWS

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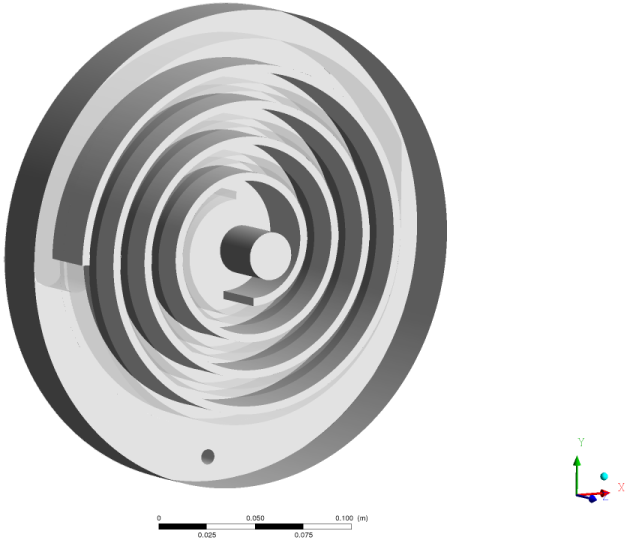
Center for High Performance Buildings at Purdue

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



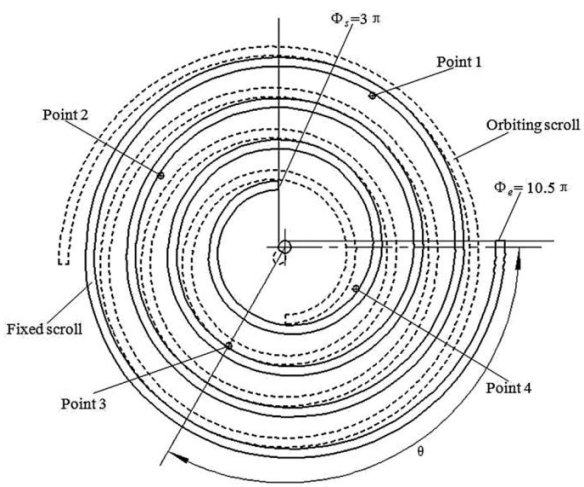
View into the working chamber of a DSVP

Introduction

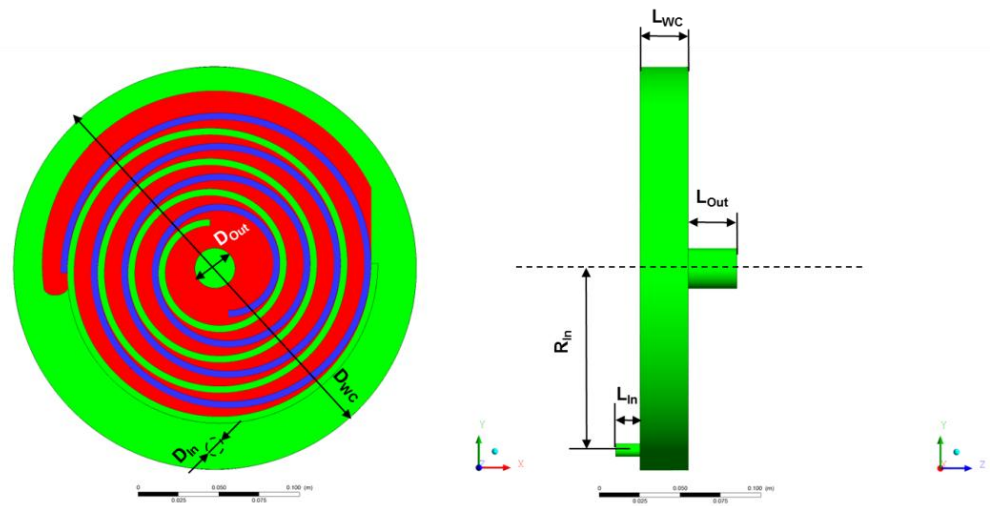
- DSVP is complex from the fluid dynamics view
  - » Orbiting scroll wrap relative to the fixed scroll wrap → time changing working chamber volume
  - » Small radial gaps between the wraps and axial gaps between wraps and casing
  - » Compressible fluid
  - » Properties of the vacuum have to be taken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

Geometry

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



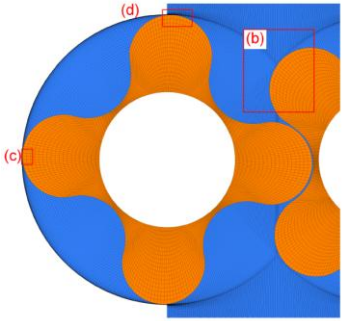
Geometry of the scroll wraps (Yue et al., 2015)

