CFD Simulation of a Two-Sided Screw Compressor with FEM Simulation of Pressure Load

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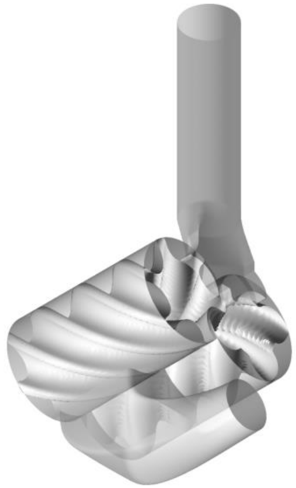
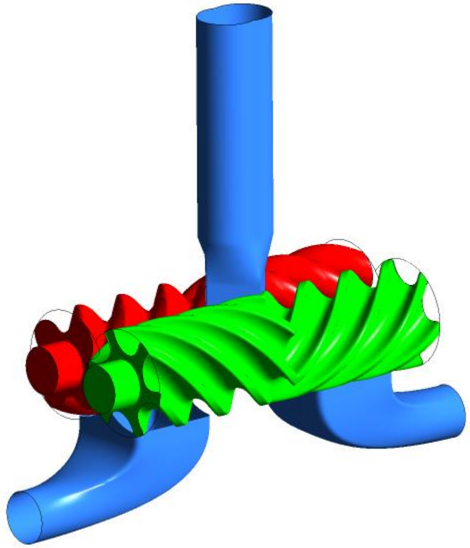
9th International Conference on Compressor and Refrigeration

July 10th-12th, 2019

Contents

- Screw compressors and TwinMesh
- Motivation for two-sided setup
- Geometry, mesh, setup
- CFD results for straight rotors
- Pressure load and FEM simulation
- CFD results for bent rotors
- Summary and outlook





Screw Compressors and TwinMesh

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3D CFD simulation of screw compressors:

- High numerical effort due to
  - large meshes to resolve gap flows
  - complex physics, e.g. IAPWS, CHT, MPF
  - small time step sizes to ensure convergence at high rpm
  - long simulation times to reach periodic state
- Own product „TwinMesh“
  - for pre-generation of all meshes for fluid volumes in chambers
  - scripts for automated setup and reports
  - meshes are read by solver at run-time
- Established simulation process
  - with meshing, setup, simulation, and postprocessing
  - For screw, scroll, vane, roots blower

CAD

↓

TwinMesh™

1. Import geometry
2. Set boundary conditions
3. Generate interfaces
4. Define mesh settings
5. Generate meshes
6. Check mesh quality
7. Export all meshes
8. Export scripts

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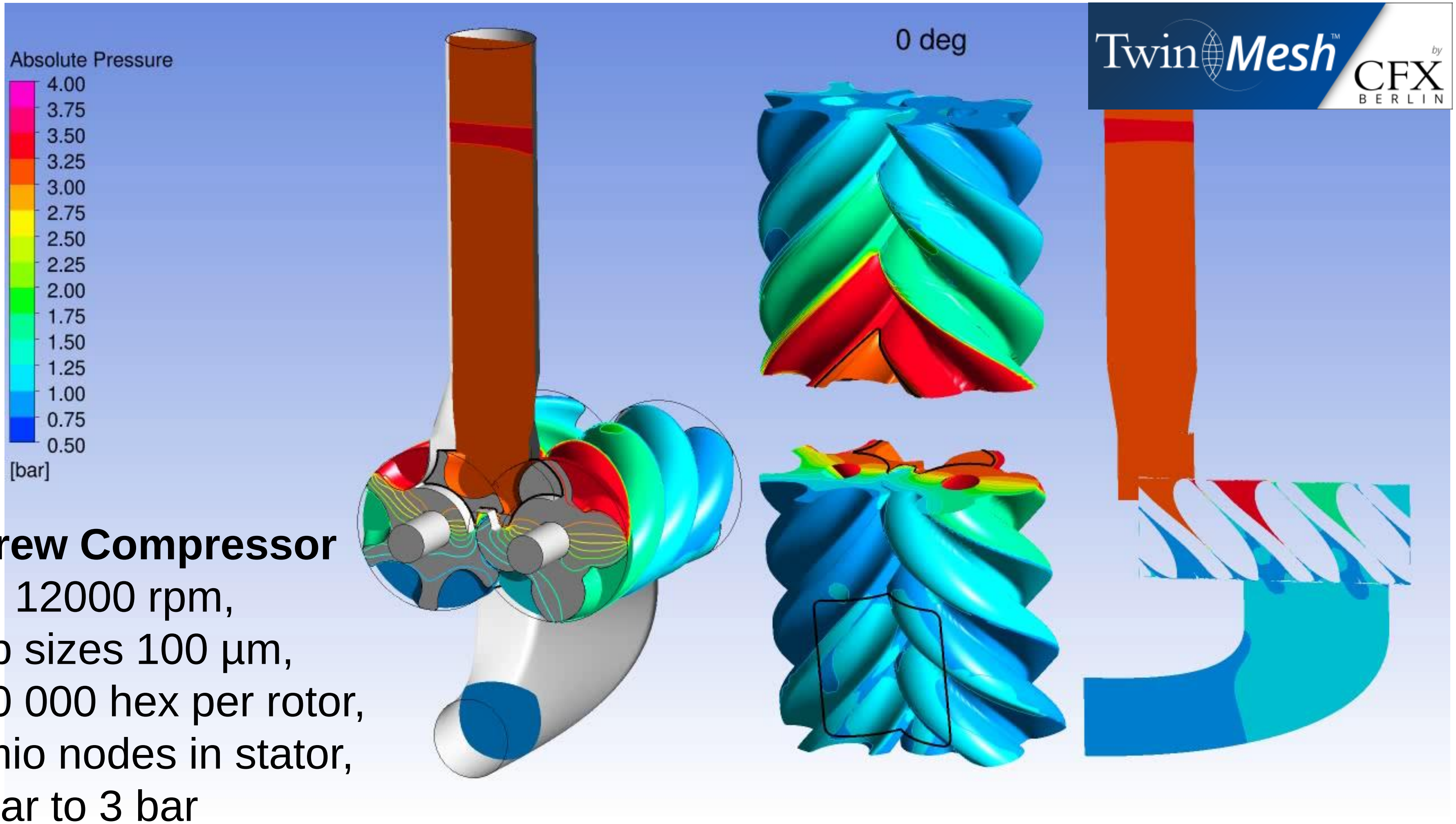
ANSYS

