CFD Simulation of a Two-Stage Twin Screw Compressor including Leakage Flows and Comparison with Experimental Data

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Introduction

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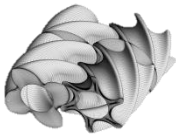
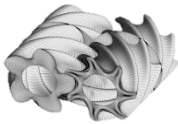
- CFD Simulation of a two stage twin screw compressor (oil free)
- Sample screw compressor from Sullair A Hitachi Group Company
- Feasibility study:
  - Direct coupling of the stages regarding flow field instead of separate simulations with adequate boundary conditions at discharge port (1st stage) and suction port (2nd stage)
- Comparison with experimental data
  - Characteristic curve for volumetric flow rate and power
- Challenges:
  - Time dependent change of complex rotor chambers
  - Coupling of two compressor stages in one simulation setup
  - Different rotational speeds and pitch angles for each stage whereas time step size is the same for the entire model
  - Modeling of cooler between stages

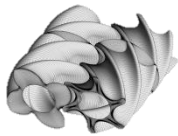
Compressor setup





Suction → Stage 1 → Cooler → Stage 2 → Discharge

Compressor setup



Suction → Stage 1 → Cooler → Stage 2 → Discharge

Main shaft → Friction gear

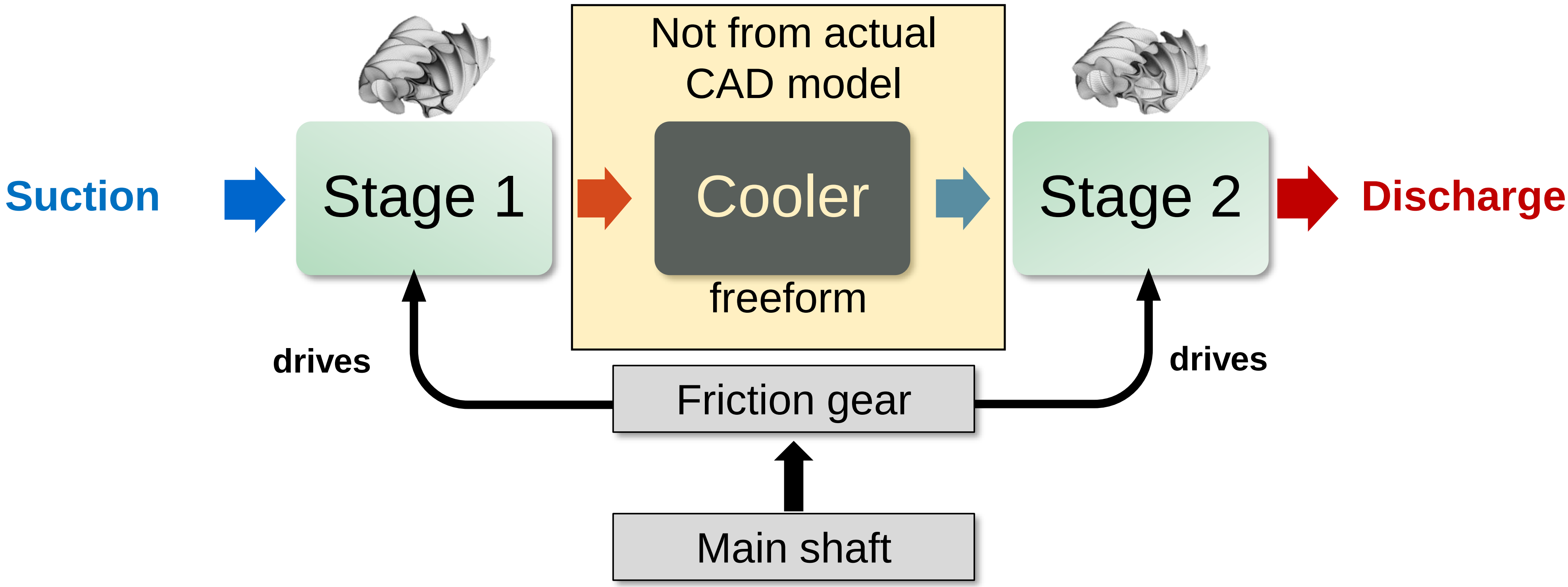
Friction gear drives Stage 1

Friction gear drives Stage 2

MS/Male S1= 6.226
S2 Male /S1 Male= 1.53

1490 rev/min
1790 rev/min
2100 rev/min

Compressor setup

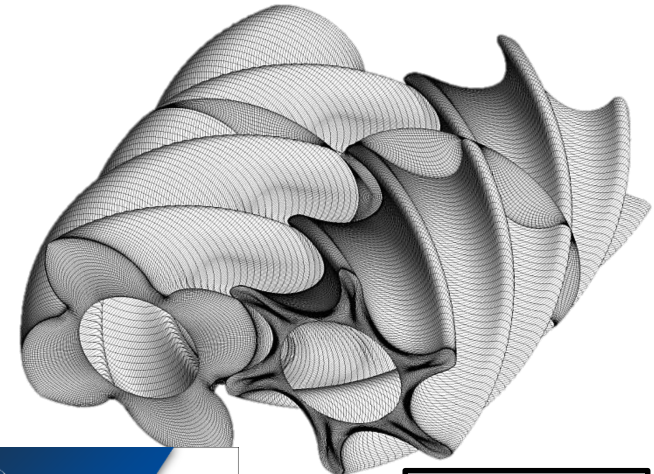


S1 Male / MS = 6.226
S2 Male / S1 Male = 1.53

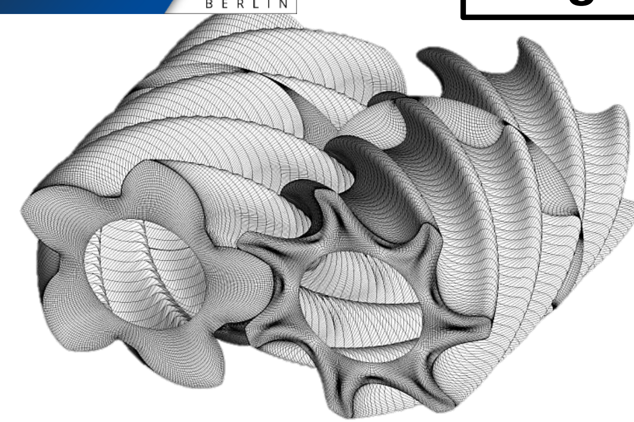
1490 rev/min
1790 rev/min
2100 rev/min

Meshing

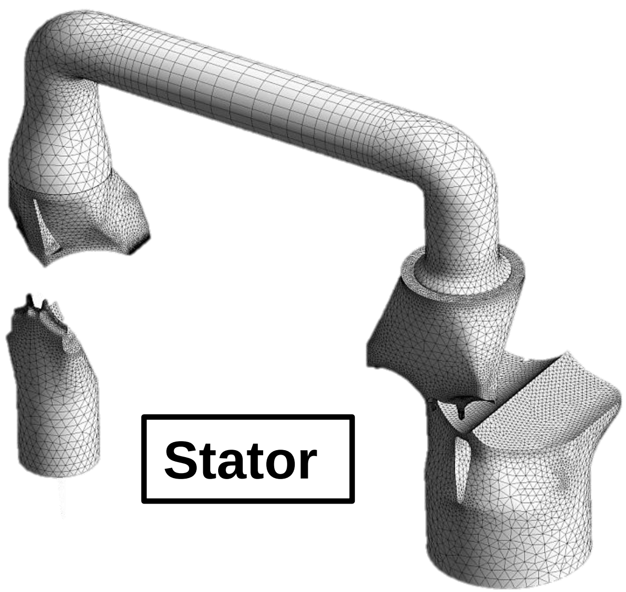
- Stator volumes meshed with ANSYS Meshing
  - 591 625 elements in total
- Rotor volumes meshed with TwinMesh
  - 3 266 560 hexahedrons in total



