



Several Examples of Turbomachinery Design and CFD-Simulation using **CFturbo[®] and STAR CCM+**

Ralph Peter Mueller
CFturbo Software & Engineering GmbH
Munich, Germany

in collaboration with Michael Hailfinger, Daniel Poescha, Anne Schubert and Ganeshkumar Udayakumar

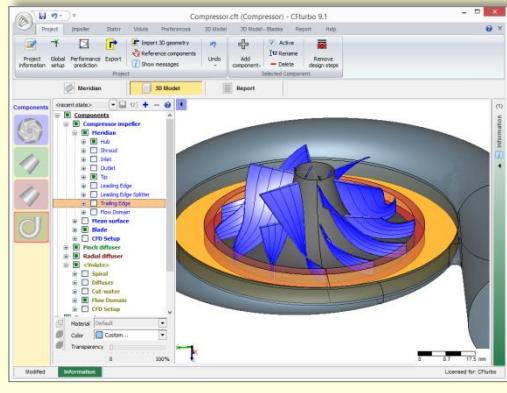
兆水科技應用案例
www.cfturbo.com

Company

CFturbo® Software & Engineering GmbH

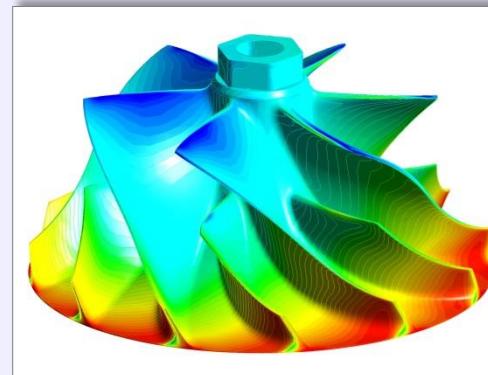
CFturbo® Software

- Turbomachinery Design Software
- Automated Workflows



Engineering

- Turbomachinery Conceptual Design
- CFD/FEA Simulation
- Optimization



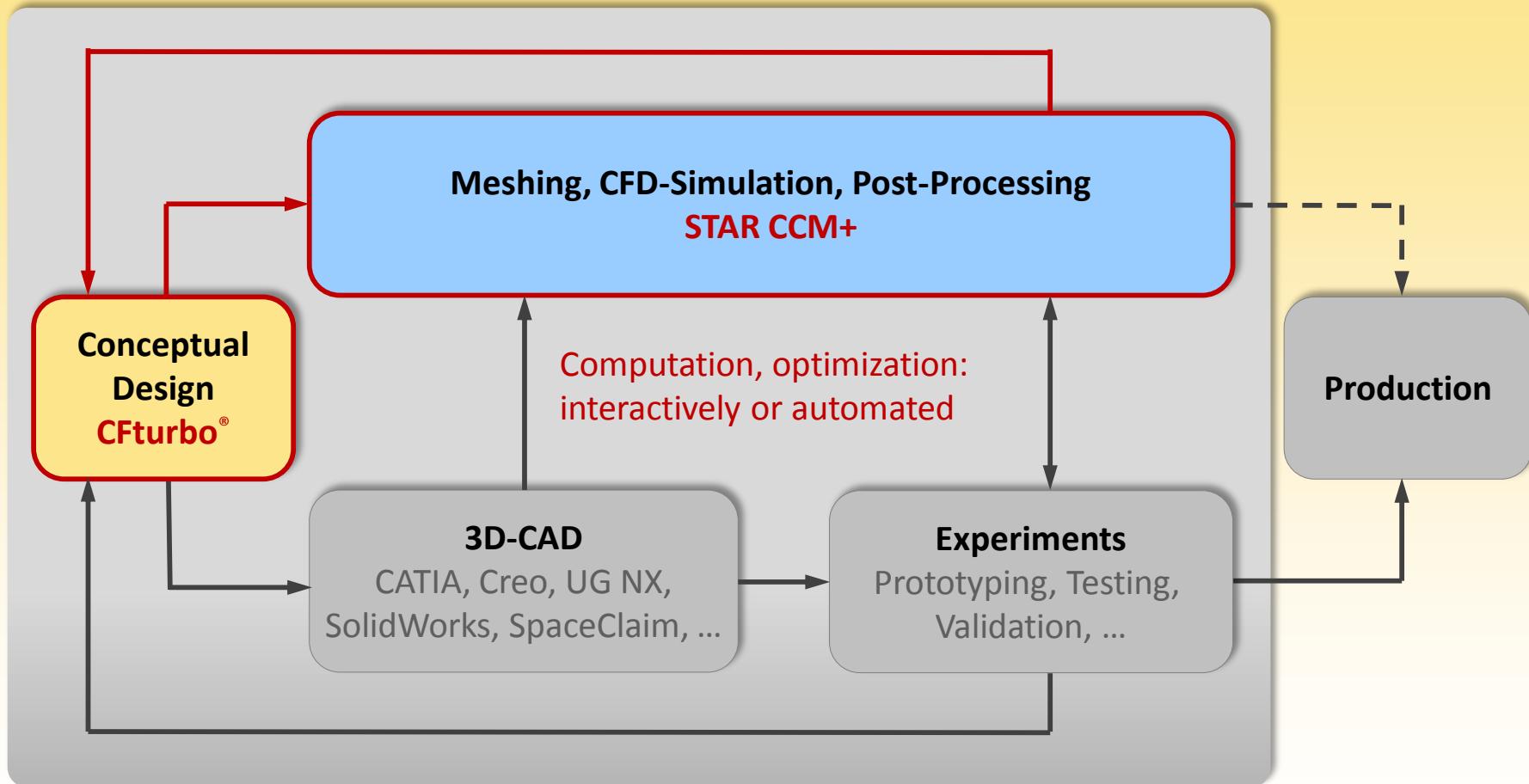
CAD & Prototyping

- 3D-CAD Modeling
- Prototyping
- Testing, Validation



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Turbomachinery Design Process



Manual „Optimization“ Workflow

→ Transsonic Radial Compressor

Traditional common workflow: 5 ... 25 model variations, 1 to 4 weeks,

Design point (BEP)

Total pressure ratio:

$$\Pi_{tt} = 4$$

Mass flow rate:

$$\dot{m} = 0.11 \text{ kg/s}$$

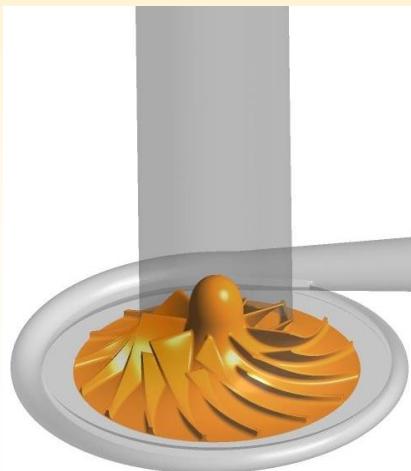
Speed:

$$n = 90.000 \text{ min}^{-1}$$

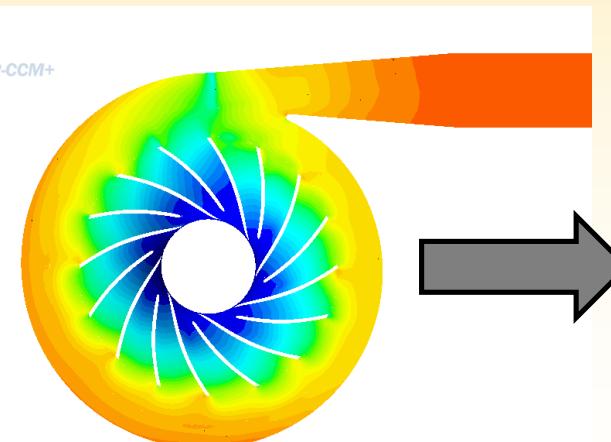
Power (limitation):

$$P_m < 30 \text{ kW}$$

20 Designs



20 Performance Curves



1 Prototype

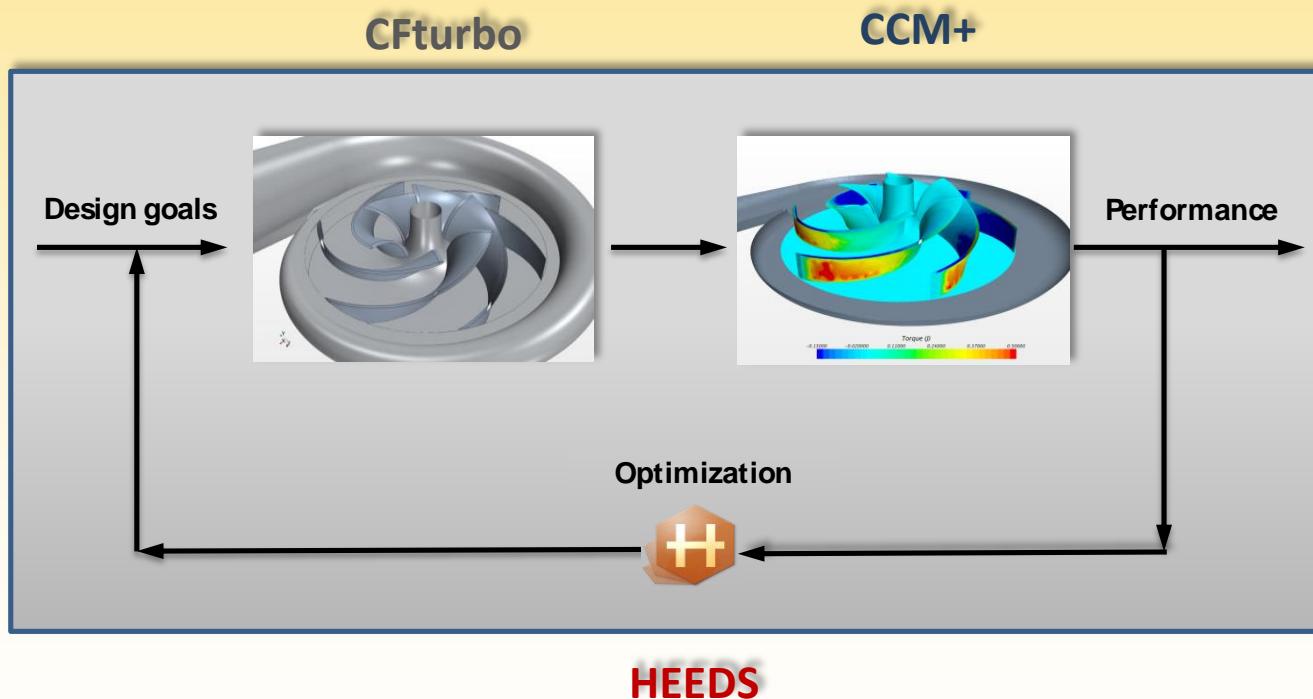


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Automated Optimization Workflow Available

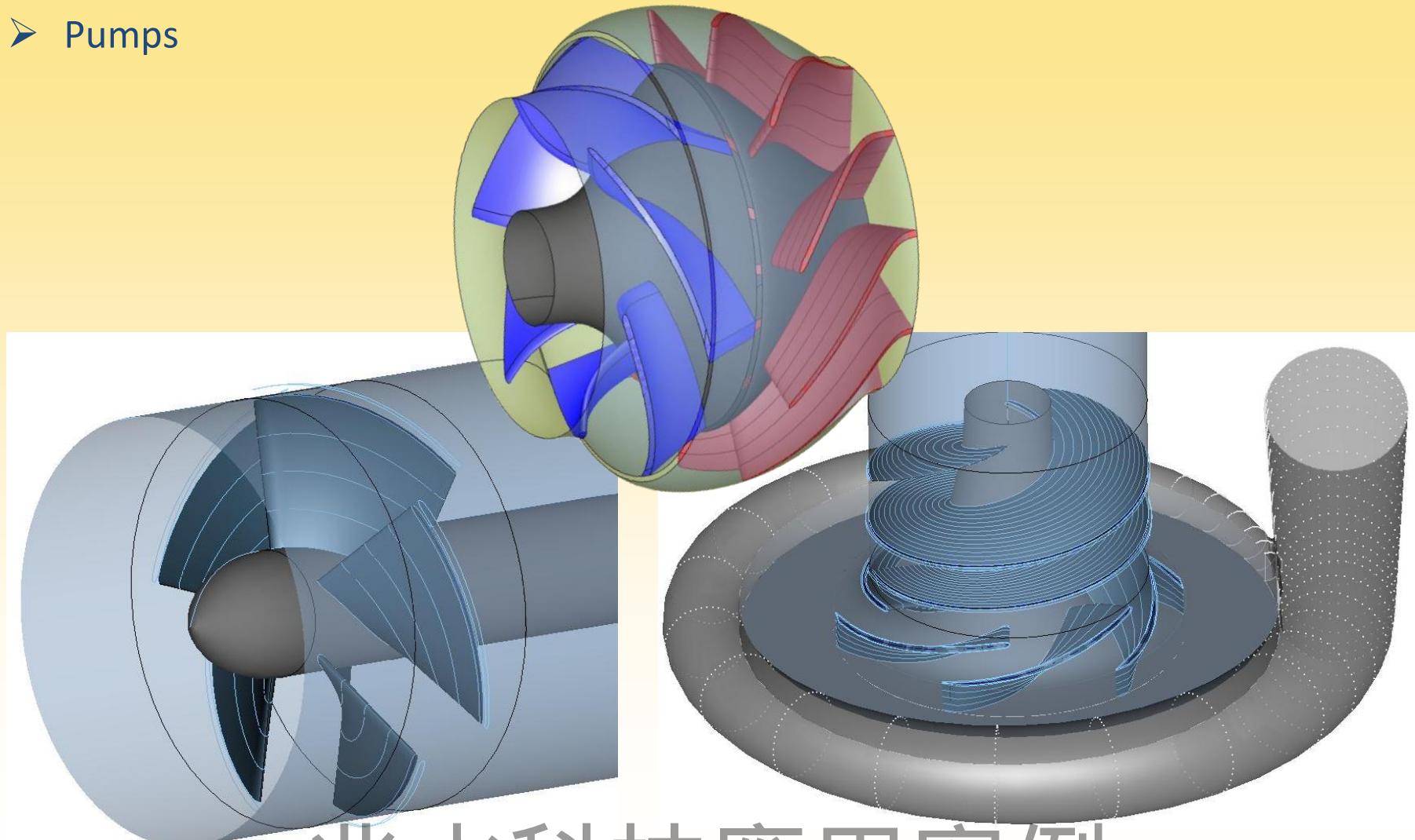
→ Centrifugal Pump Impeller Optimization