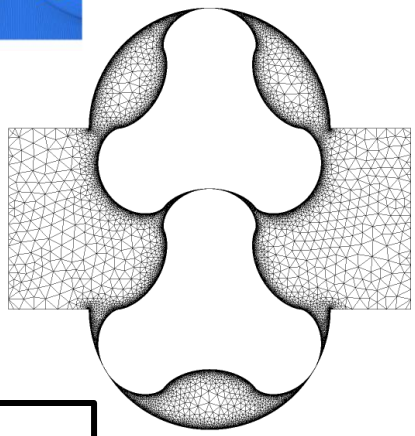


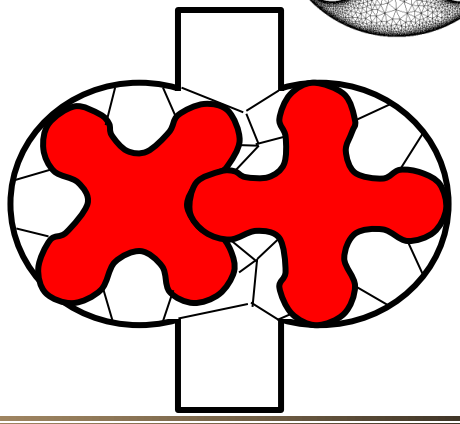
Simulation domain

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 (-)

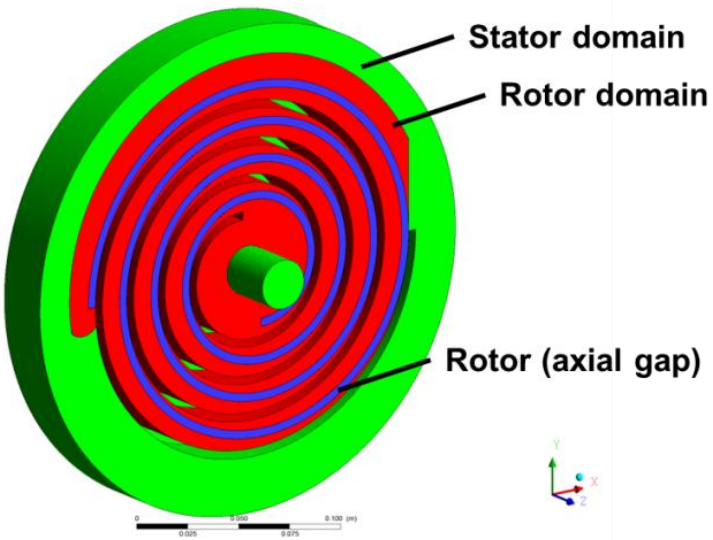


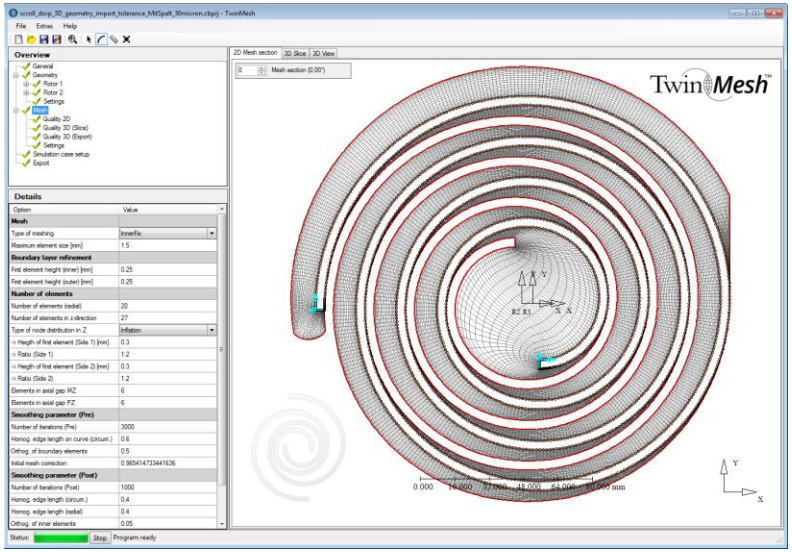




Meshing

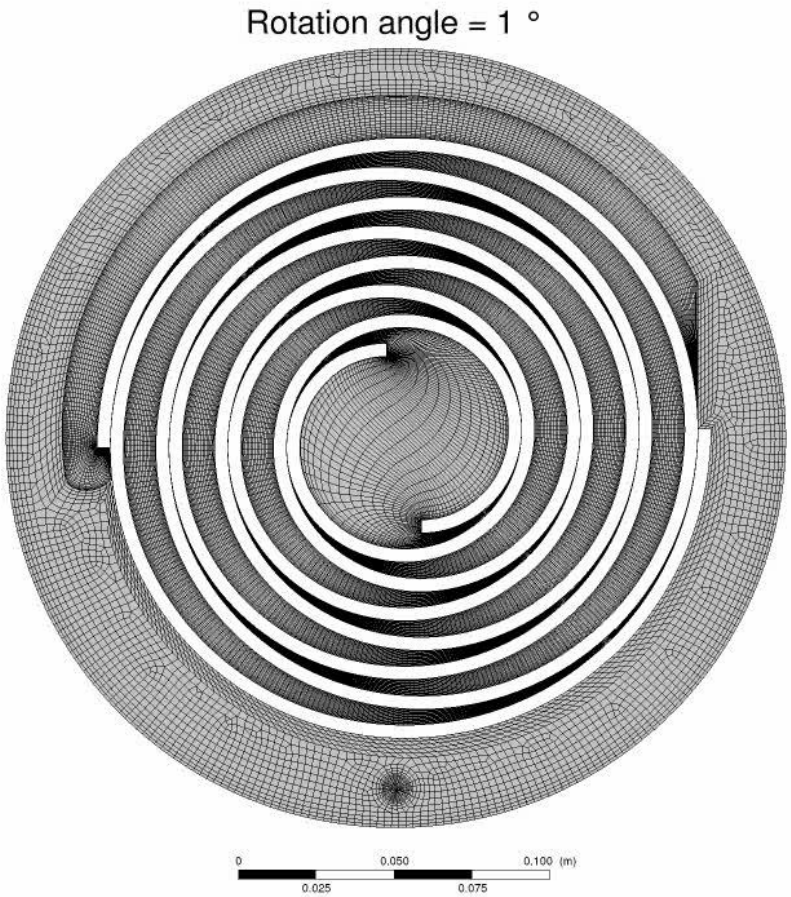
- Stator domain meshed with **ANSYS Meshing**
  - » Number of elements: 360 000
- Rotor domain meshed with **TwinMesh**
  - » Number of elements: 1.6 Mio.