Stage 1



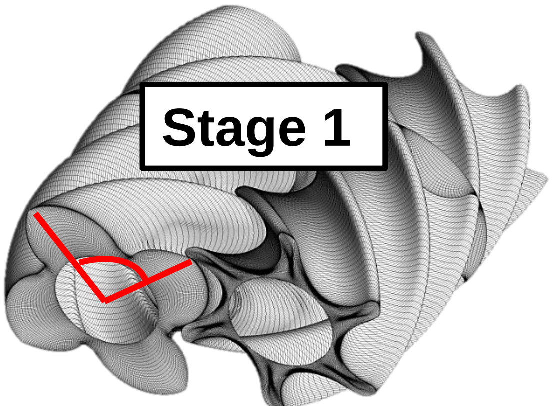
Stage 2



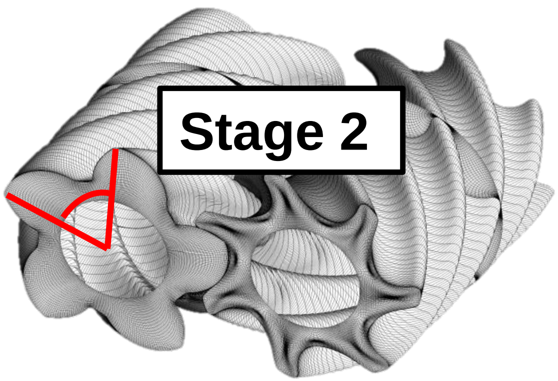
Stator

Meshing

- Coupling of both stages for speed ratio 1.530:



4/6 lobes: pitch angle = 90°



5/7 lobes: pitch angle = 72°

90 meshes for 90° pitch angle = 1°/Δt

47 meshes for 72° pitch angle = 1.532°/Δt

Representation of two rotational speeds with a fixed time step size Δt

Meshing

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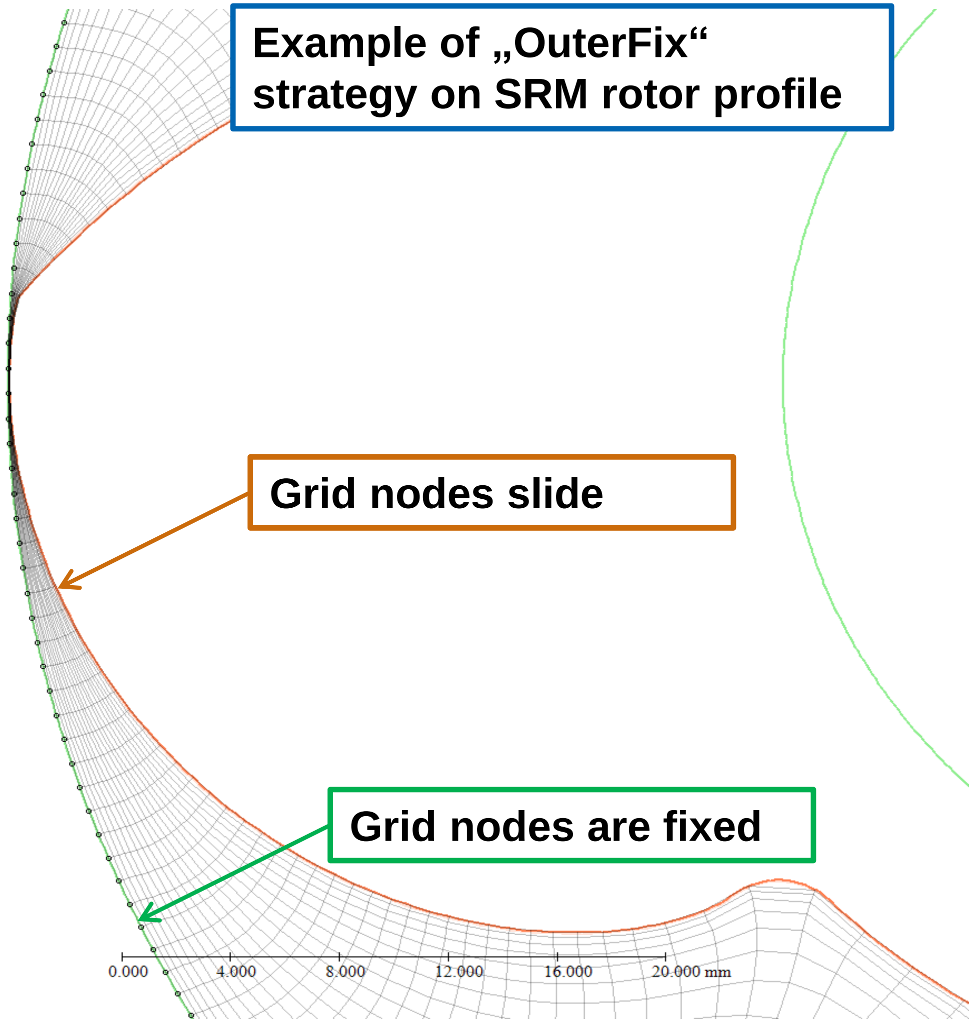
- Meshing strategy (Rotors)
  - Meshes for all rotor positions are pre-generated with TwinMesh
    - 90 meshes with 1° for stage 1
    - 47 meshes with 1.532° for stage 2
  - Nodes are fixed on stator curves and can slide along rotor curves („OuterFix“)
  - After a completed pitch angle (90°/72°), grid nodes have the same position as in the initial position
  - CFD solver needs no interpolation