300 automated model variations, time & cost depending on available resources



CFturbo Model Overview

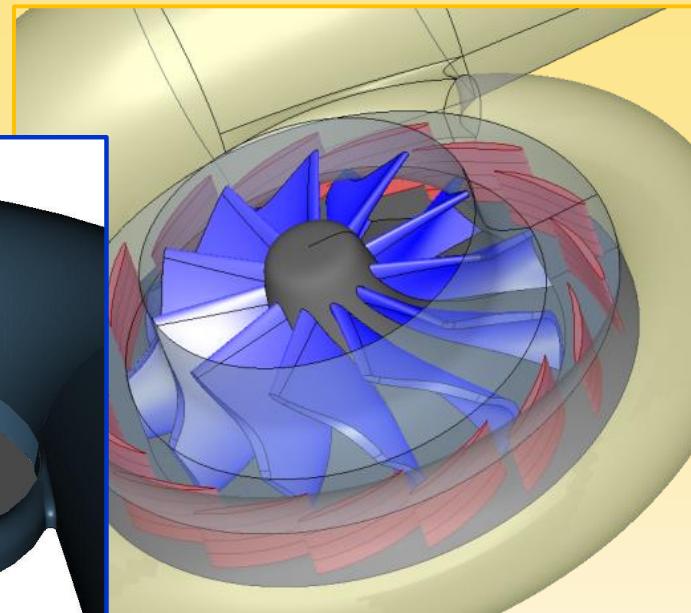
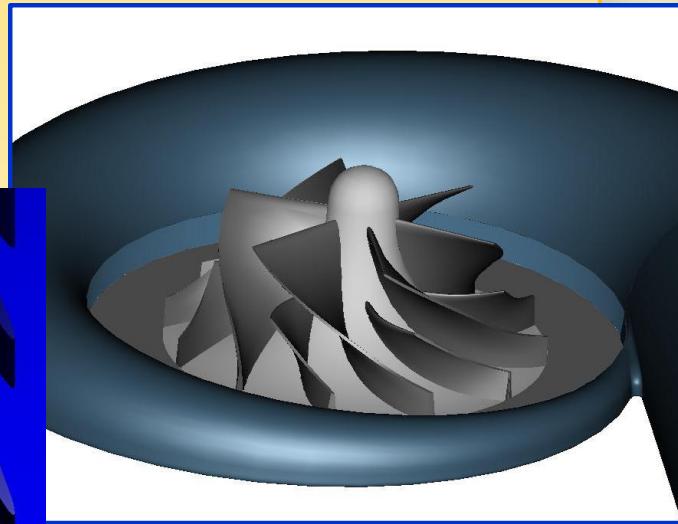
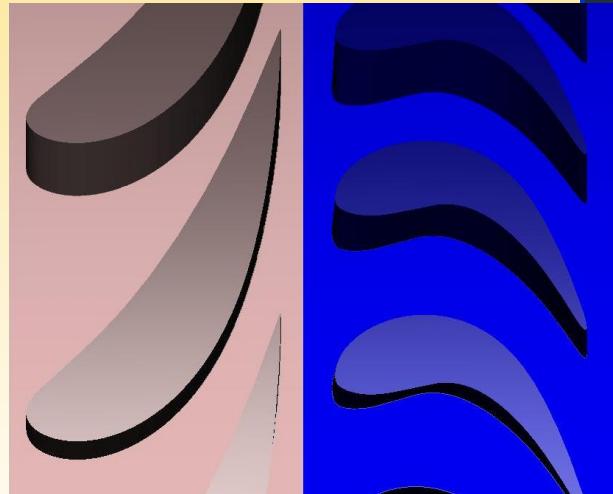
- Pumps



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CFturbo Model Overview

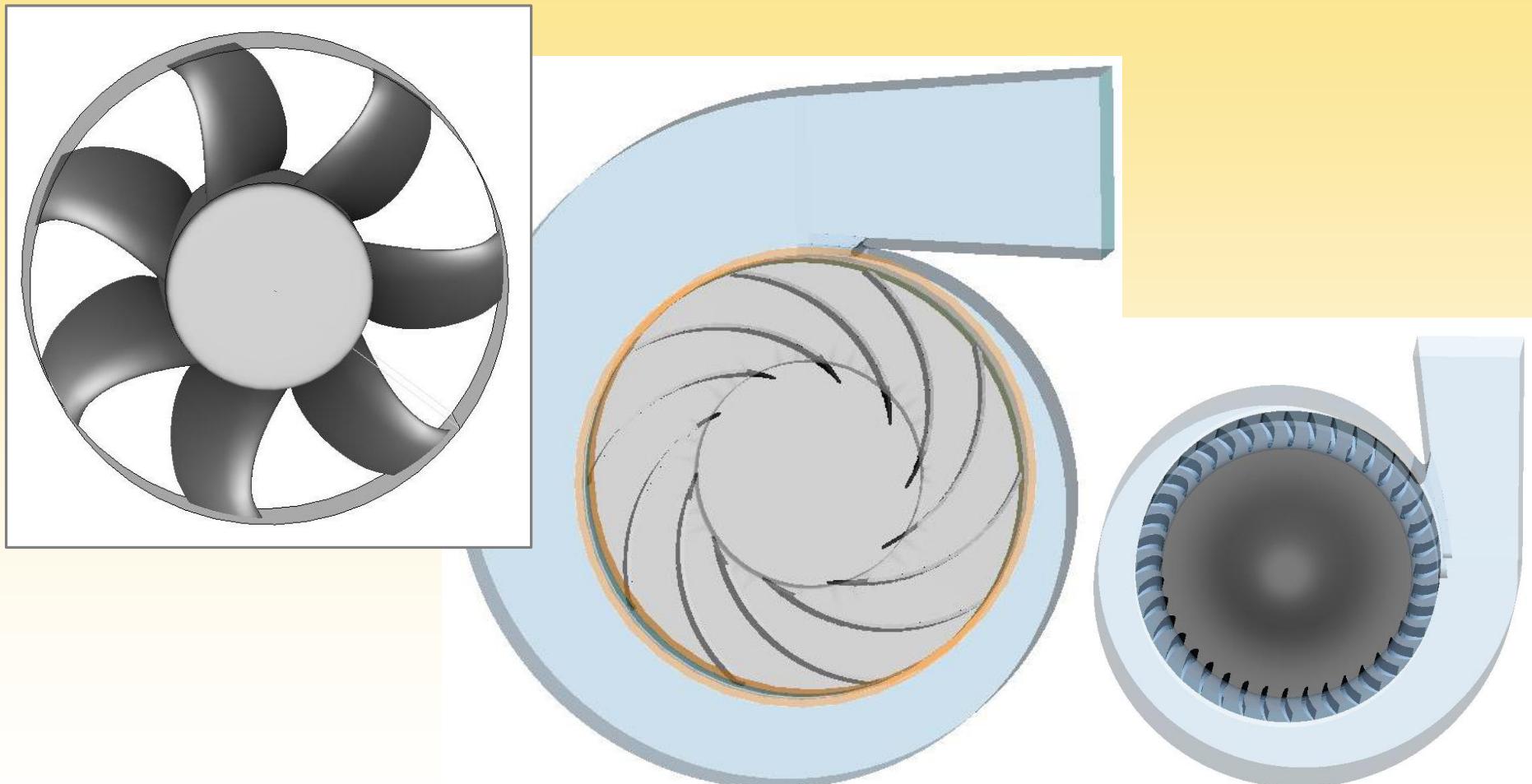
- Compressors, Turbines



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CFturbo Model Overview

- Fans, Blowers

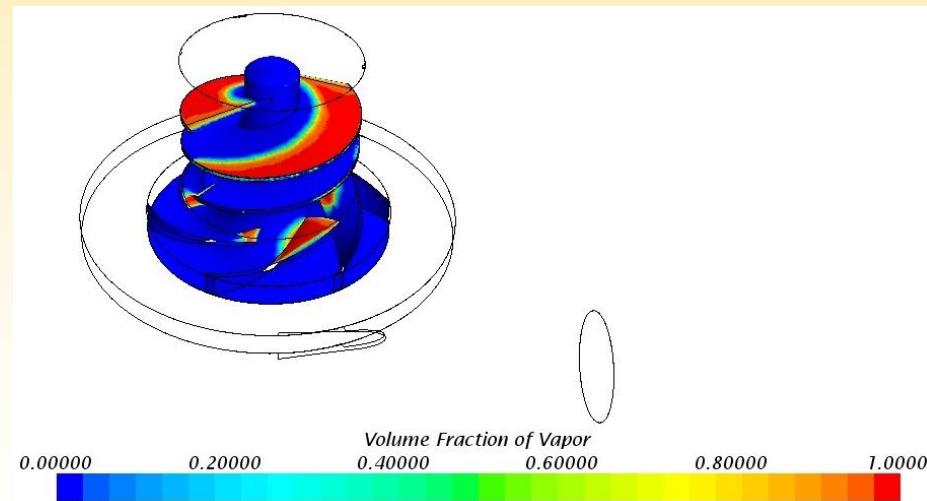
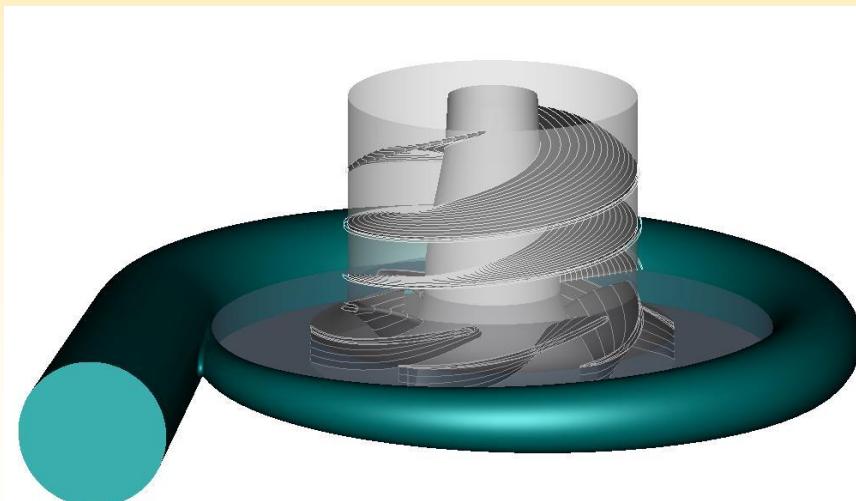
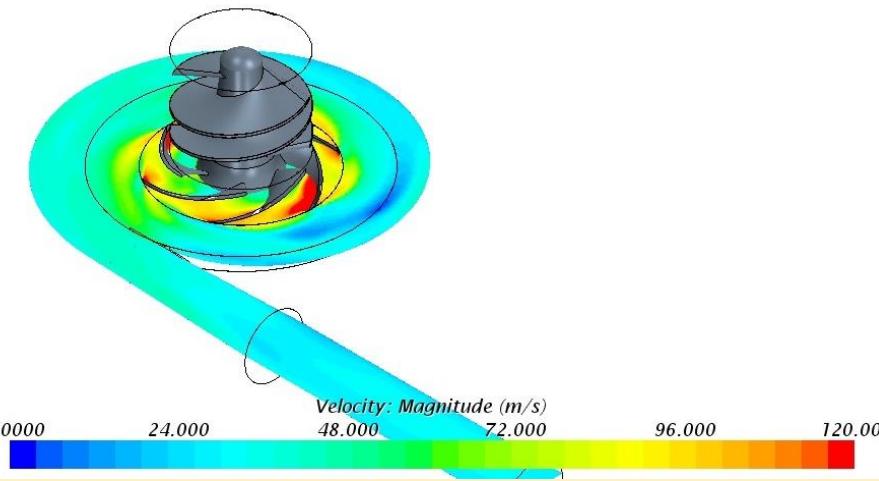