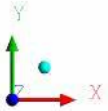




Meshing

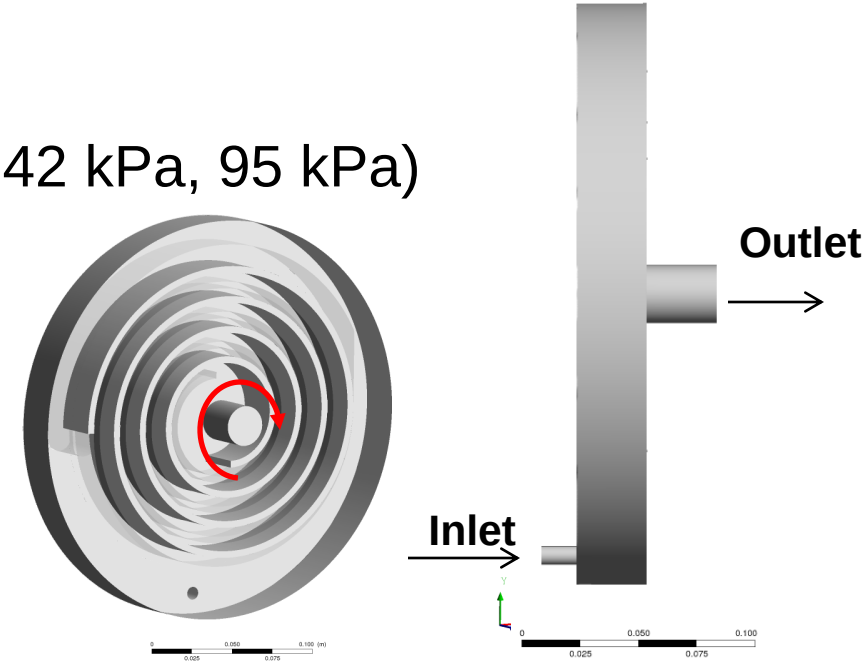
- Animation of the mesh movement





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, 42 kPa, 95 kPa)
  - » Temperature (20°)
- Outlet
  - » Absolute Pressure (95 kPa)
- Rotational speed (1704 rpm)