TwinMesh™ by CFX BERLIN



Meshing

- Pre-generated rotor meshes from TwinMesh:

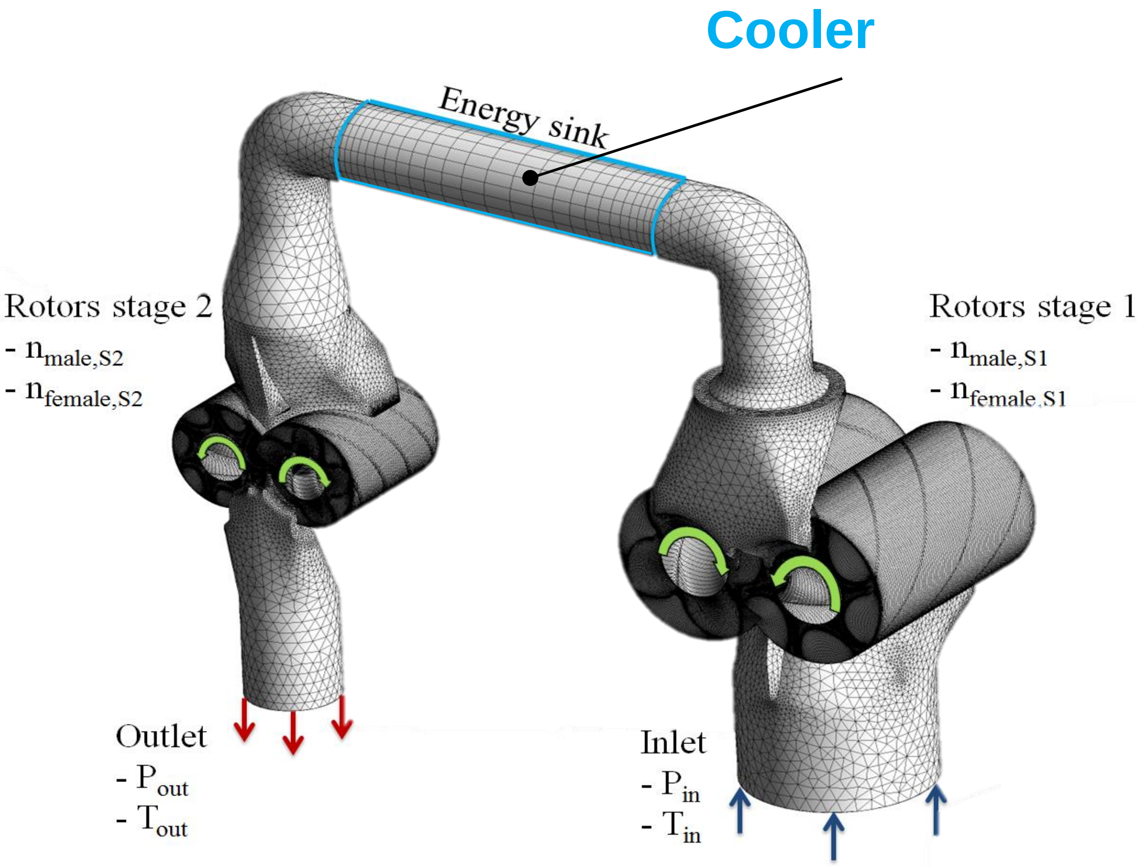
FORTRAN Routine called from ANSYS CFX

Stage 1 fluid domain	Stage 2 fluid domain
Rotor grids 1	Rotor grids 1
Rotor grids 2	Rotor grids 2
Rotor grids 3	Rotor grids 3
.	.
.	.
.	.
Rotor grids 90	Rotor grids 72

1° angle increment | **1.532° angle increment**

Boundary Conditions

- Rotational speeds
  - For each rotor based on gear ratios
- Inlet
  - Absolute Pressure
  - Temperature
- Outlet
  - Absolute Pressure
  - Temperature
- Cooler
  - Energy sink controller with target temperature