1. Apply Pre script with initial mesh
2. Read further meshes at run-time

Screw Compressors and TwinMesh



Screw Compressor
Air, 12000 rpm,
gap sizes 100 µm,
550 000 hex per rotor,
1 mio nodes in stator,
1 bar to 3 bar

Motivation for Two-sided Setup

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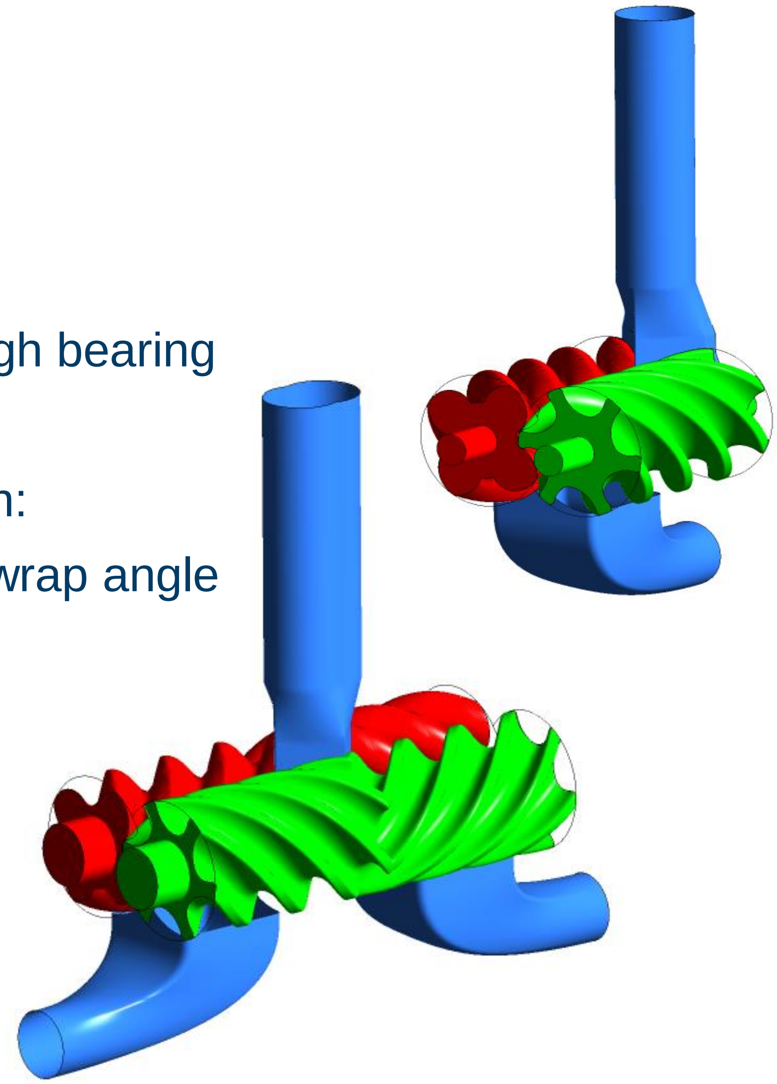
Disadvantage of standard screw compressor:

- Unequal pressure distribution on rotors
  → axial force on bearings
- High pressure at pressure side bearing
  → sealed bearing to prevent (hot) gas flow through bearing