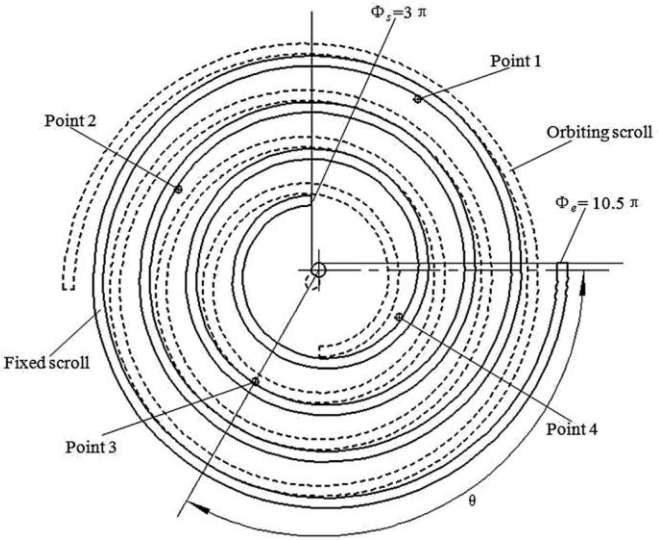


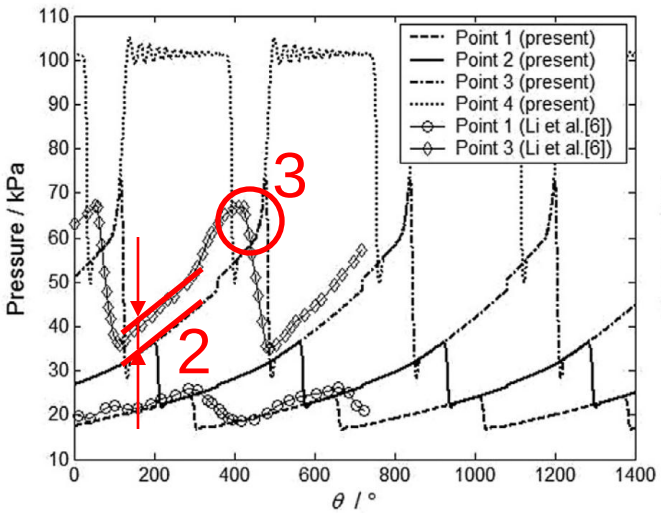
Simulation Setup

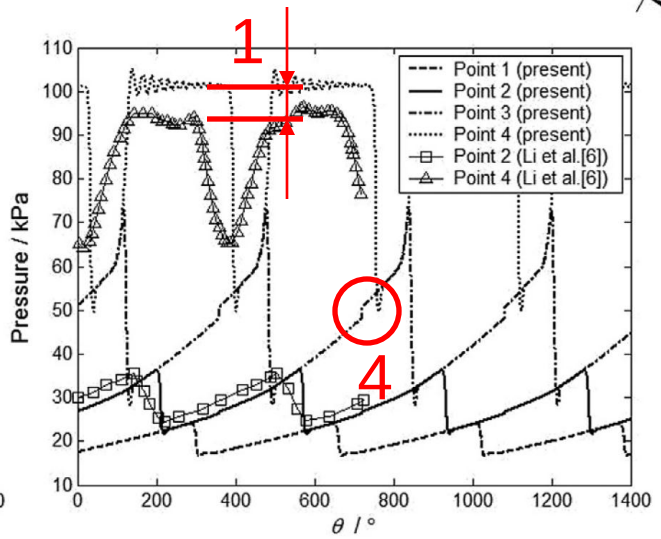
- Time step
  - » Calculated from the rotational speed and the angle step
  - » Angle step is 1 degree
- Flow regime
  - » Boundary condition set to no slip wall (Knudsen < 0.01)
- Discretization
  - » Advection scheme: high resolution
  - » Transient scheme: second order backward Euler
- Simulation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

Simulation Results

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







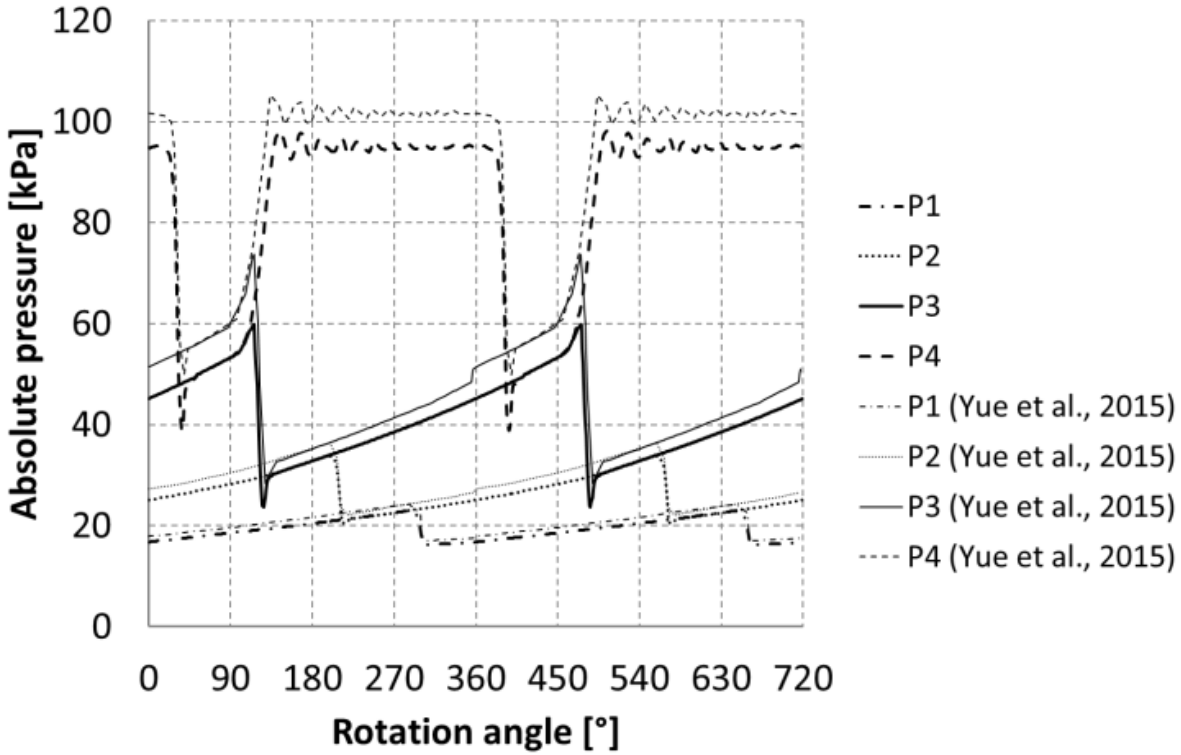
Working process (suction pressure 17kPa, 1704 rpm) (Yue et al., 2015)