Boundary Conditions

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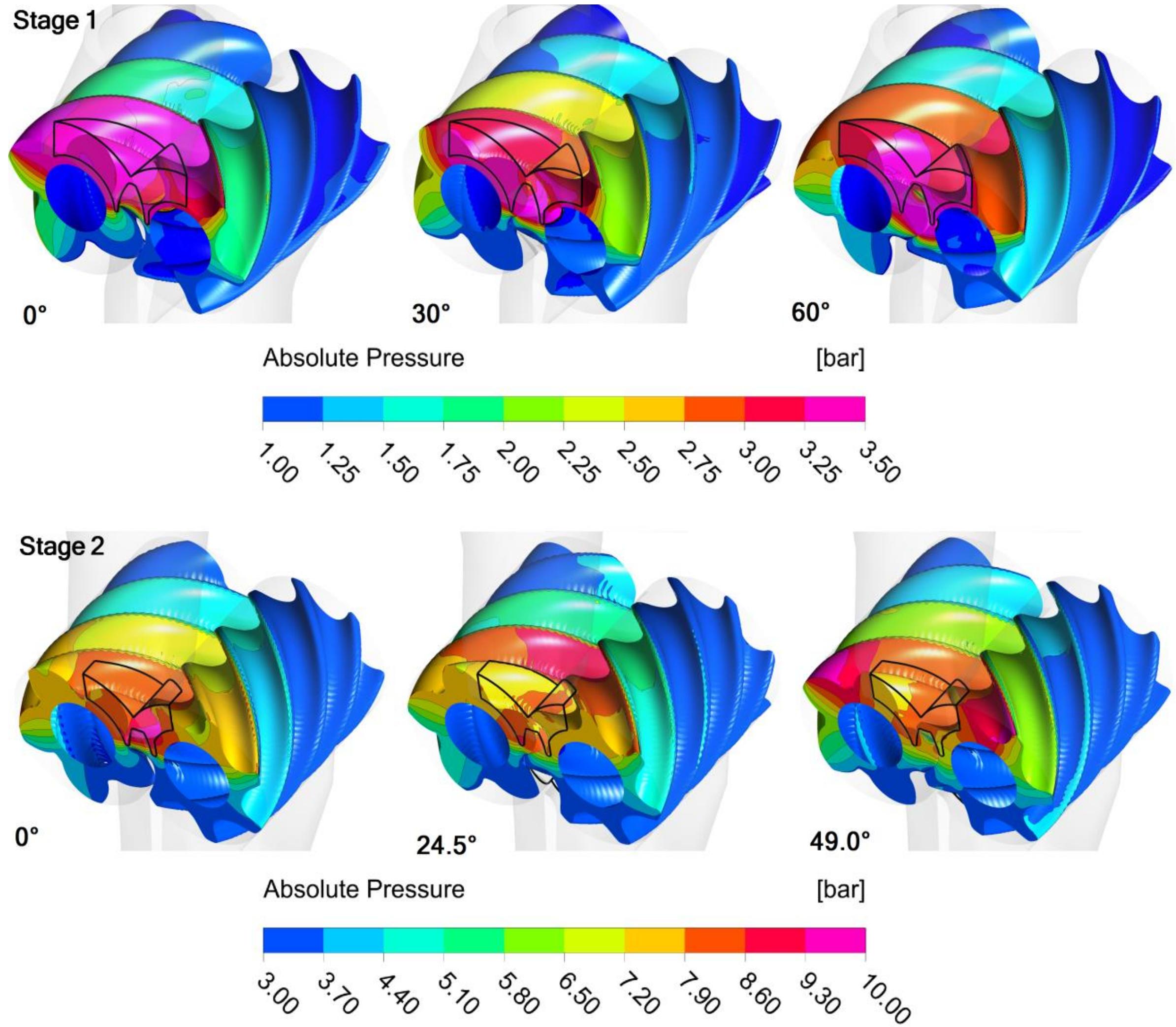
- Simulated operating points (OP)
  - Fluid: Air ideal gas
  - No additional pressure loss modeled for cooler
  - Adiabatic walls
  - SST turbulence model
  - Angle increment of 2° (rotor grids generated with 1° steps)
  - ANSYS CFX on 16 cores: 19 hours/revolution of 1st stage (total 30 revolutions)