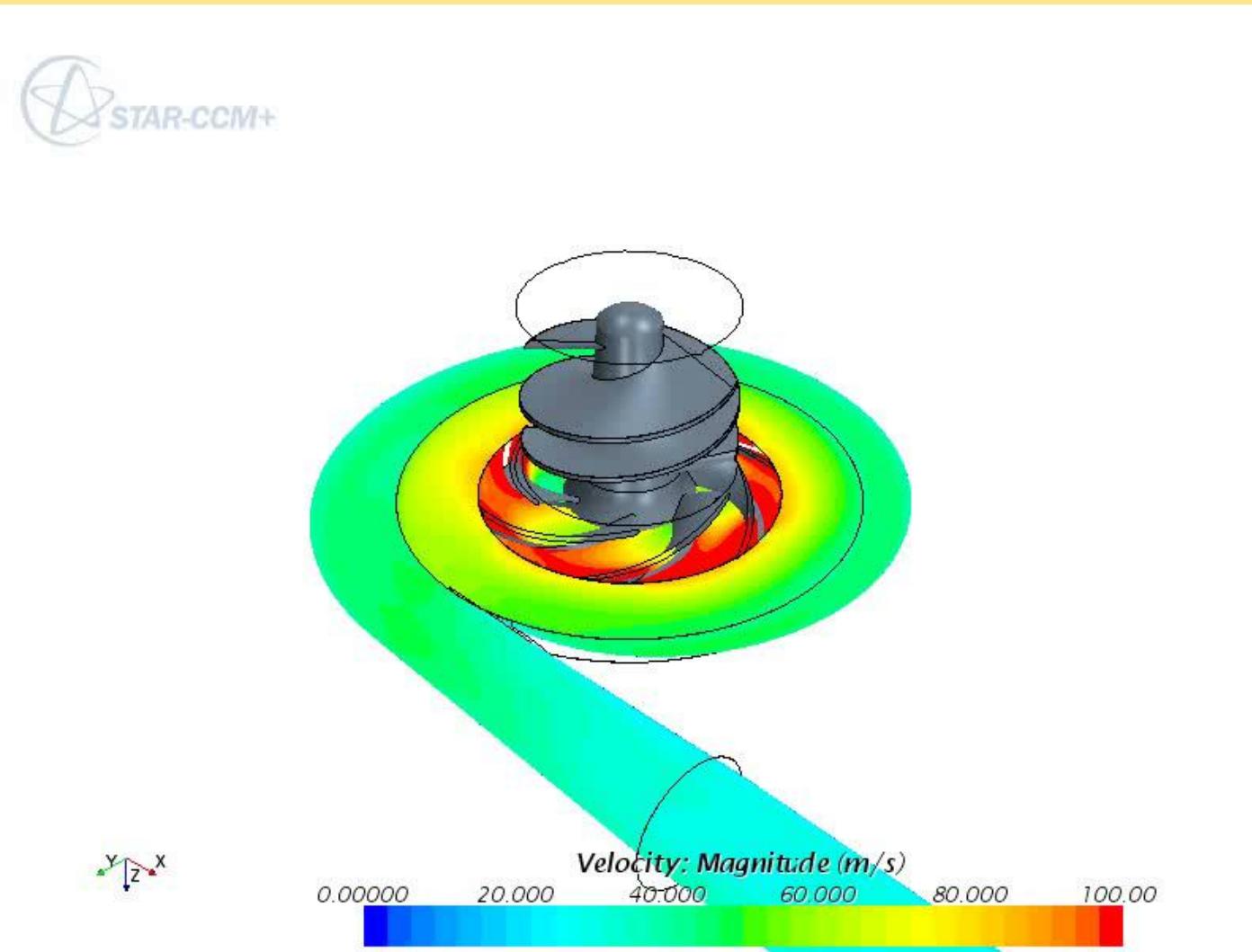
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Example 1. Radial Pump with Inducer

Comments

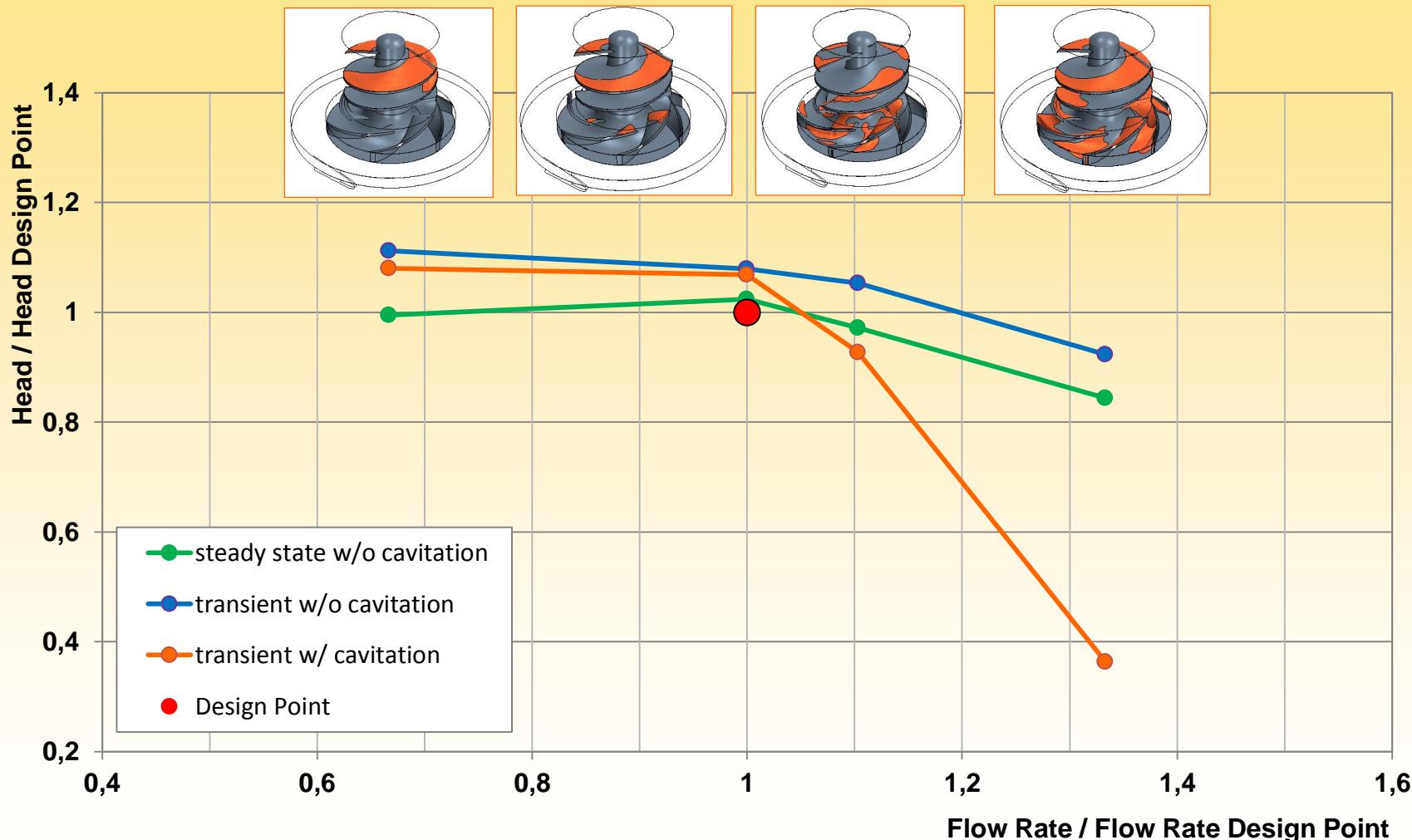
- Generic CFturbo design, 5 design variations
- $Q=600 \text{ m}^3/\text{h}$, $\Pi=120 \text{ bar}$, $n=12000 \text{ rpm}$
- Compare CFD-simulation
 - Steady State, no cavitation
 - Transient flow, no cavitation
 - Transient flow, with cavitation
- No experimental are data available



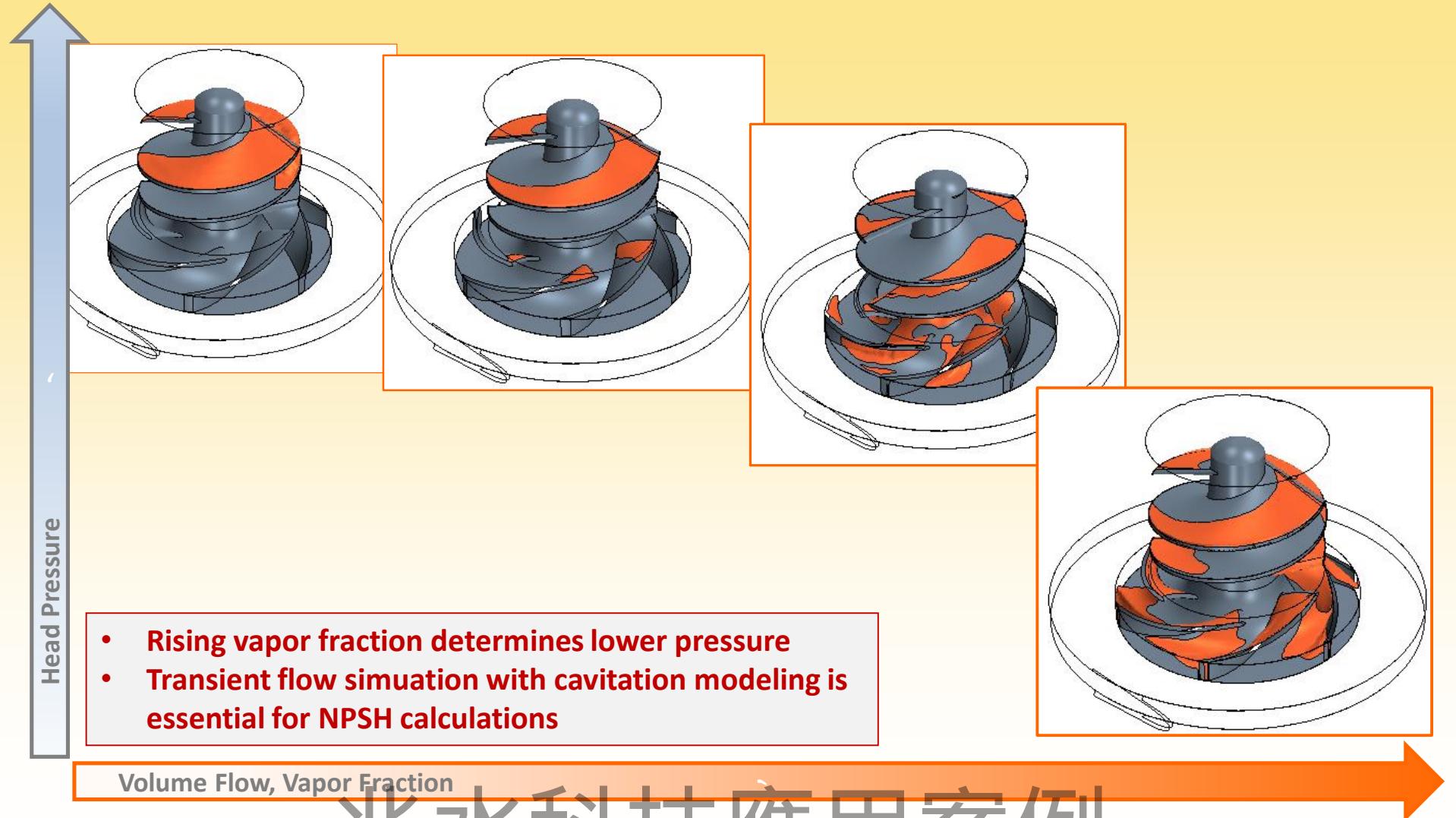


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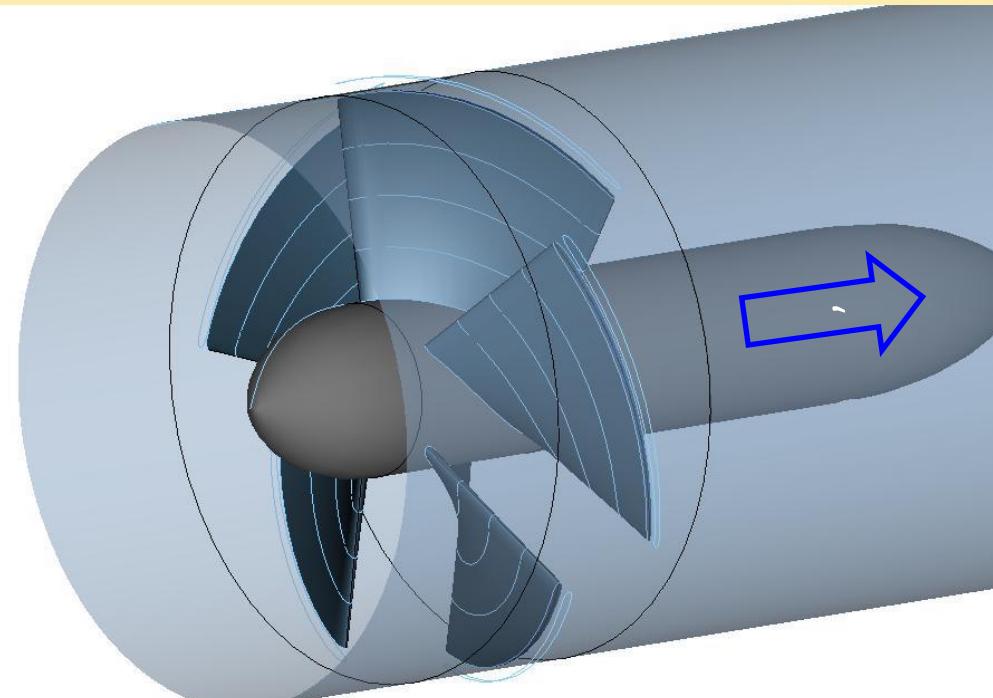