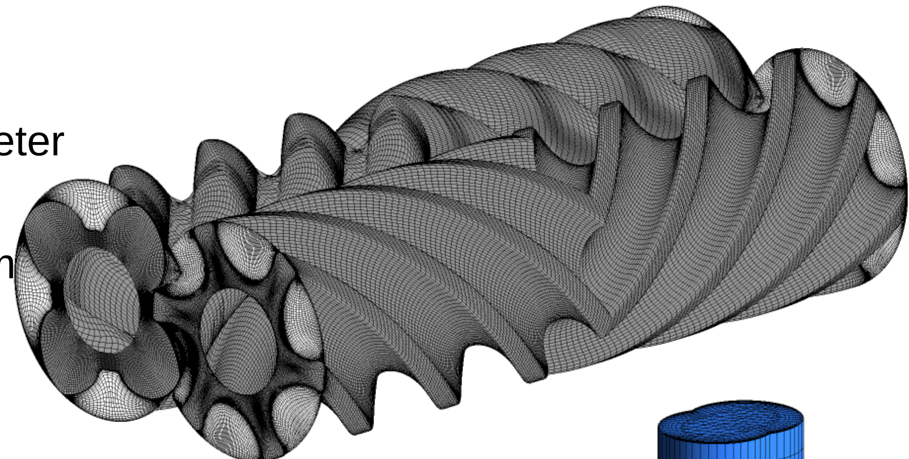
Two-sided (or double flow) screw compressor design:

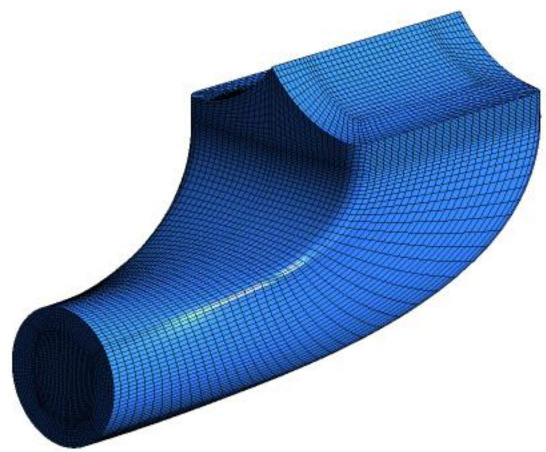
- Doubled length with same profiles, but negative wrap angle
- Symmetric pressure distribution
  → no axial force on bearings
- Both bearings at atmospheric pressure
  → no special sealing necessary
- BUT: longer rotors
  → pressure load may lead to deflection of rotors

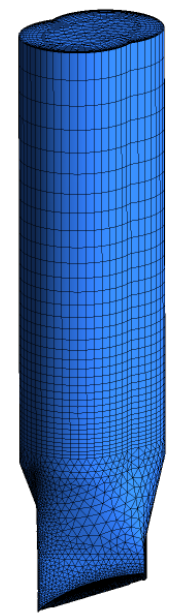


Geometry, Mesh, Setup

- Rotors:
  - Length 336.2 mm, wrap angle 2x 300°
  - Male rotor: 4 lobes, 102 mm outer diameter
  - Female rotor: 6 lobes, 101.2 mm outer diameter
  - Distance between rotation axes: 80 mm
  - Radial gaps to casing 25 µm, between 50 µm
  - Axial gaps 100 µm each
  - Mesh resolution: 2.4 mio hexahedrons
    300/200 x 20 x (200+2x8) elements
- Stator:
  - 2 suction pipes with 200 mm length and
    50 mm diameter: 110,000 hexahedrons
  - Pressure pipe with 260 mm length for
    built-in volume ratio 2.2:
    64,000 tets, 67,000 wedges, 20,000 hex







CFD Results for Straight Rotors

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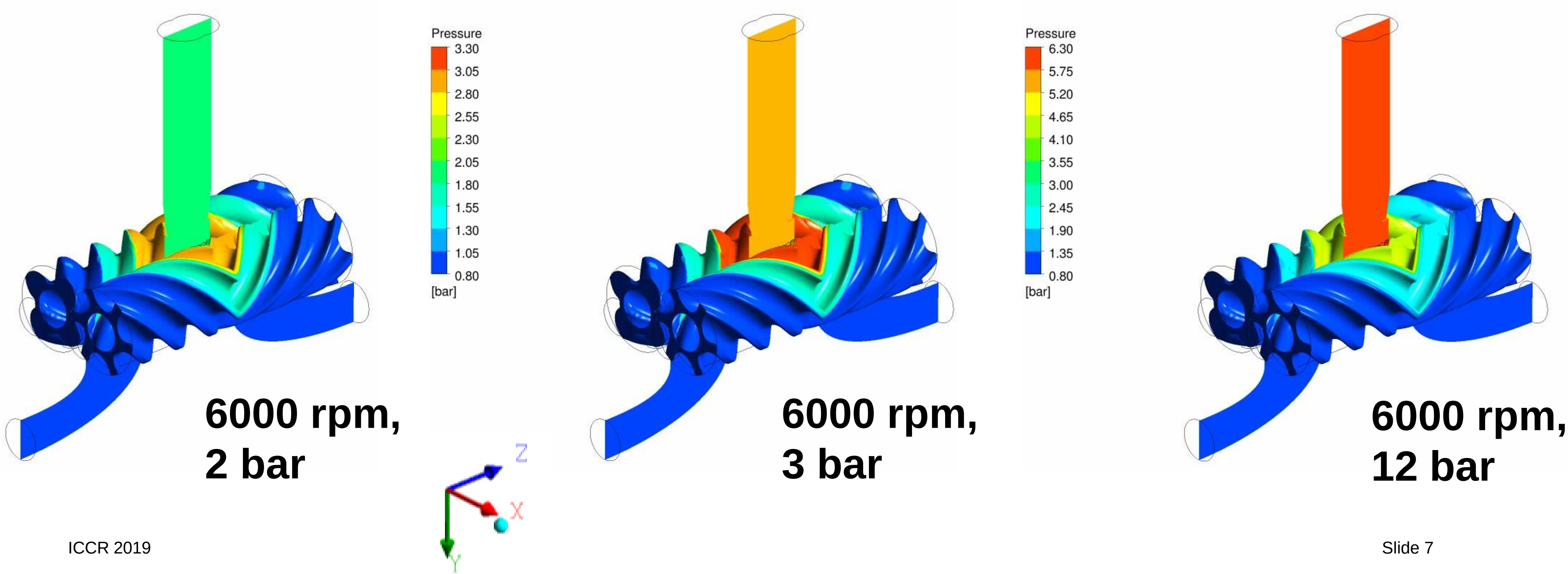
Boundary conditions for air as ideal gas:

- Rotational speeds of male rotor: 6000 rpm and 12000 rpm
- Outlet pressure: 2 bar (over-compression), 3 bar, 6 bar (under-compression)

Simulation time:

- 2 days per revolution on 4 cores



CFD Results for Straight Rotors

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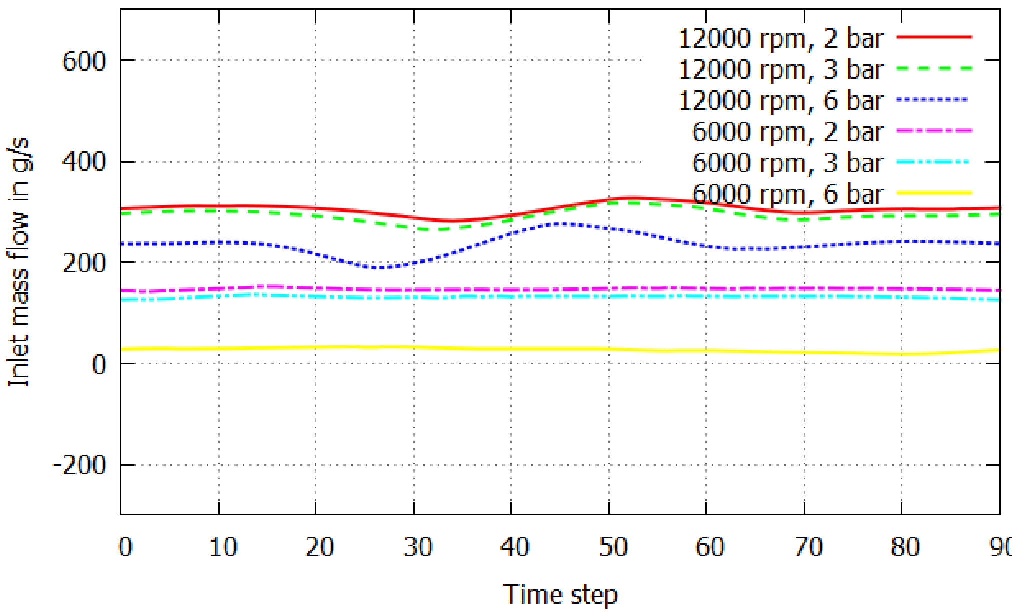
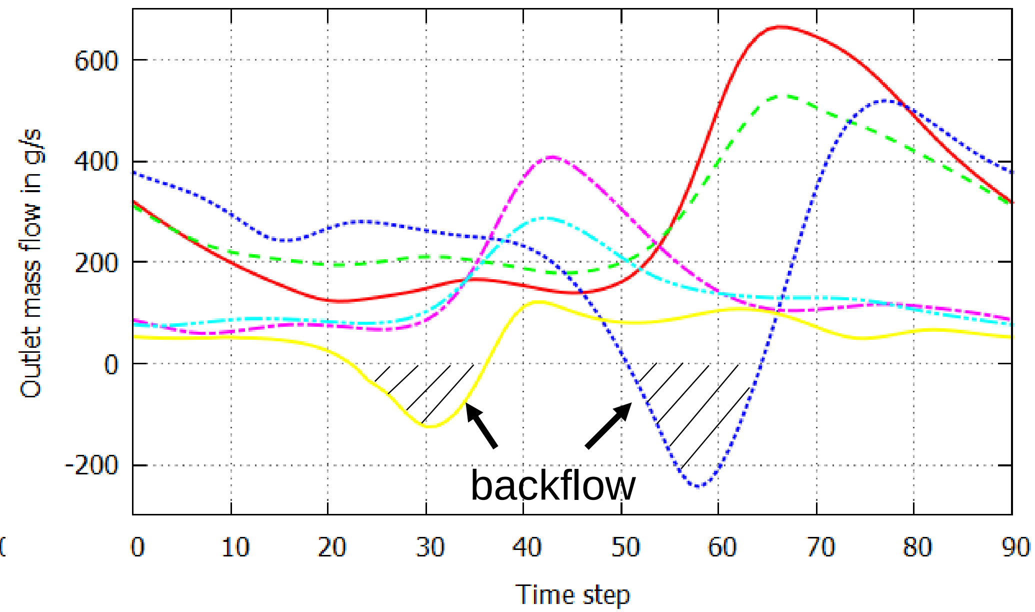
Comparison of mass flow rates:

- Mass flow rate increases with rpm
- Mass flow rate decreases with pressure
- 6 bar at 6000 rpm has almost no mass flow
- 6 bar (under-compression) has backflow at outlet

Rotational speed of male rotor	Pressure at outlet	Average mass flow
6000 rpm	2 bar	147.5 g/s
	3 bar	131.3 g/s
	6 bar	28.7 g/s
12000 rpm	2 bar	304.0 g/s
	3 bar	292.2 g/s
	6 bar	235.1 g/s





CFD Results for Straight Rotors

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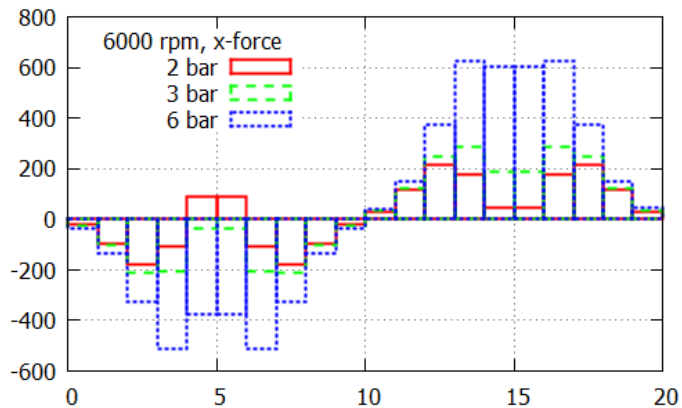
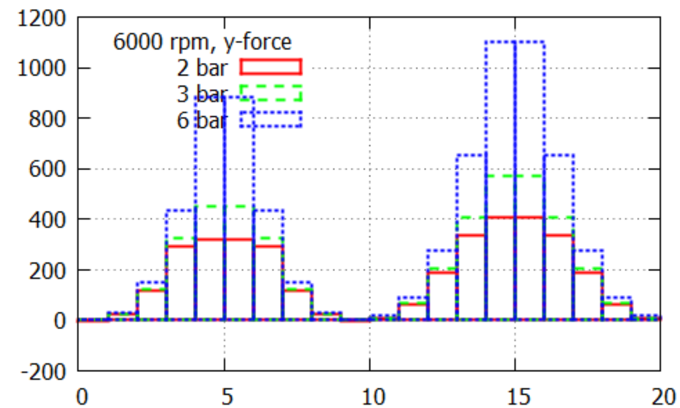
Time-averaged forces on 10 rotor segments:

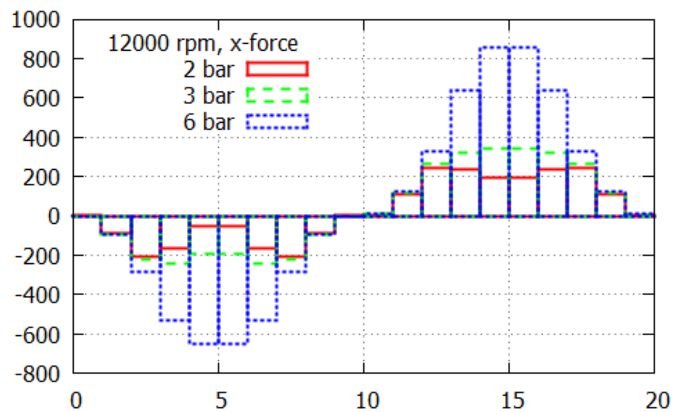
Outward forces („x“) | Downward forces („y“)