Case	Main shaft speed [rev/min]	Inlet Pressure [bar(a)]	Outlet pressure [bar(a)]	Inlet temp. 1st stage [C]	Inlet temp. 2nd stage [C]	Outlet temp. 2nd stage [C]
OP1	1480	1.0	7.98	30.8	31.9	136.1
OP2	1780	1.0	7.98	28.6	34.1	143.0
OP3	2100	1.0	7.98	27.0	37.9	150.8
OP4	1780	1.0	7.89	28.6	34.1	143.0
(Decreased radial clearances)	Housing clearances uniformly by 20%, intermesh closest point by 50%					

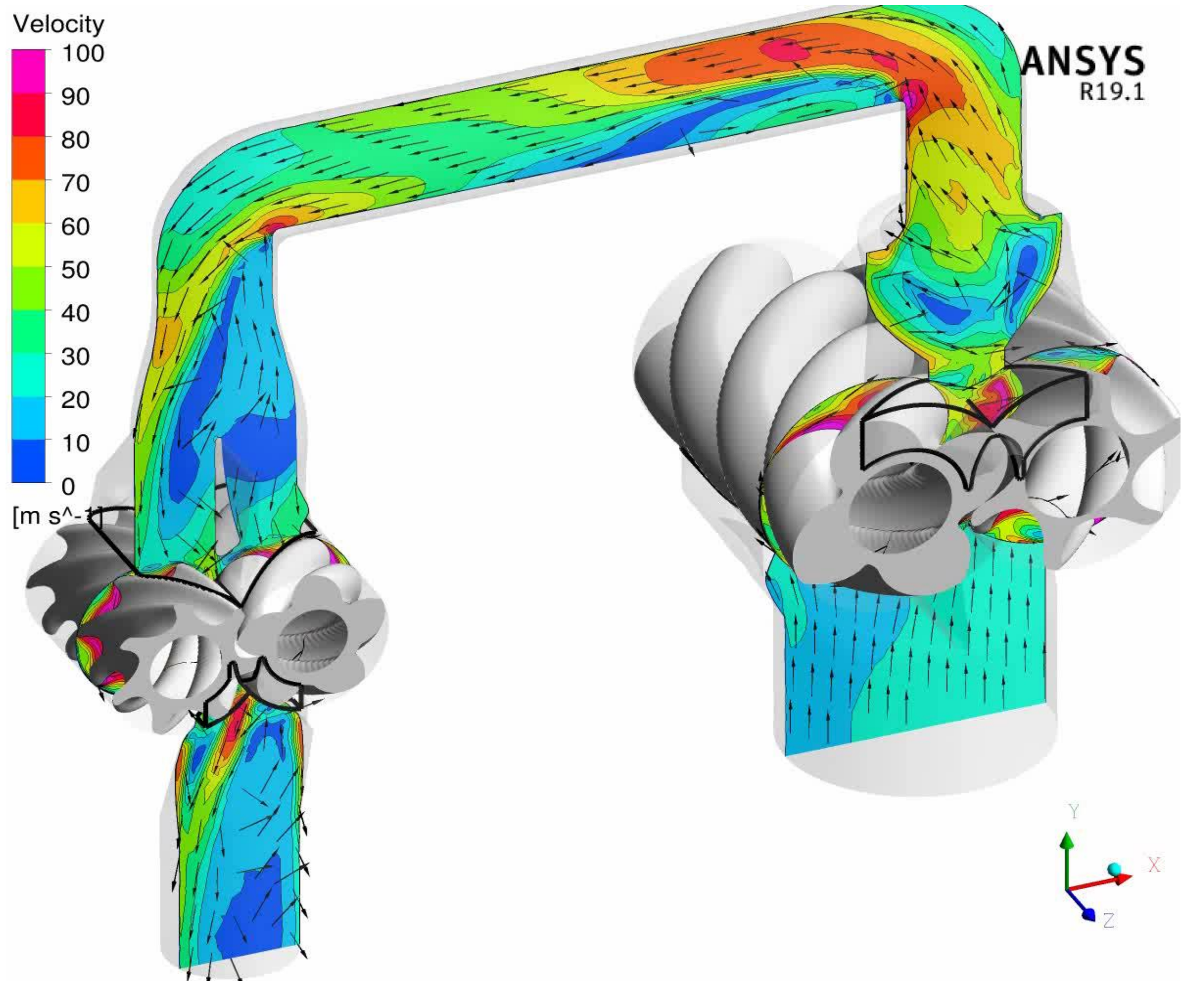
Simulation Results

- Static pressure (OP2)
  - Instantaneous pressure on rotors
  - Cycle over one pitch angle for each stage (repetitive scheme)