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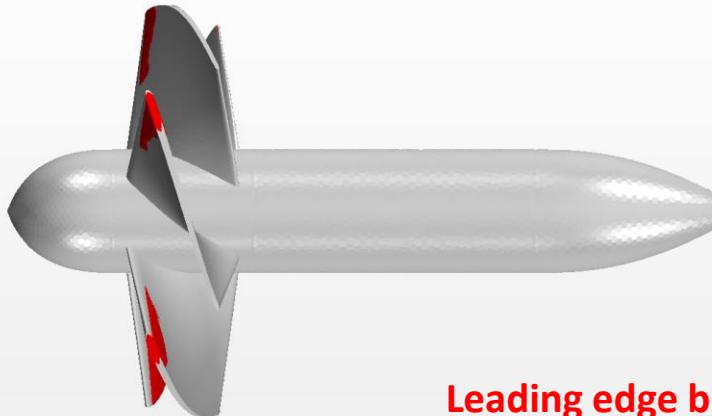
Example 2. Initial Design Axial Pump

- Typical design point for axial pump defined
- First initial conceptual design by CFturbo
- No diffuser or inlet guide vane. Rotor in pipe.
 - $n = 780$ rpm
 - $H = 15.6$ feet
 - $Q = 23,400$ gpm
 - $NPSH_r = 27$ feet
 - Tip diameter = 23 inches
 - Shroud diameter = 23.25 inches
 - 0.3 hub/tip ratio
- Steady state & transient Simulation,
- Cavitation

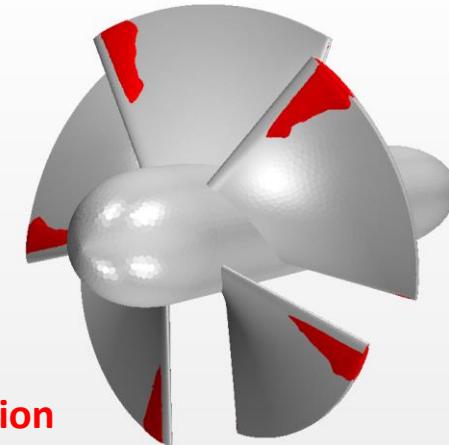


Example 2. Initial Design Axial Pump

STAR-CCM+



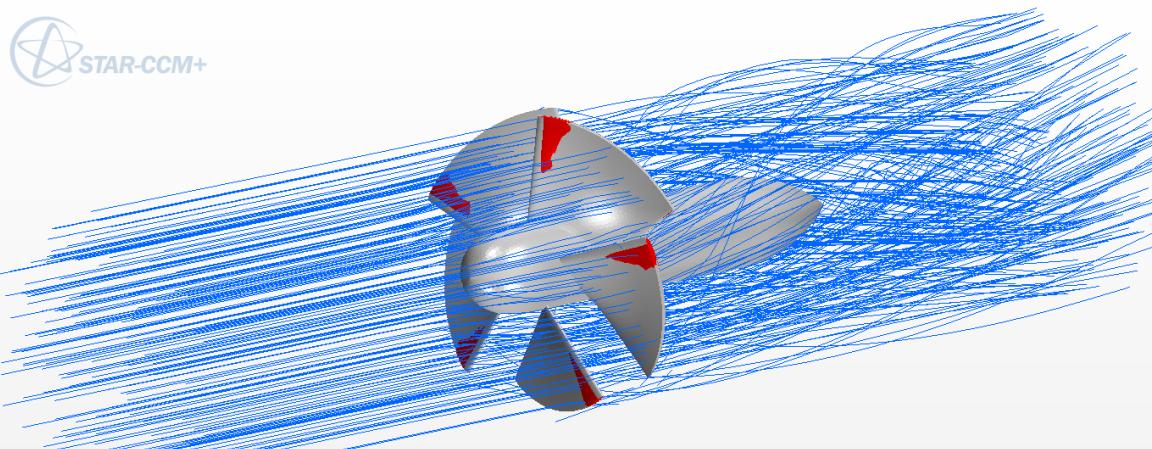
STAR-CCM+



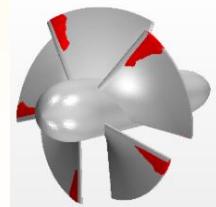
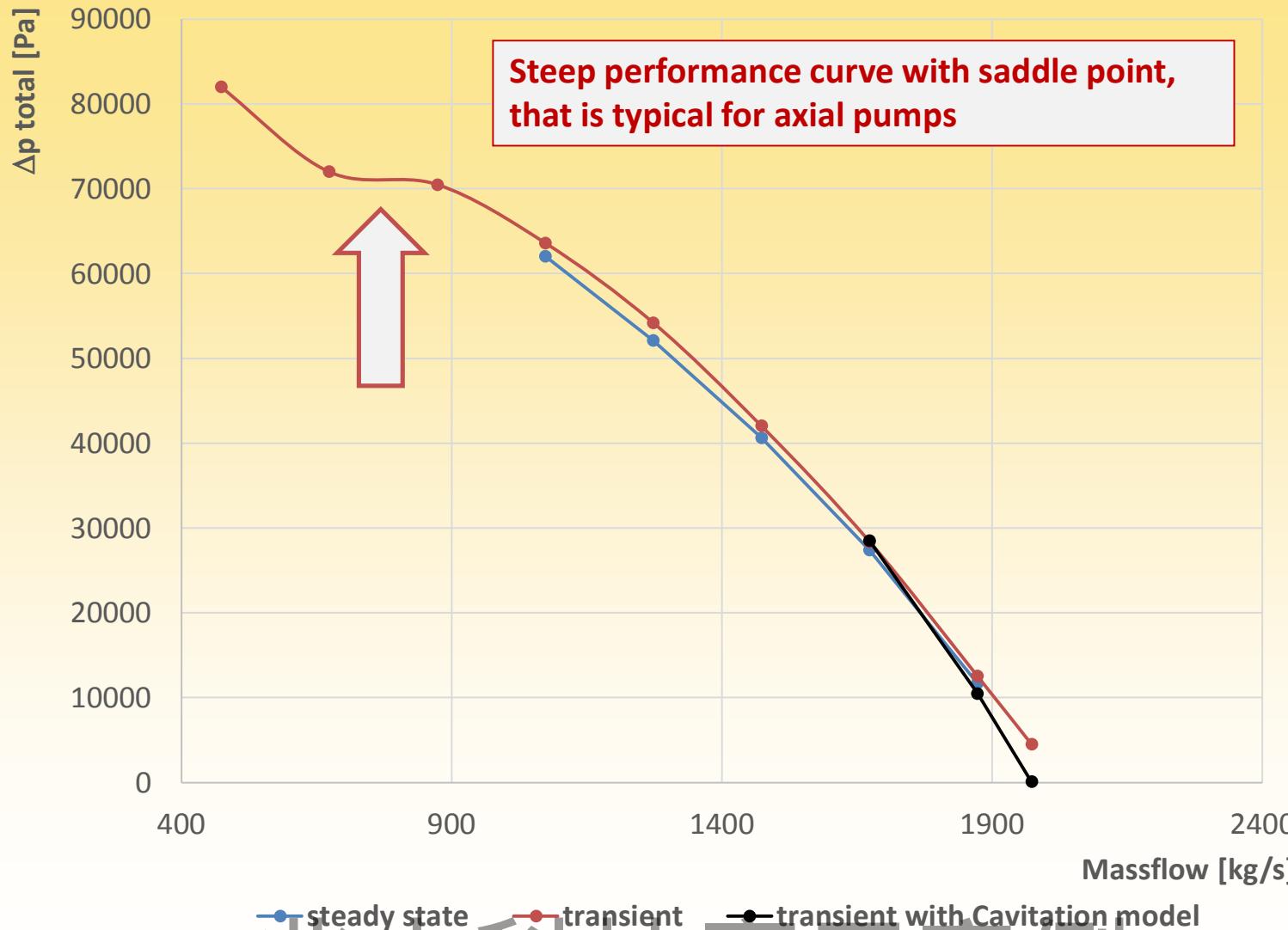
Leading edge blade tip cavitation

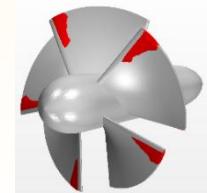
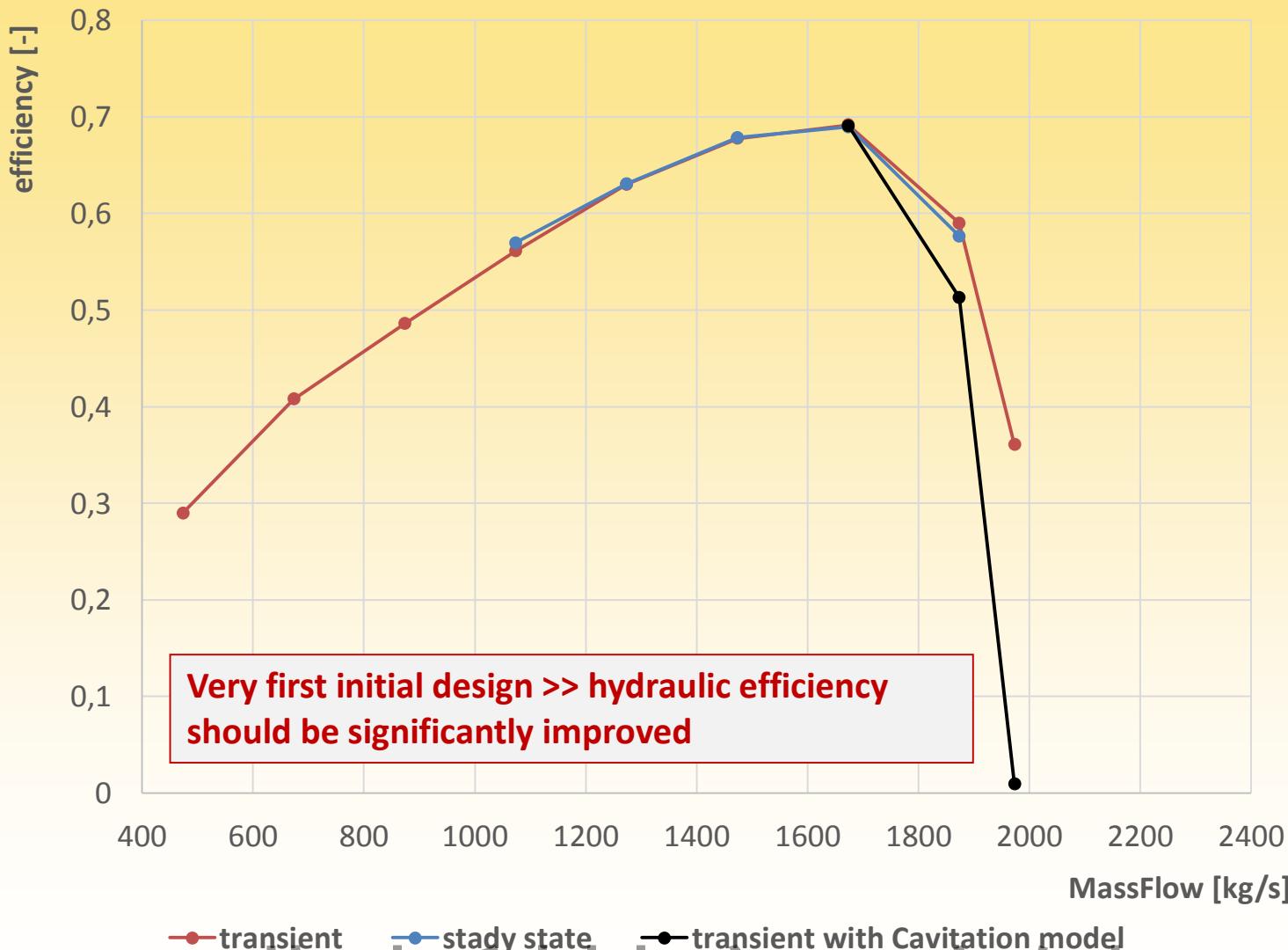
x y z