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

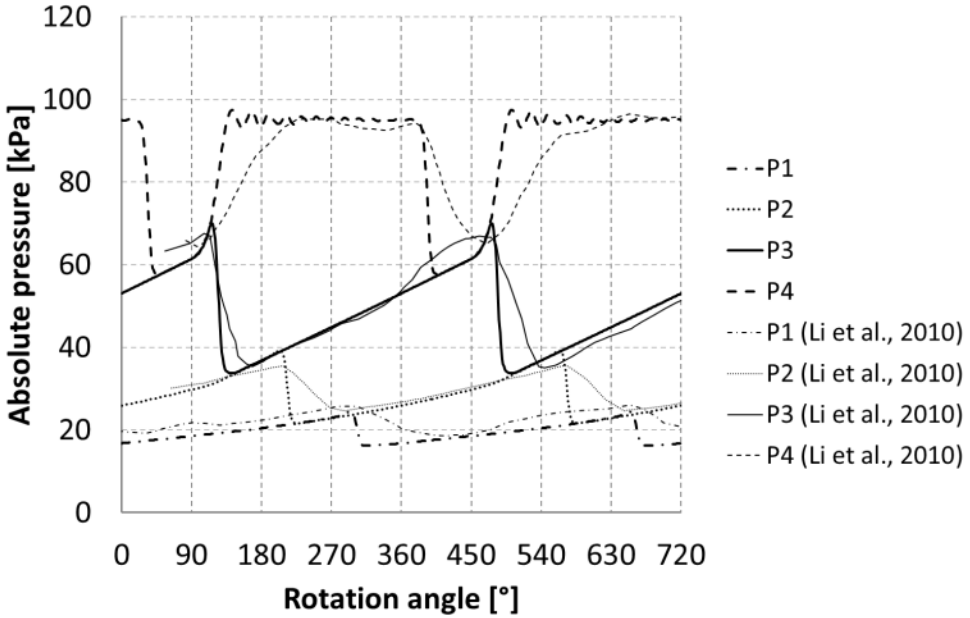
- Our CFD results in comparison with Yue's CFD results
  - » Same setup except the outlet pressure



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

Simulation Results

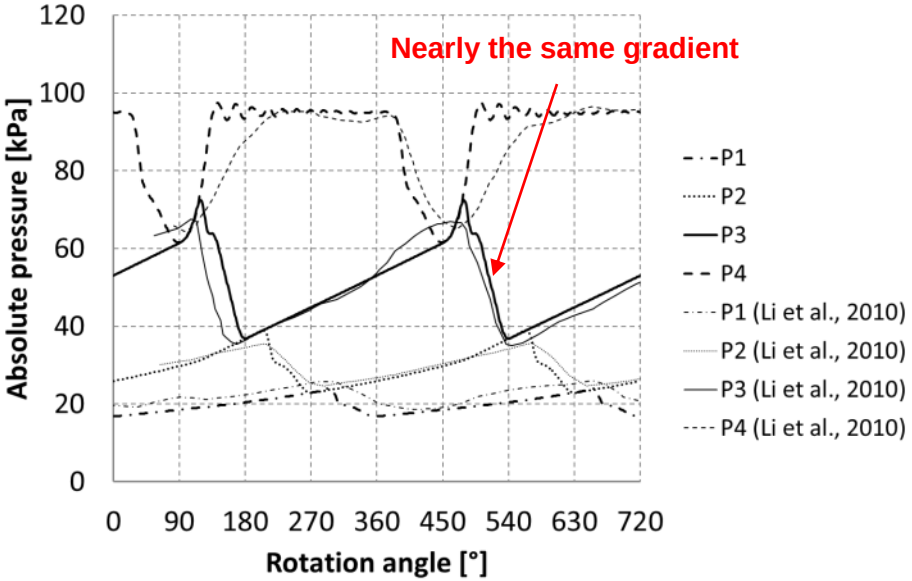
- Our CFD results in comparison with Li's measurement results
  - » Measurement data is shifted to get the correct pressure drop position

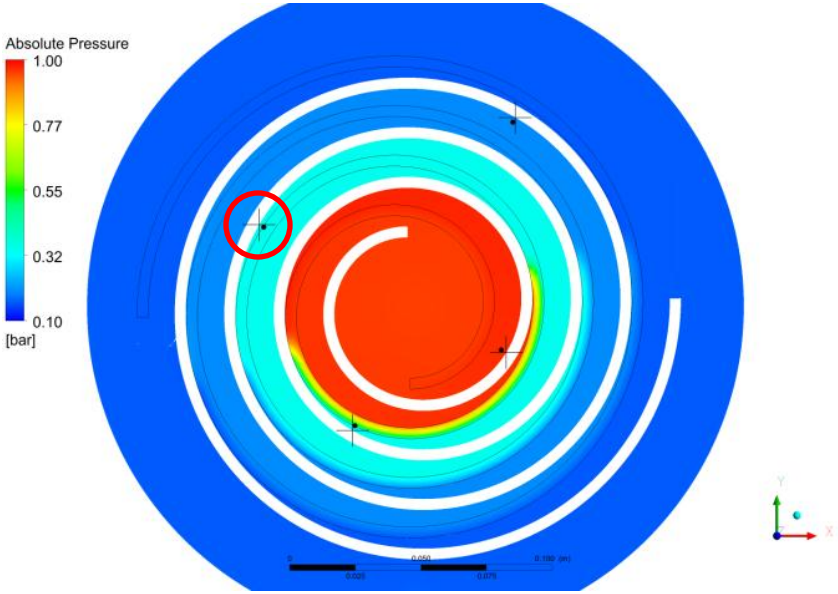


Comparison of our CFD results with measurements of Li et al. (2010, Vacuum 85)