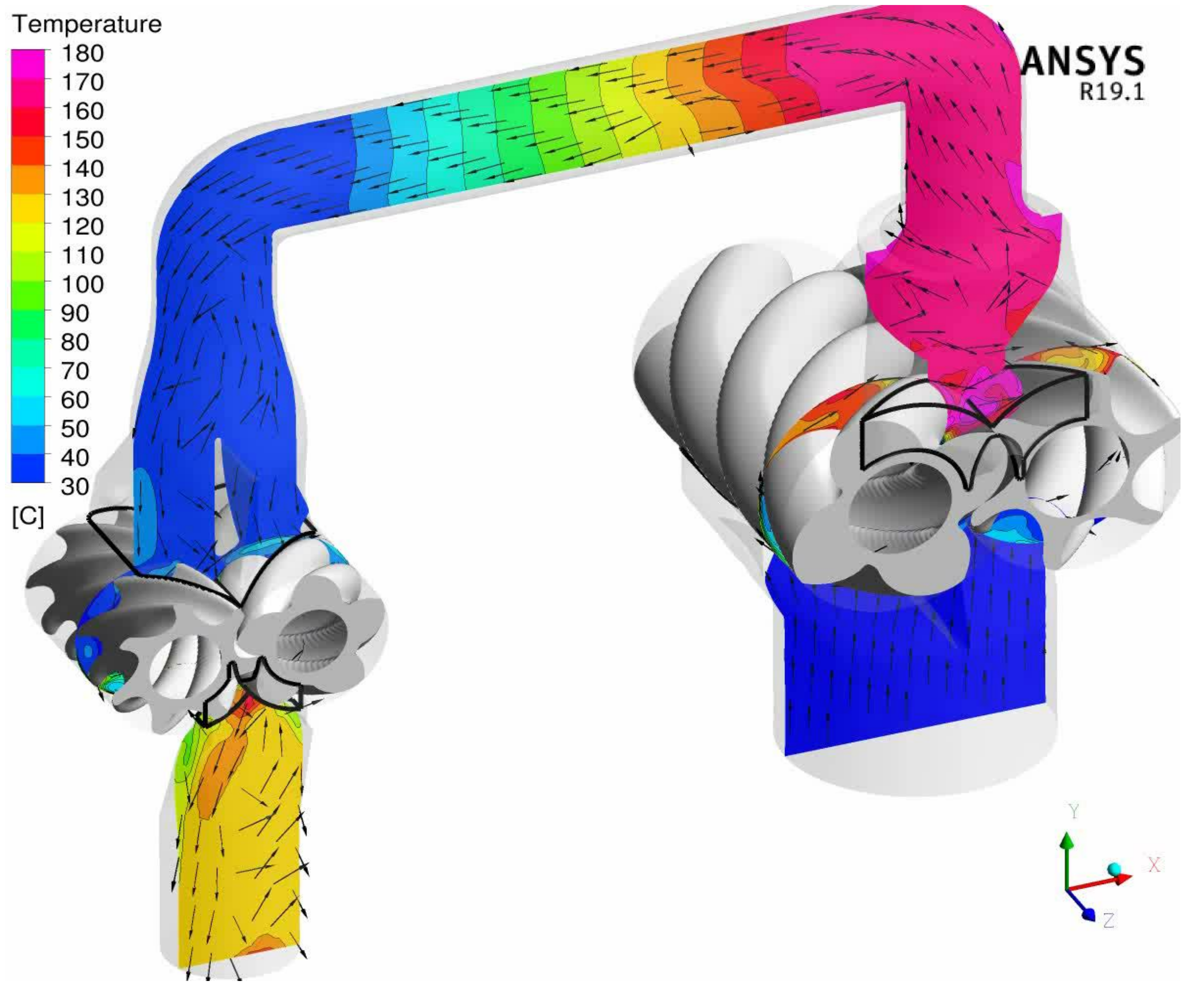
Simulation Results

- Velocity (OP2)
  - Velocity field on a cross section plane through both stages and cooler
  - Animation over 1 revolution of 1st stage male rotor