STAR-CCM+



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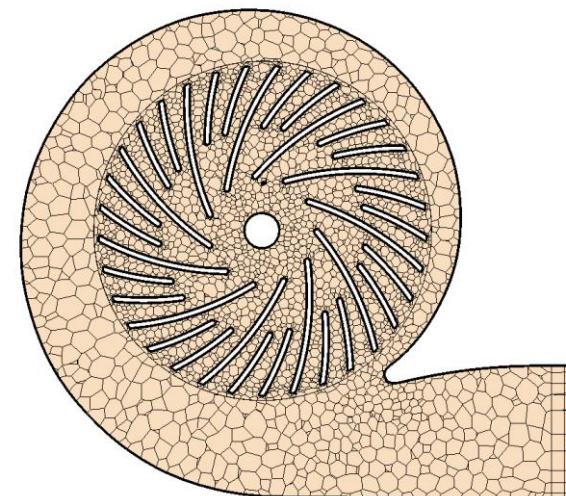
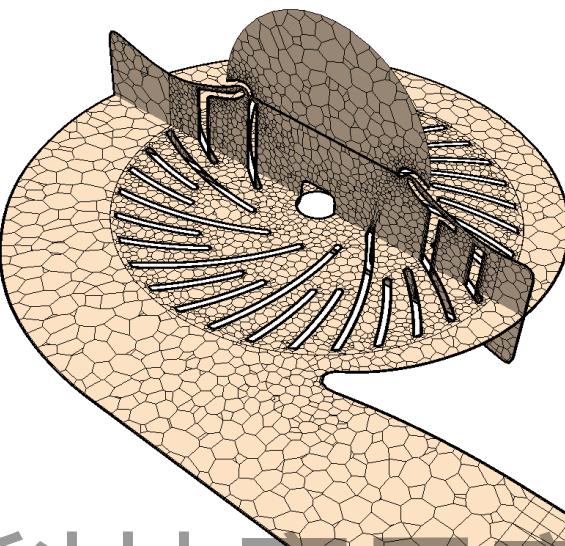
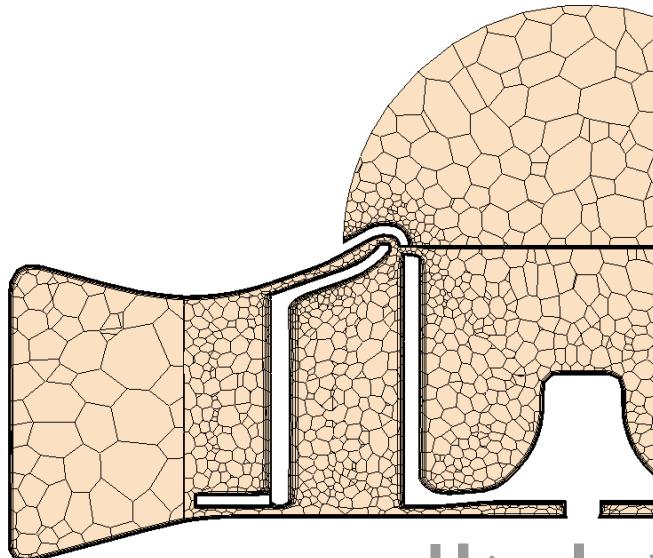
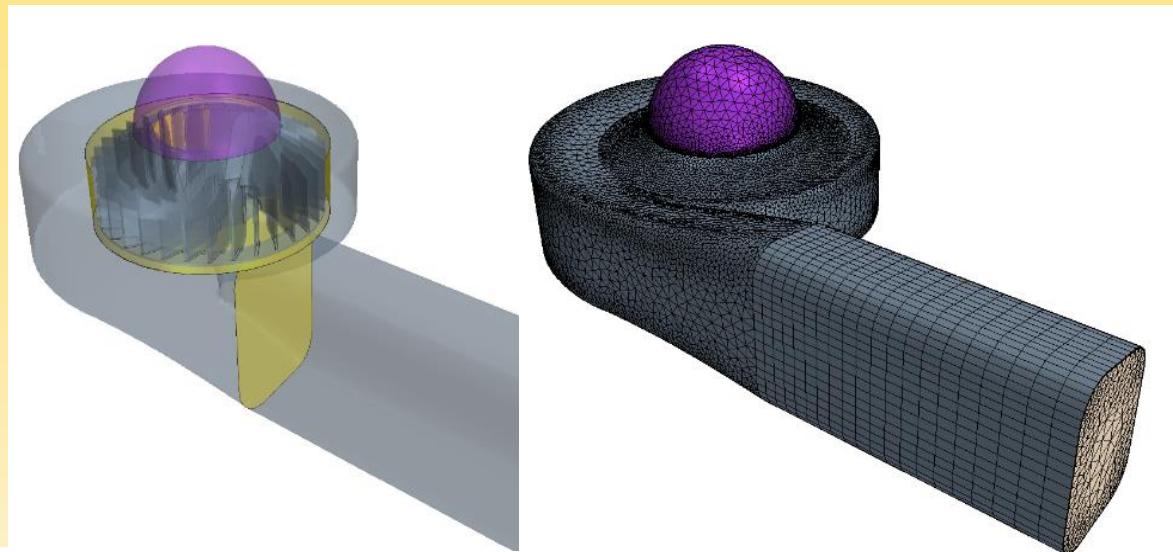




Example 3. Radial Blower

Comments

- Customer design
- CFD-Solver-Benchmark
- Steady state (MFR) and transient flow
- Coarse mesh (approx. 1 Mio. nodes)
- Experimental data available

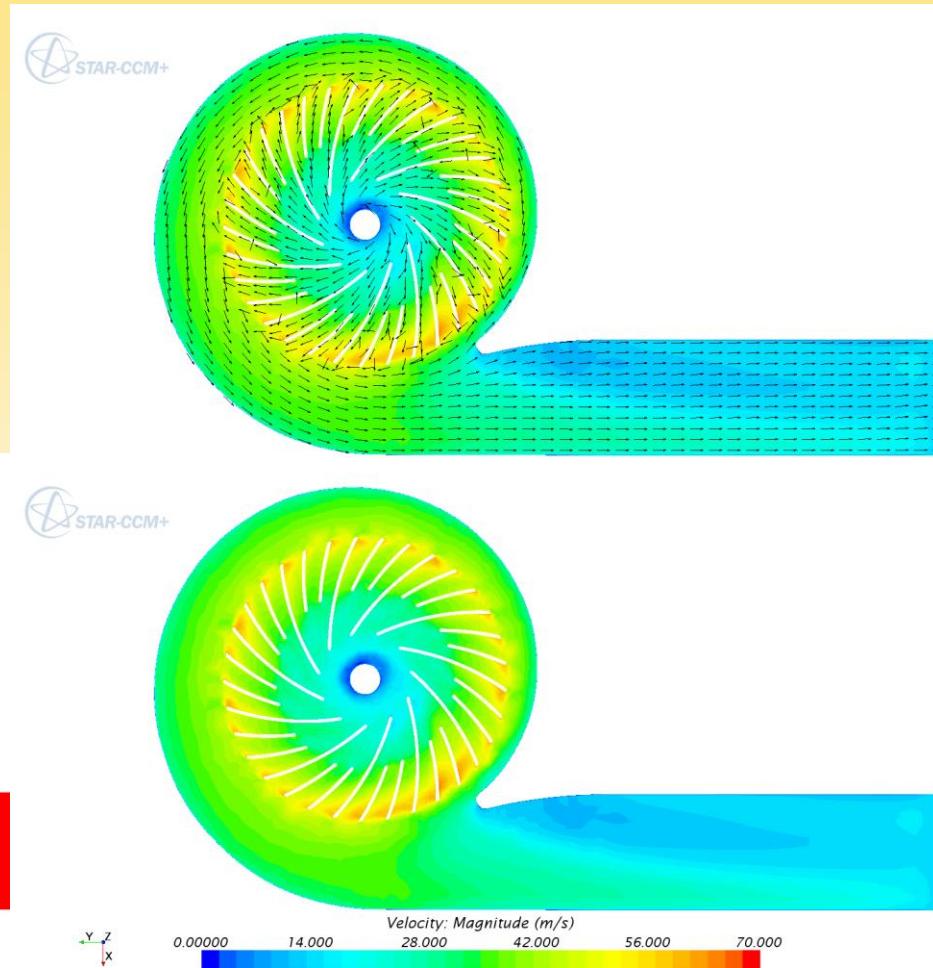
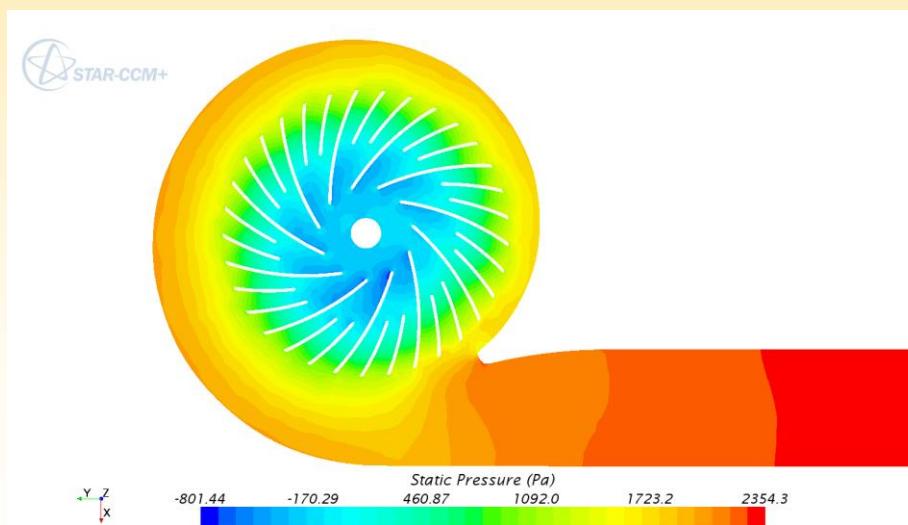


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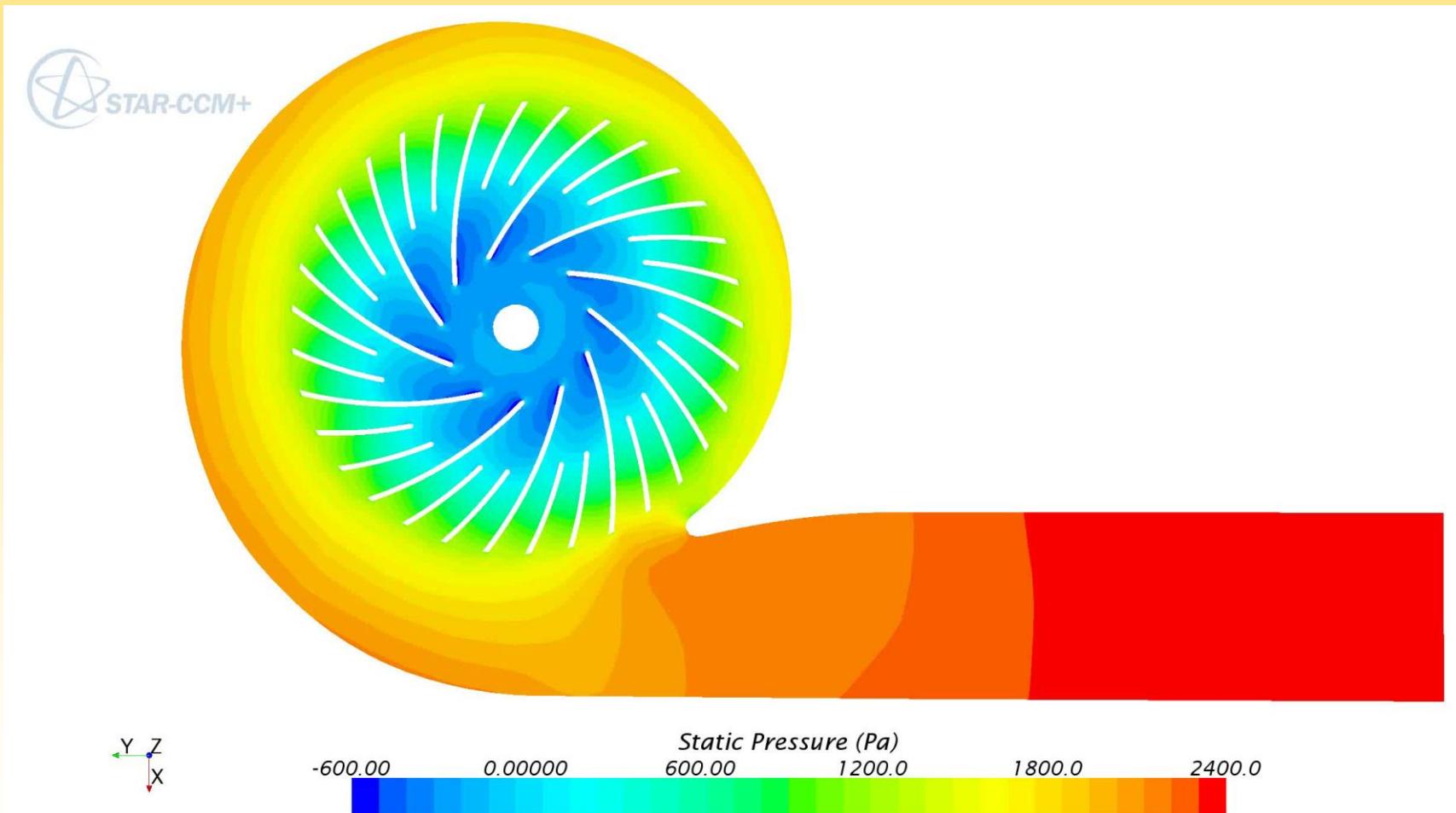
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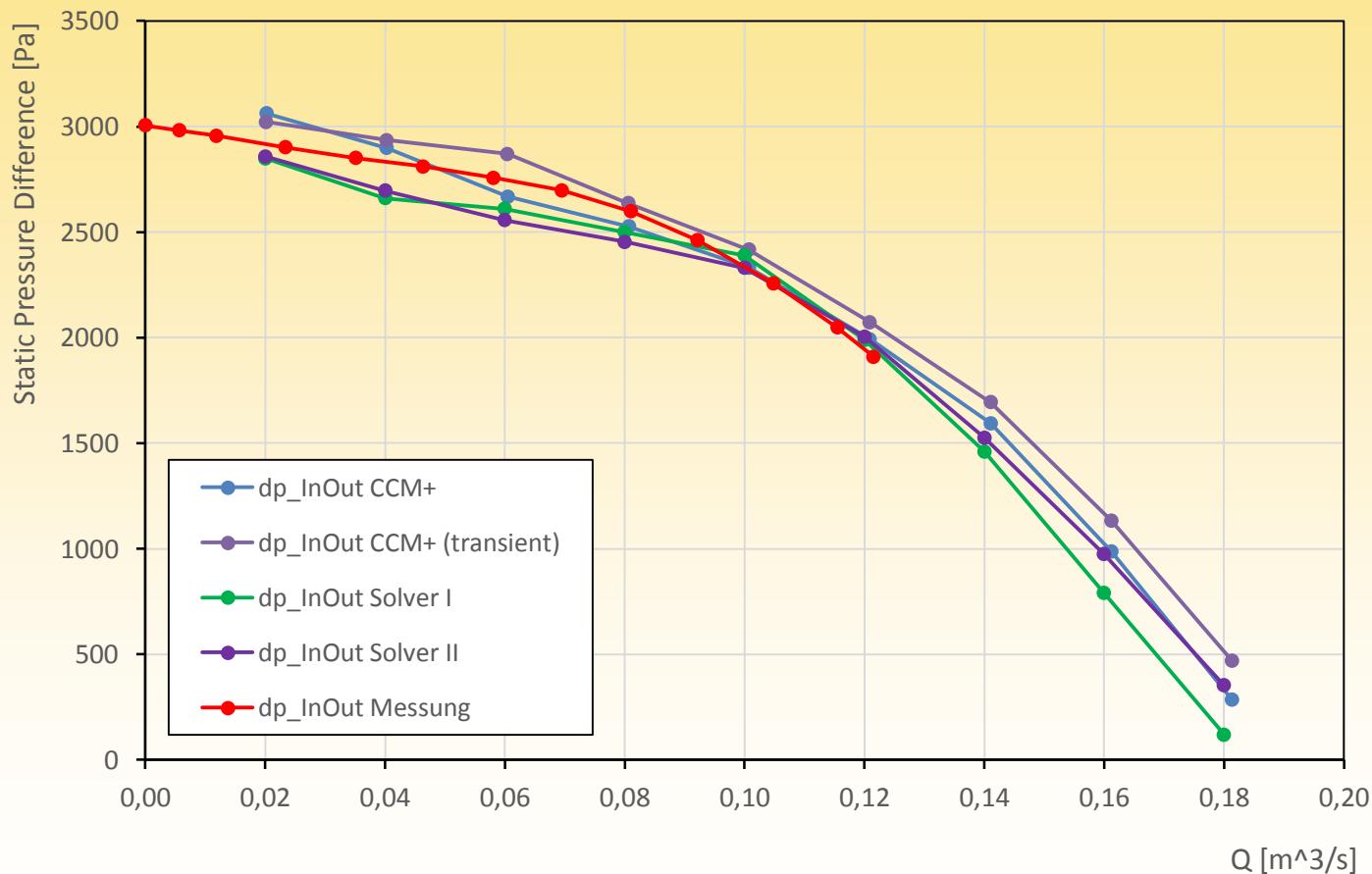