Simulation Results

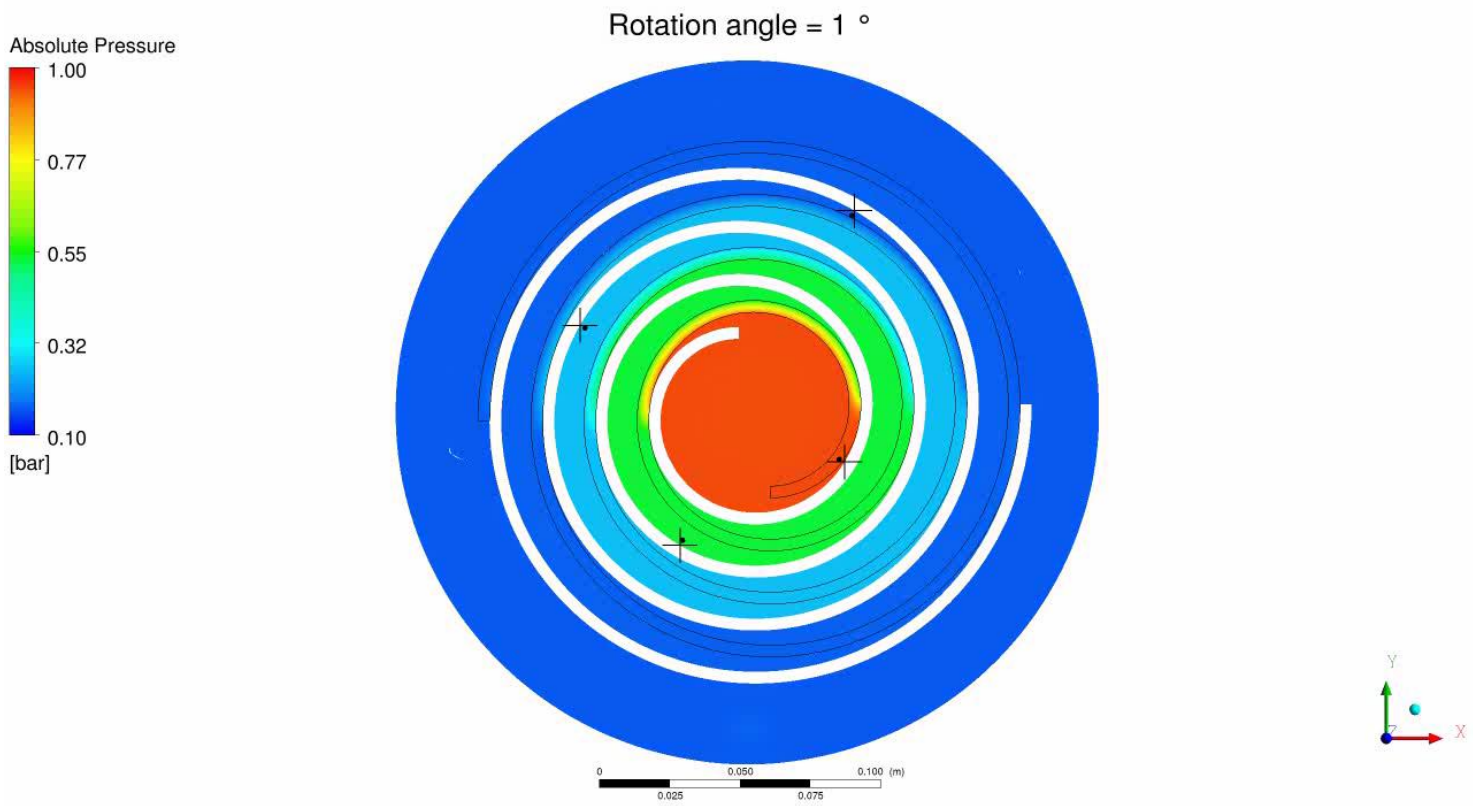
- Our CFD results in comparison with Li's measurement results
  - » Change the post-processing method from measurement point to measurement circle with a location away from the wrap