Simulation Results

- Temperature (OP2)
  - Temperature field on a cross section plane through both stages and cooler
  - Animation over 1 revolution of 1st stage male rotor



Simulation Results

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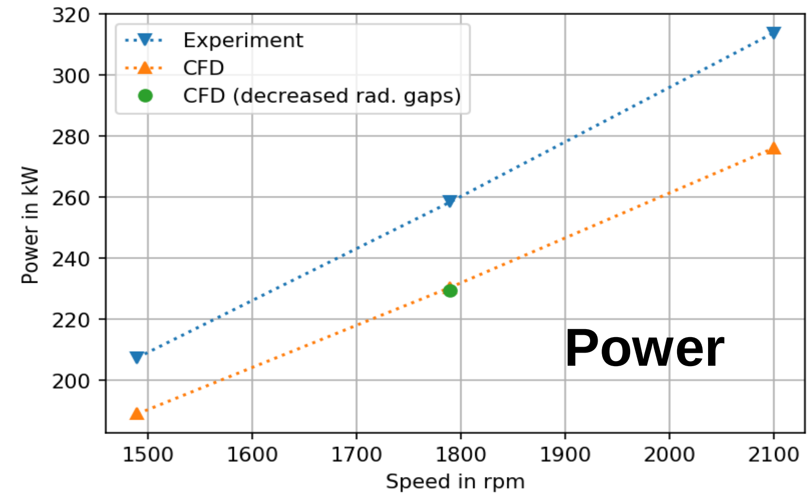
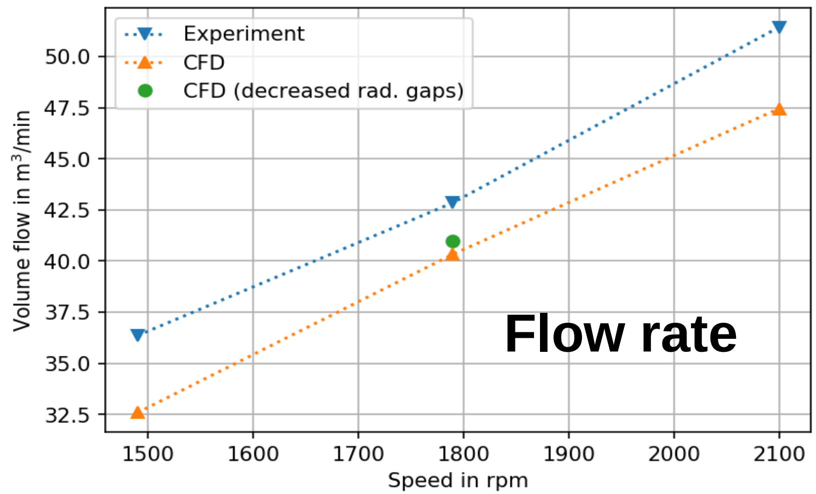
- Comparison with measurements
  - Volumetric flow rate, power and specific power (power/flow rate)
  - 10 to 12% less power necessary
  - 10 to 8% less volume flow rate

	Relative Deviation (CFD from experiment)		
	Flow Rate [%]	Power [%]	Specific Power [%]
OP1	-10.4%	-9.4%	1.1%
OP2	-5.9%	-10.8%	-5.3%
OP3	-7.7%	-12%	-4.7%
OP4	-4.4%	-11.2%	-7.1%





Conclusion and Outlook

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- Successful coupling of both compressor stages within one simulation setup
  - Different rotational speeds modeled with fixed time step size
  - Reasonable results and good match with experimental data
  - Deviation from experiments of 10% in power and 10 to 8% in volume flow rate
  - Little influence of performed clearance change (20% decrease)

- Uncertainties
  - Clearance sizes while compressor is running (cold clearances modelled)
  - Simplified cooler and interstage geometry (no pressure loss)
  - Power losses due to gears and bearings not included

- Outlook
  - Analysis with non-reflective boundary conditions
  - Effect of solid heating / CHT with thermal expansion and forces on gap sizes
  - (Spline) interpolation between pre-generated meshes allows independent meshing

More information…

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.
- Turkey: Navist Mühendislik

Some TwinMesh users…