Example 3. Radial Blower

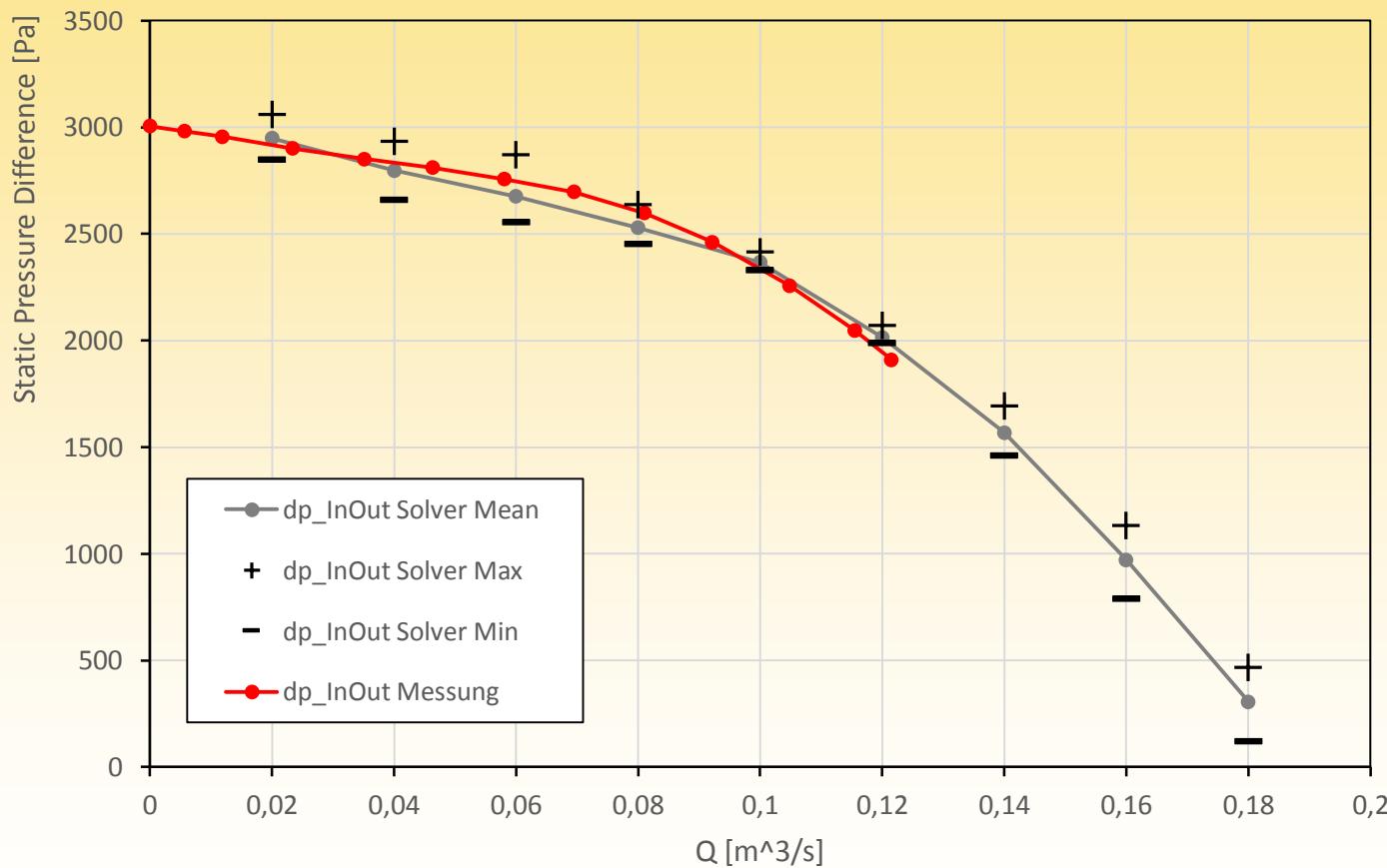


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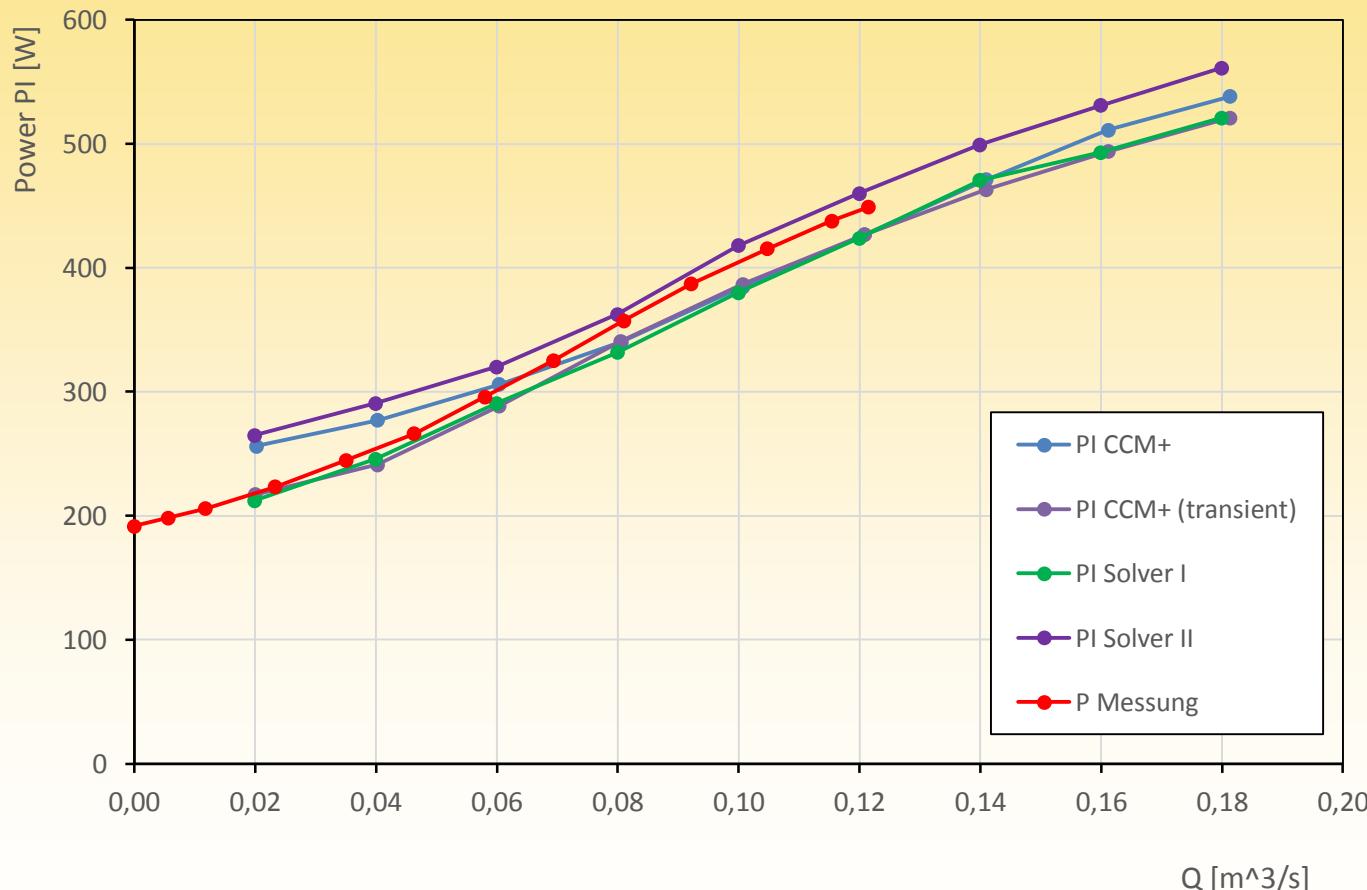
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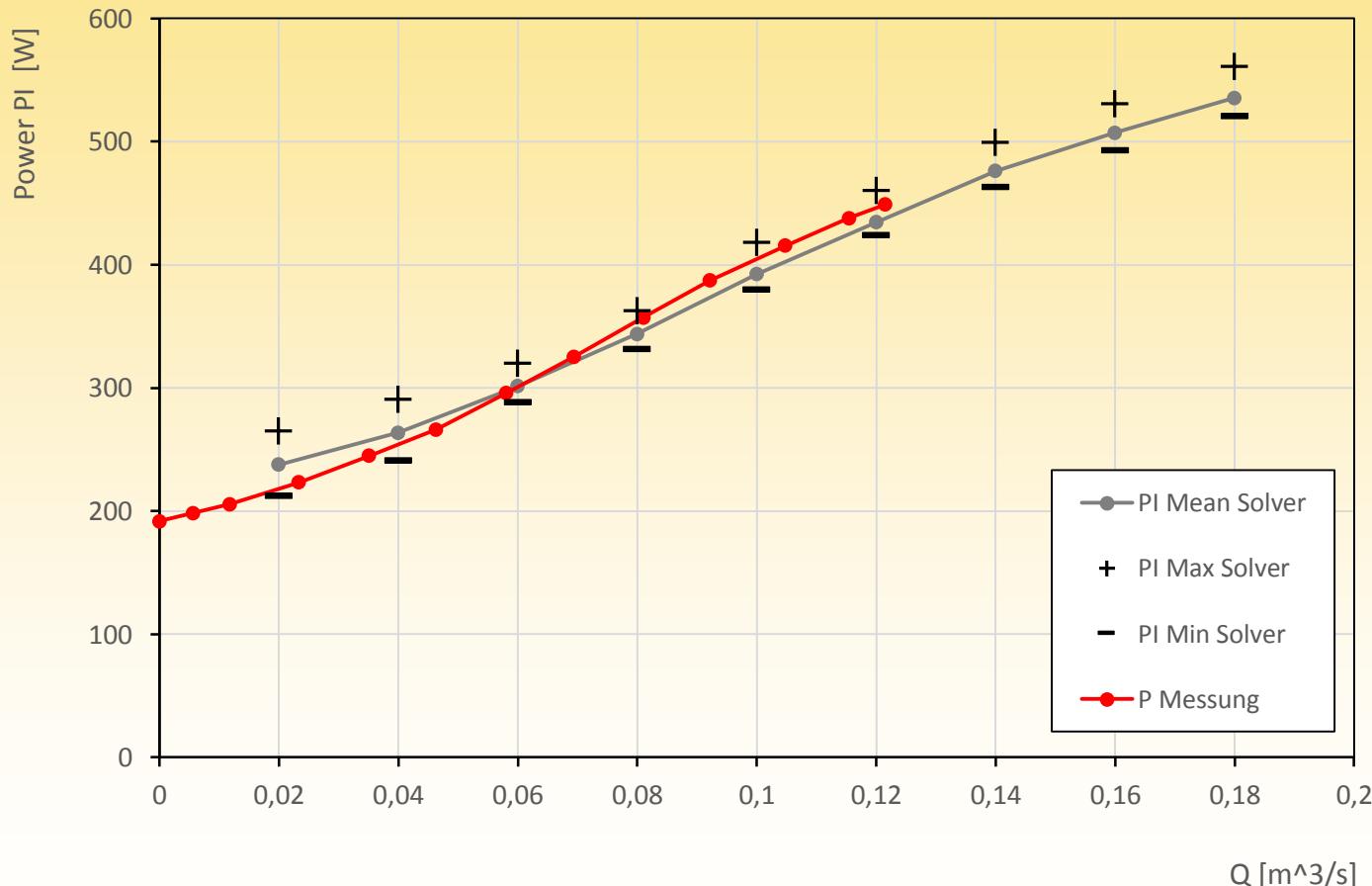
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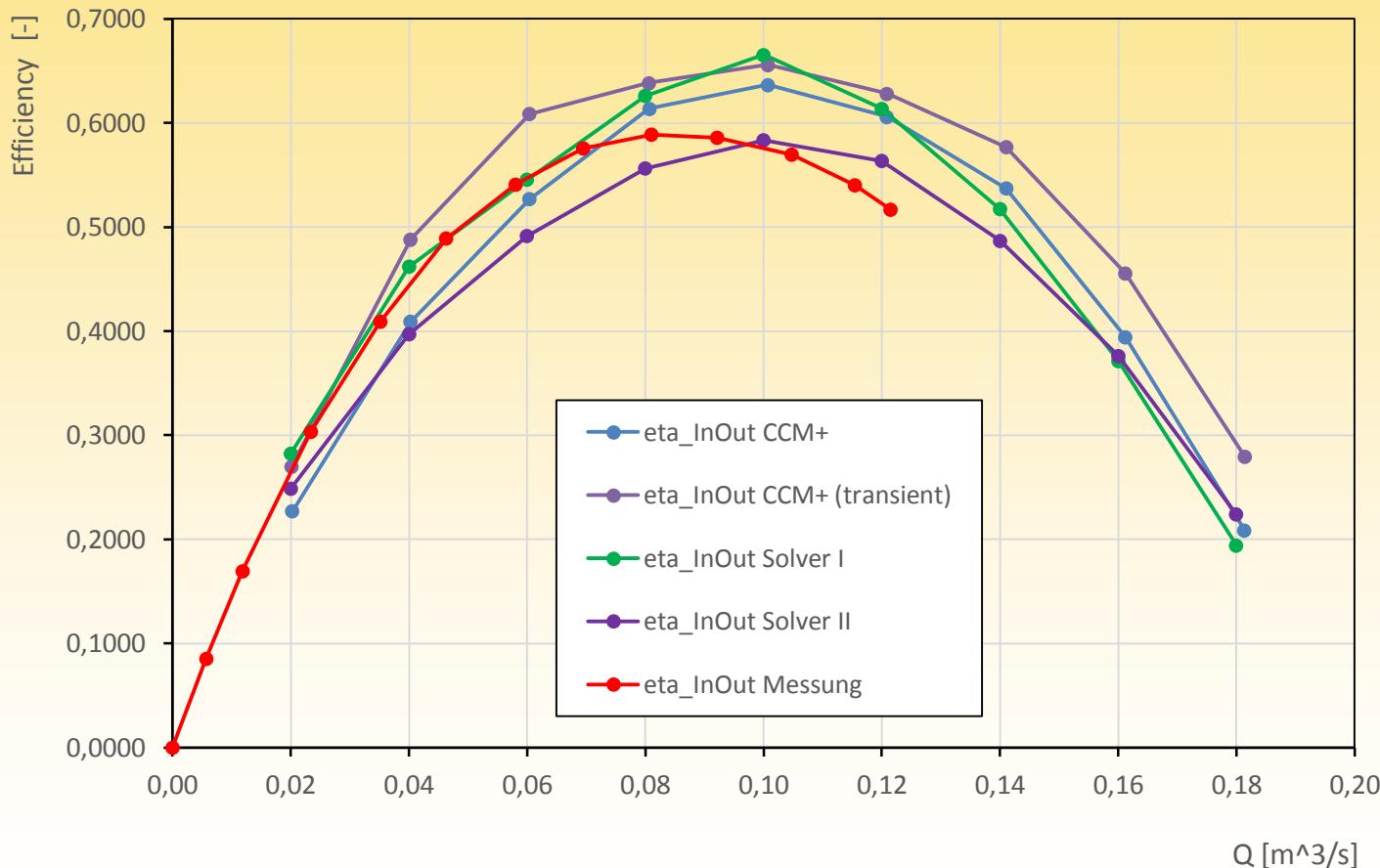
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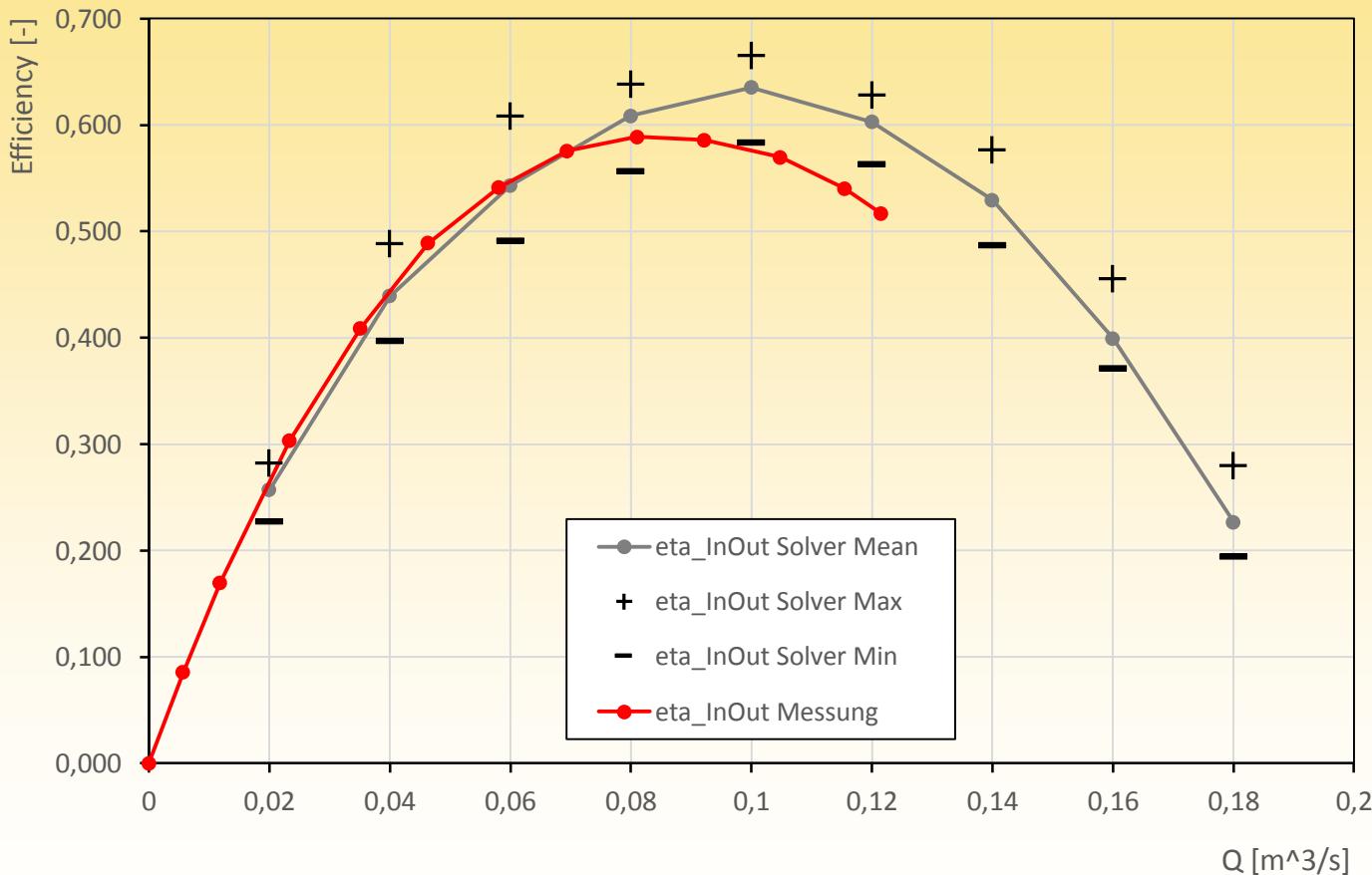