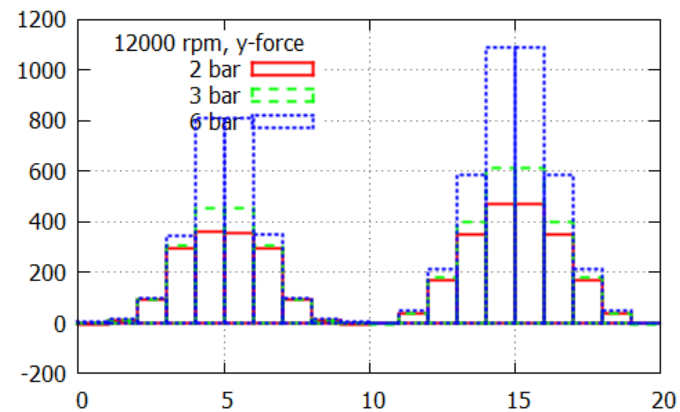
6000 rpm

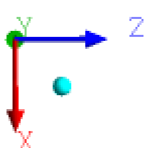


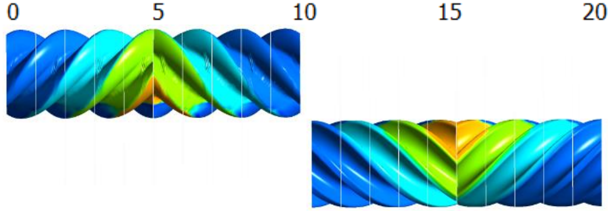


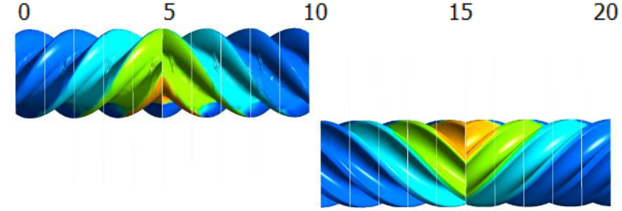
12000 rpm







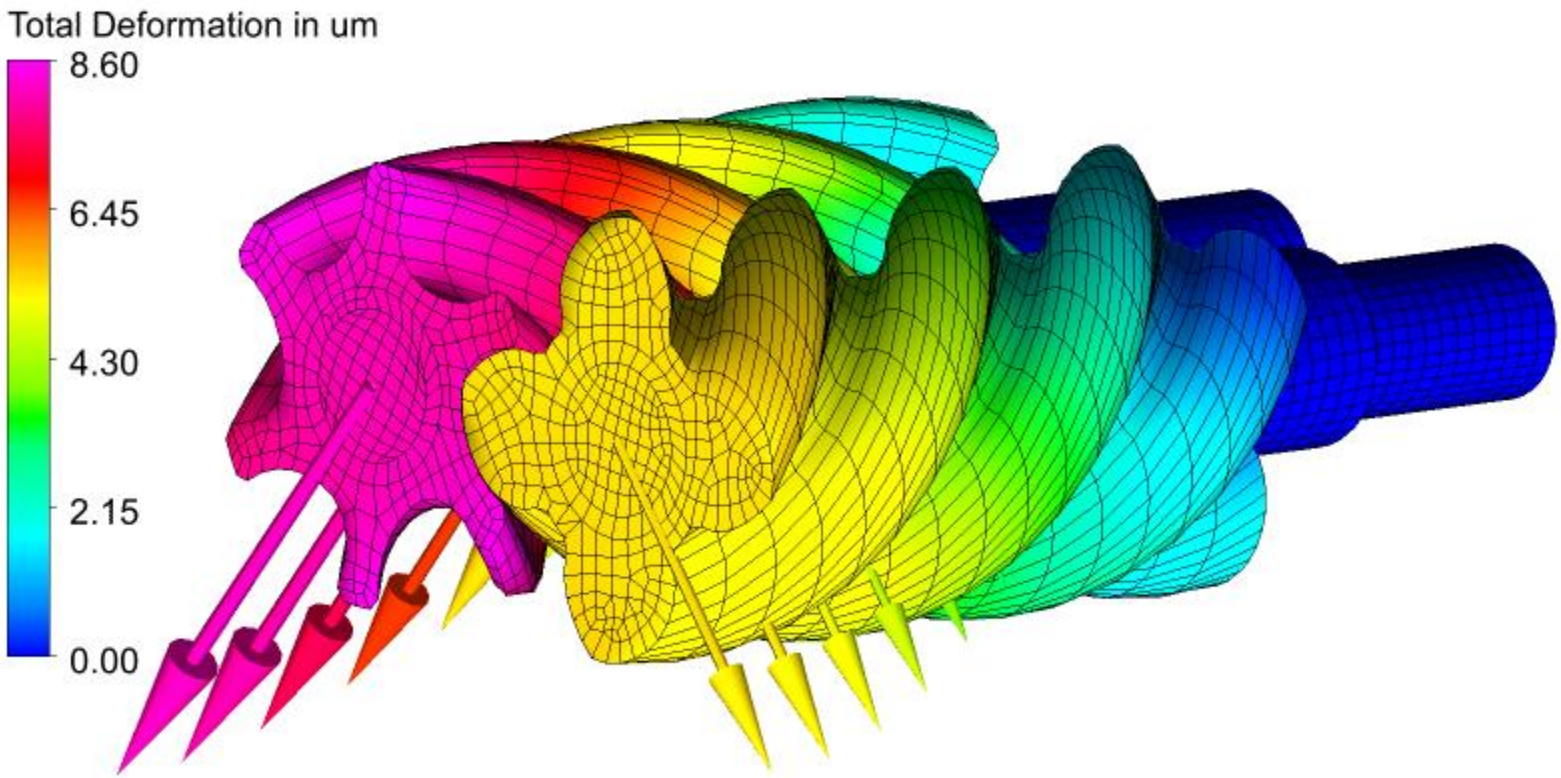




FEM Simulation

Calculation of deformation in steady-state CSM simulation with forces on segments as loads:

- Cylindrical fixation at shaft, symmetry at mid of rotors
- Deformation (and mesh of CSM simulation) for half rotors at 6000 rpm, 6 bar:



FEM Simulation

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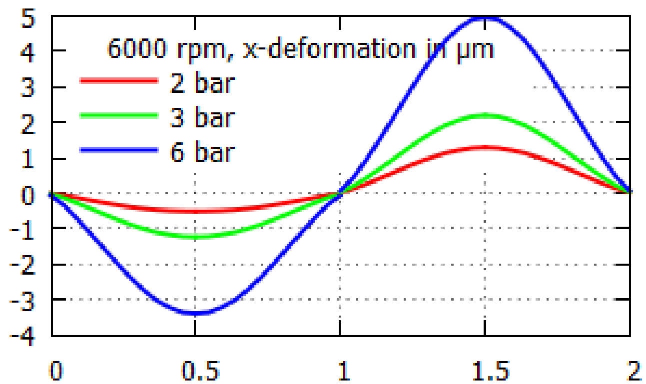
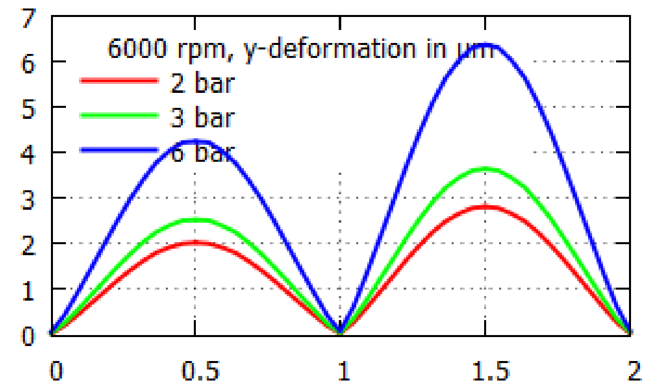
Deformation results in µm from steady-state CSM simulations:

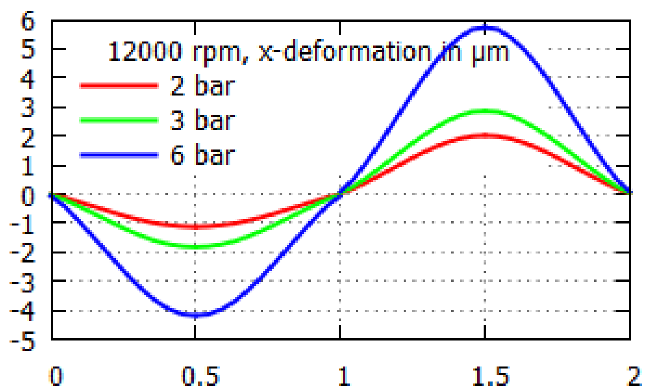
Outward deformation („x“) | Downward deformation („y“)