Simulation Results

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

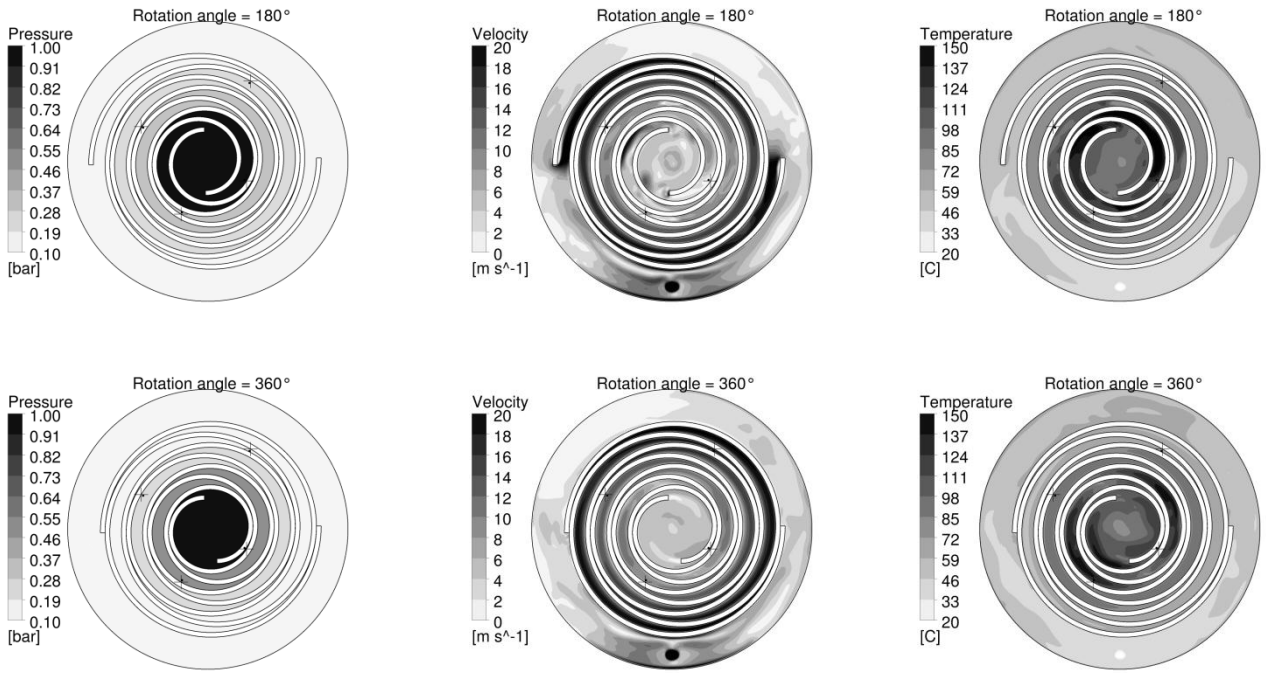


Simulation Results

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

180°

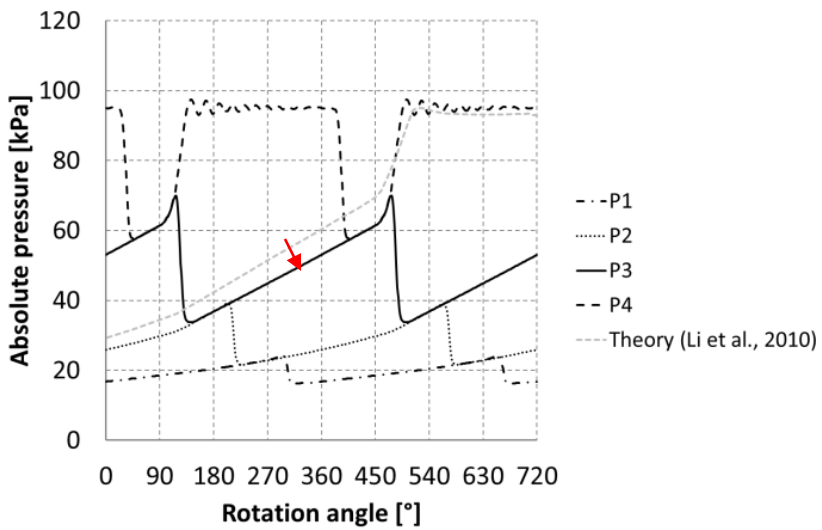
360°



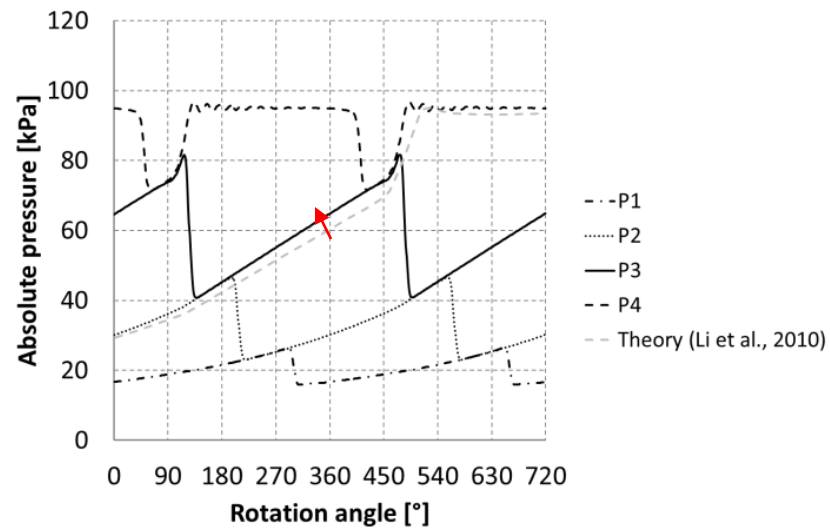
Pressure Velocity Temperature

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



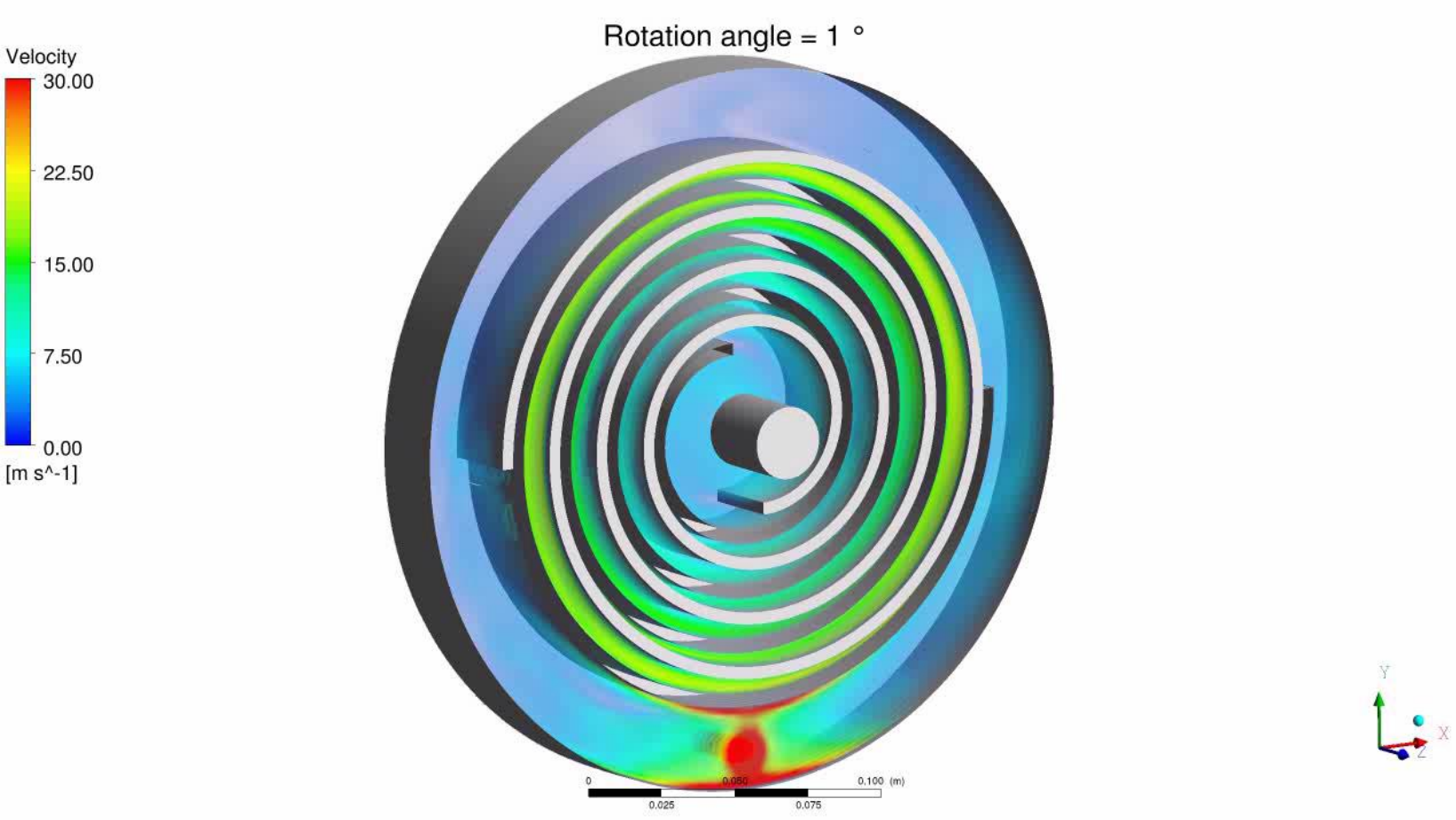
Temperature of 65°C



Adiabatic

Simulation Results

- Animation of the flow velocity



Summary

- 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

- Perform CFD simulations with realistic temperature boundary conditions or CHT solid.
- Get more detailed measurement data and compare it with CFD results

For More Information

- Contact:
  - » CFX Berlin Software GmbH
  - » info@twinmesh.com

- Live demonstration of TwinMesh in room **STEW 313**
  - » **Tuesday**, July 12th, 2016 – 4:00-6:00 pm
  - » **Wednesday**, July 13th, 2016 - 3:30-5:30 pm
    - – Exclusive demonstration of the TwinMesh software,
    - – Showing the fast & easy workflow,
    - – Explaining the benefit of this solution, and
    - – Answering your specific questions