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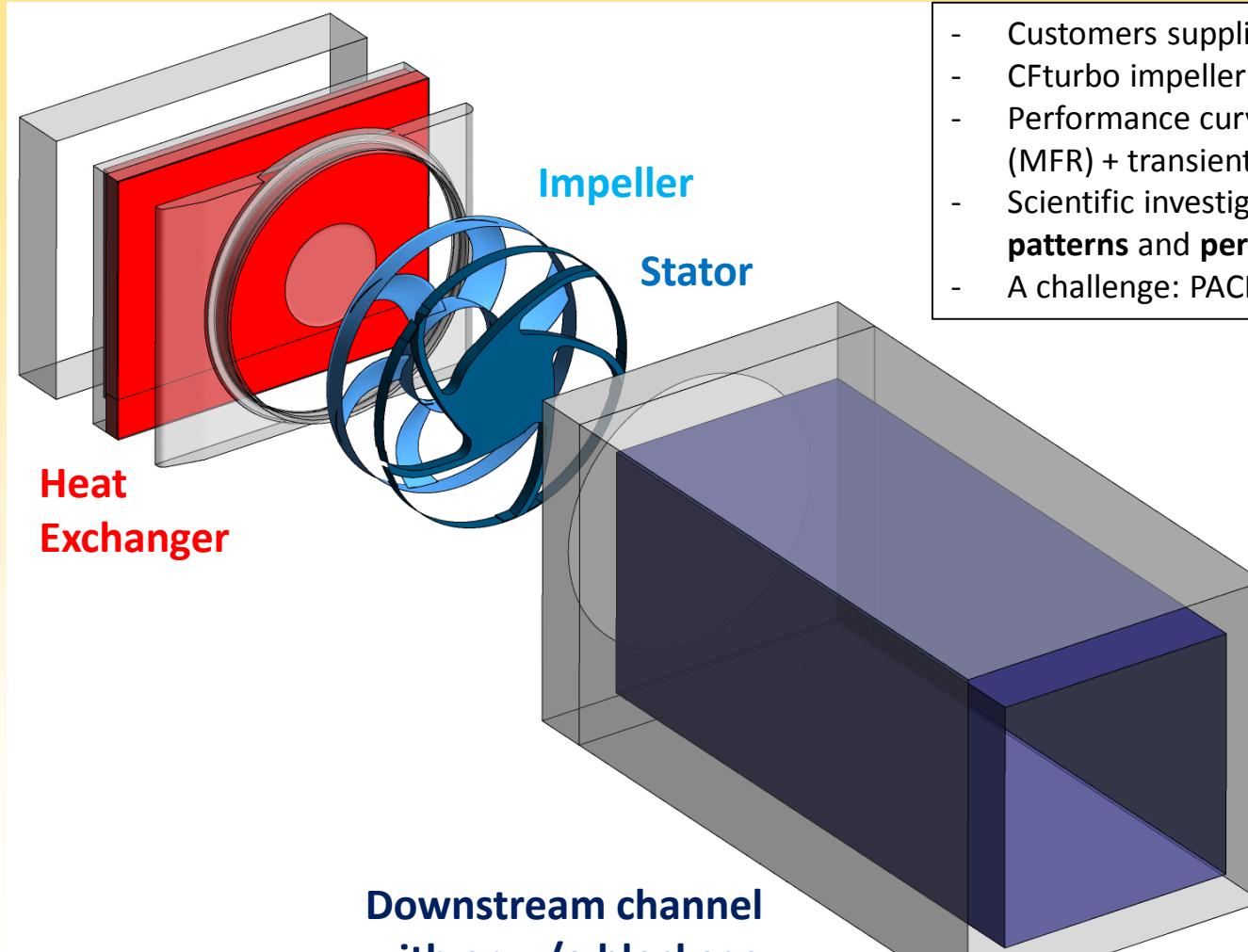


Example 3. Radial Blower

Reasons of discrepancy between simulation and measurement
should be investigated - mesh, time step, turbulence models,...
- check experimental set-up

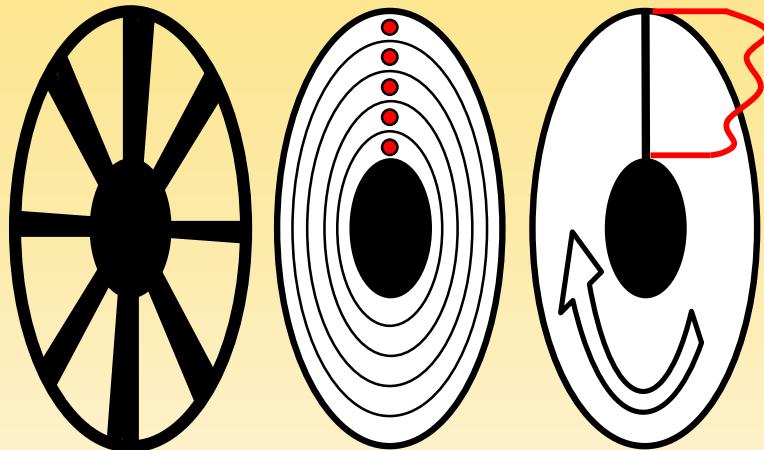
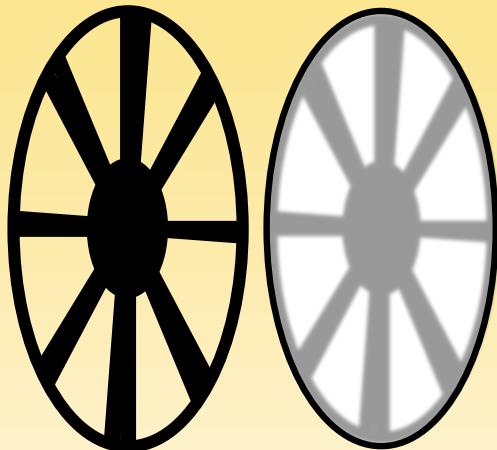