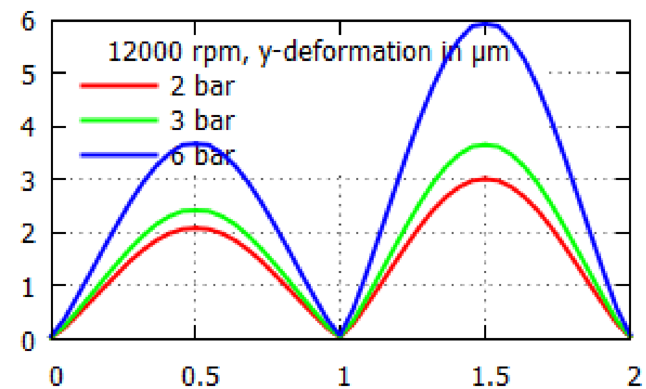
6000 rpm

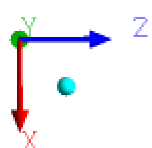


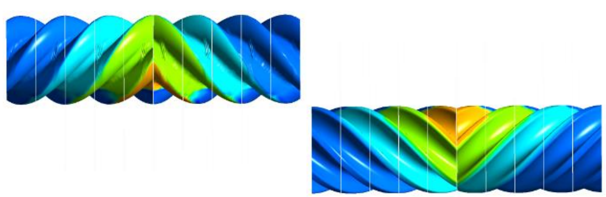


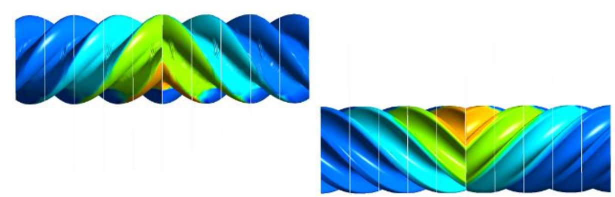
12000 rpm



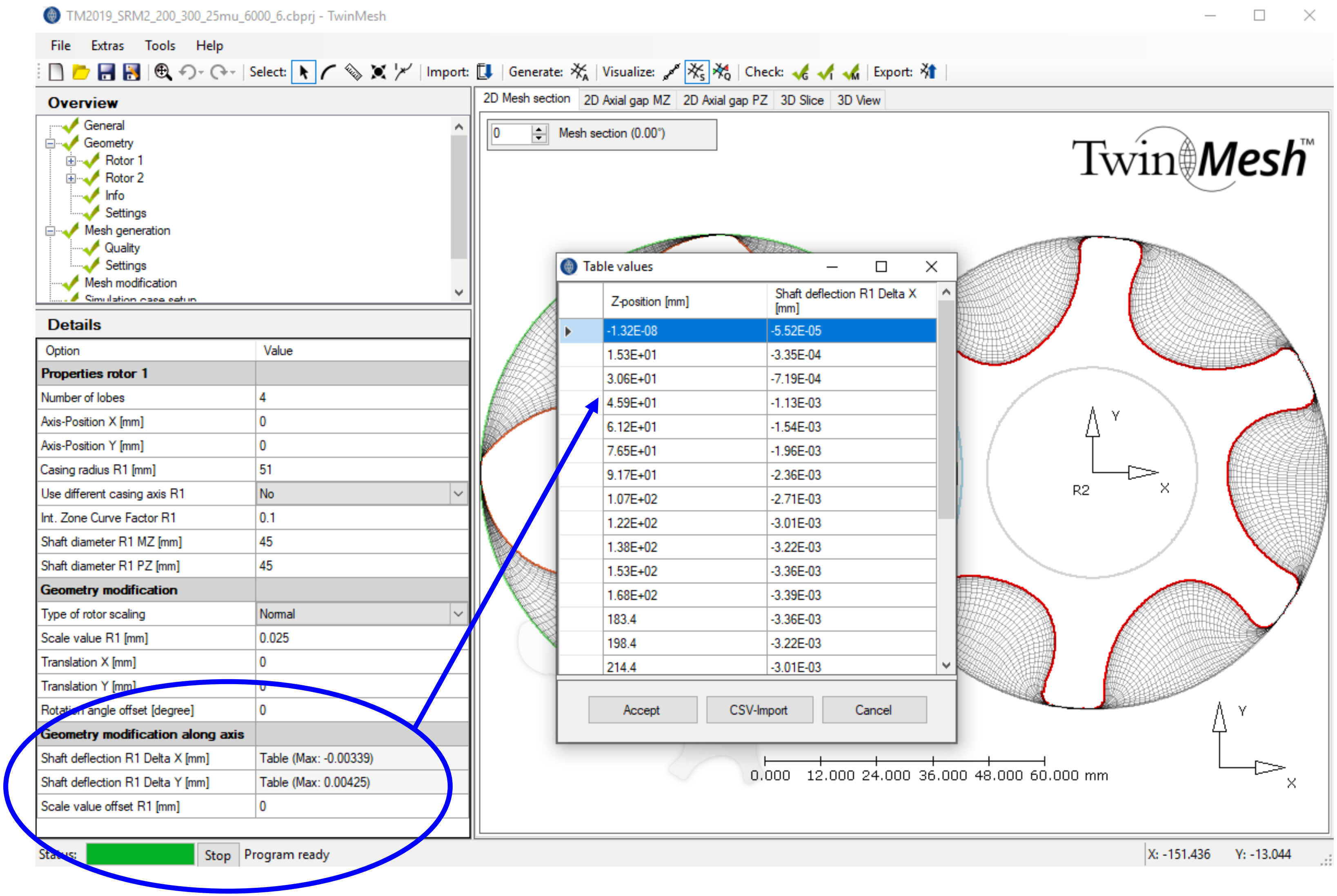








CFD Results for Bent Rotors



TwinMesh

- adds deflections in x and y as functions of z to each rotor surface, and
- deforms 3D meshes between bent rotor and straight casing
- at each rotation angle

→ New meshes

CFD Results for Bent Rotors

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CFD simulation with bent rotors :

- Deformation increases gap size between rotors (50 µm → 58 µm) and between rotor and upper casing (25 µm → 31 µm)
- Higher gap size ➔ higher leakage flow ➔ less mass flow rate
- Here effect is small (<1%), except of 6 bar cases (2% to 70%)

Configuration		Straight rotors	Bent rotors
Rotation speed of male rotor	Pressure at outlet	Average mass flow	Average mass flow
6000 rpm	2 bar	147.5 g/s	147.5 g/s
	3 bar	131.3 g/s	131.2 g/s
	6 bar	28.7 g/s	8.7 g/s
12000 rpm	2 bar	304.0 g/s	303.9 g/s
	3 bar	292.2 g/s	290.5 g/s
	6 bar	235.1 g/s	231.0 g/s

Summary and Outlook

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- 3D CFD simulation of positive displacement machines
  - Established tool for design and optimization
  - Fine meshes, complex physics, fast rotation, transient behaviour

- Simulation of two-sided screw compressor
  - No axial force, both bearings at low pressure, but high pressure in mid (→ CFD)
  - Forces on rotors lead to outward and downward deformation (→FEM simulation)
  - Deformation lines can be taken into account in rotor profile meshes (→ TwinMesh)
  - Bent rotor profiles lead to larger gaps, larger leakage flow, smaller mass flow rate

➢ Further possibilities:
  - Bearing play due to forces (shift of rotation axes)
  - Thermal expansion of rotors due to solid heating
  - Pressure and thermal effect on casing deformation (tbd)
  - Consideration of transient forces and deformations (tbd)

More information…

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Visit us at our stand here at the conference!

www.twinmesh.com → machine types, features, blog, webinars, resellers, contact info

www.youtube.com/CFXBerlin → Videos

Local resellers:

- China: PERA Global Technology Ltd
- France: A.D.D.L.
- UK/Ireland: CADFEM UK CAE Ltd.
- Italy: EnginSoft Spa
- India: CADFEM Engineering Services India Pvt. Ltd.
- Korea: ANFLUX Inc.
- Taiwan: CADMEN Taiwan Auto-Design Co.
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Some TwinMesh users…