Example 4. Virtual Automotive Cooling Fan Test Rig



- Customers supplier design
- CFturbo impeller re-design
- Performance curve simulations, Steady state (MFR) + transient flow on a virtual testbench
- Scientific investigation on **downstream flow patterns** and **performance curves**
- A challenge: PACKAGING

Example 4. Virtual Automotive Cooling Fan Test Rig



Frozen Rotor

1:1 direct transfer of all physical values to the other side of the interface

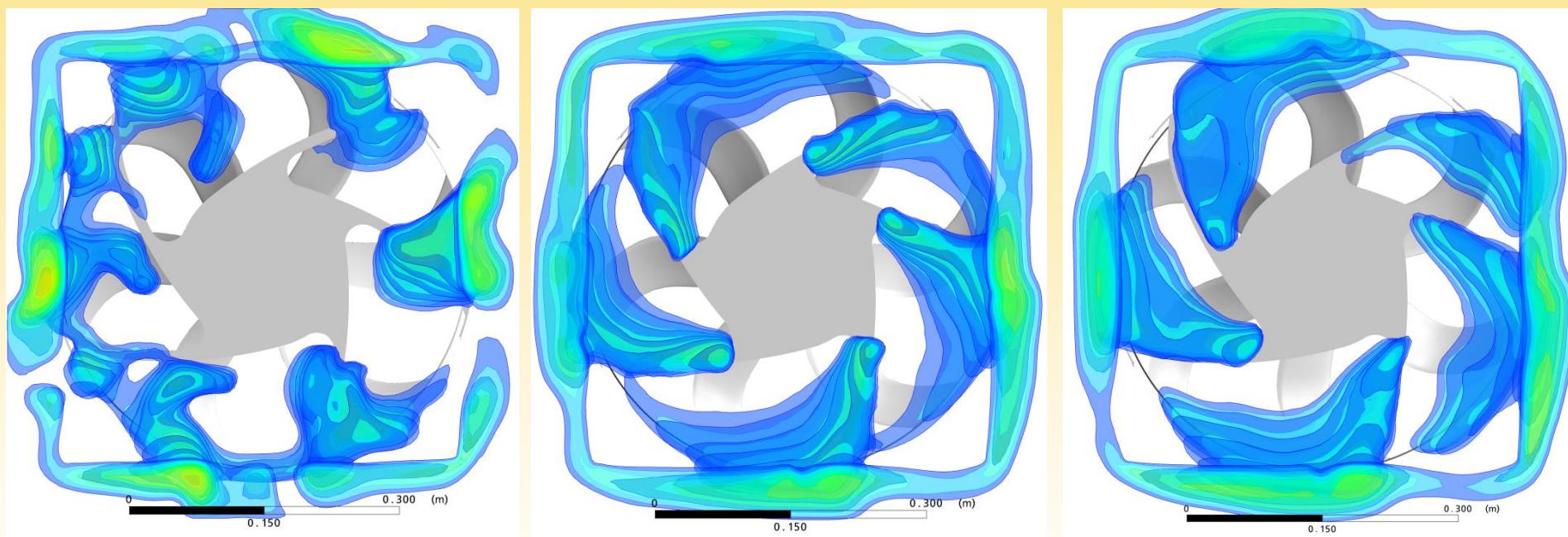
Mixing Plane (Stage Interface)

Mean values of pressure and momentum are used to provide radial distribution

- Are these steady state models a good alternatives compared to transient simulation of axial automotive cooling fans?

Example 4. Virtual Automotive Cooling Fan Test Rig

Downstream flow patterns

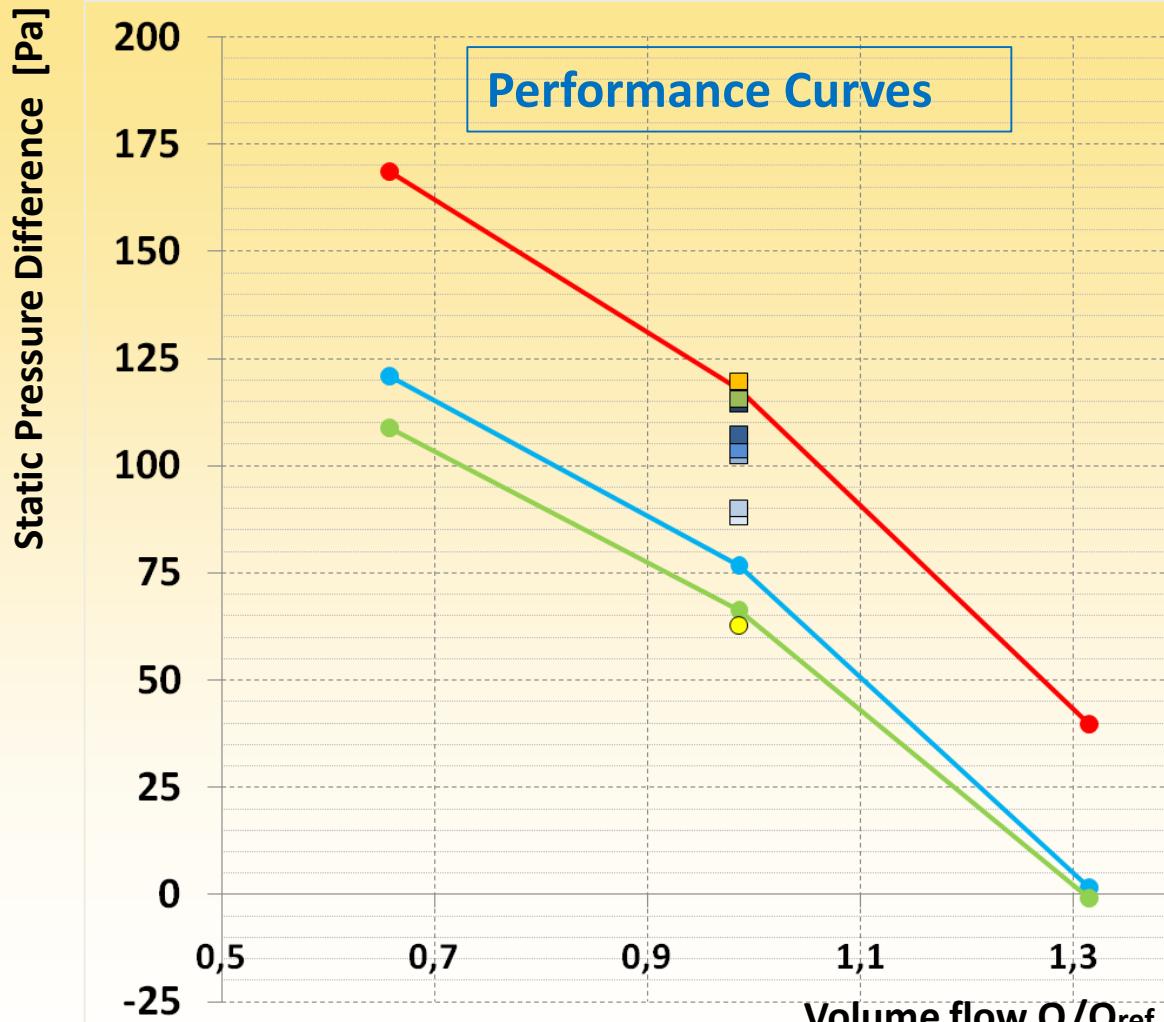


Frozen Rotor

Mixing Plane

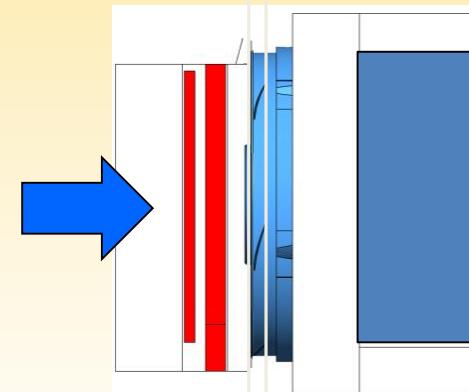
Transient

Example 4. Virtual Automotive Cooling Fan Test Rig



Steady state CFD-solutions are dependent on the position of the Rotor-Stator-Interfaces!

>> Computation of energy transmission within the impeller is affected!

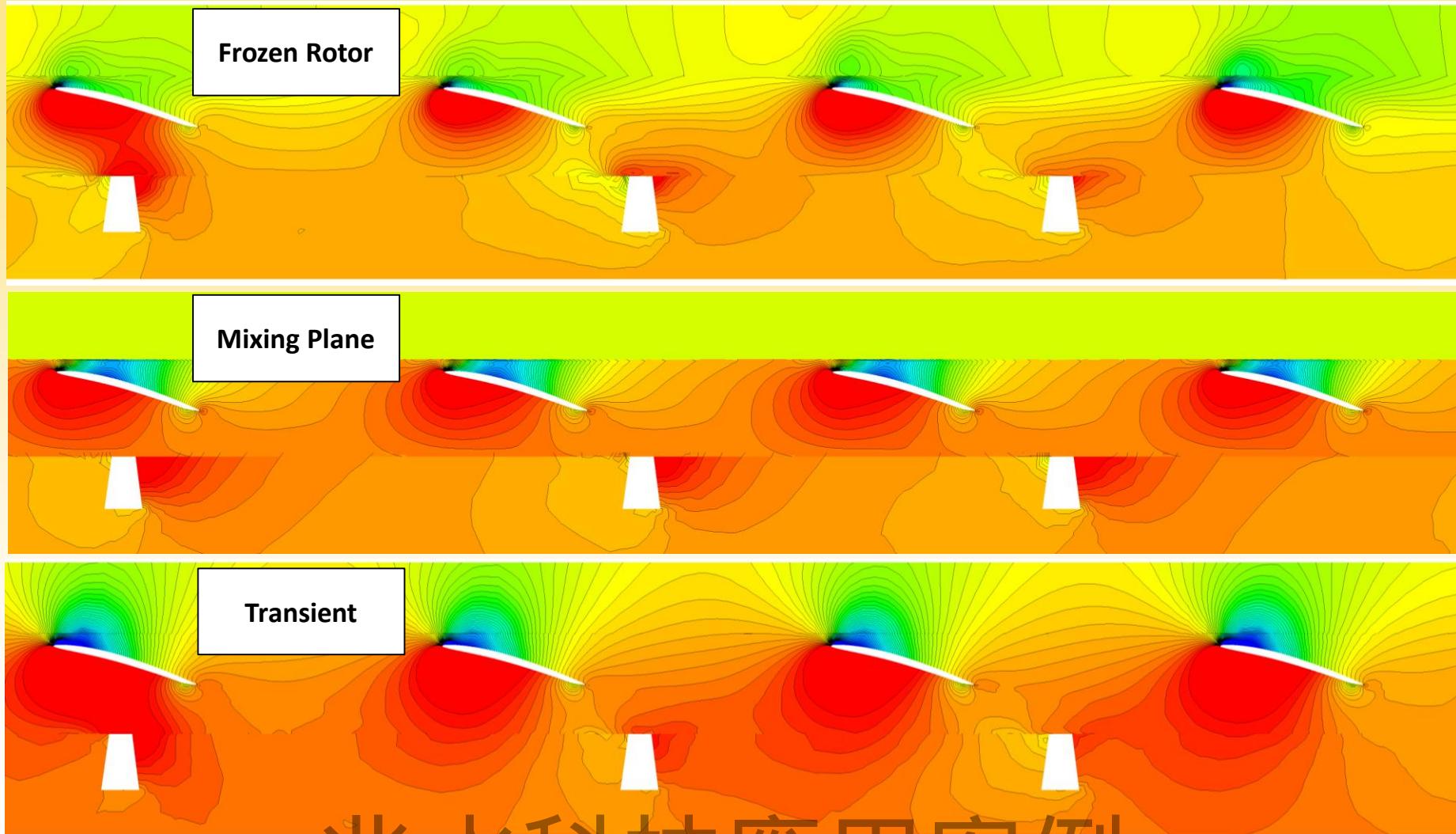


Transient

Mixing Plane (MP)

Frozen Rotor (FR)

Example 4. Virtual Automotive Cooling Fan Test Rig



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Summary

- ❖ CFturbo® and STAR CCM+ is a powerful combination for conceptual Turbomachinery design and 3D-CFD-simulation
- ❖ For different Turbomachinery applications different methodologies may be necessary
- ❖ Transient simulations do provide more accurate results im most cases
- ❖ Automated workflows and multi-objective optimization processes are available by additional application of OPTIMATE™ and HEEDS™
- ❖ Various types of Turbomachinery can be designed and investigated effectively
 - pumps, blowers, compressors, turbines
 - radial, mixed-flow and axial type
 - incompressible and compressible flow
 - without and with cavitation