2015 ESSS CONFERENCE & ANSYS USERS MEETING

Grand Mercure São Paulo Ibirapuera
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Rapid Design of an optimized Radial Compressor using CFturbo and ANSYS

Enrique Correa, Marius Korfanty, Sebastian Stübing

CFturbo Software & Engineering GmbH, Dresden (Germany)

ANSYS CONVERGENCE 2015 REGIONAL CONFERENCES

PRESENTATION TOPICS

1. Company overview
2. Aerodynamic compressor design
3. Automated simulation process
4. Results
5. Conclusion and next steps

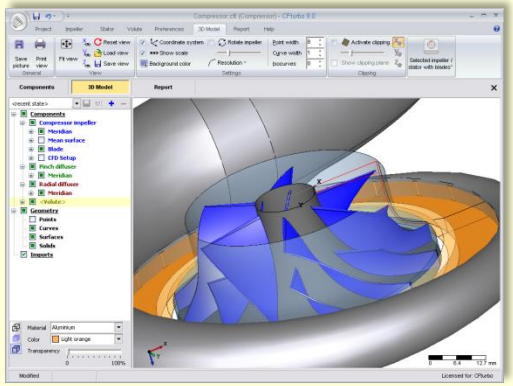
1. Company overview

Fields of activity

CFturbo® Software & Engineering GmbH (Germany)

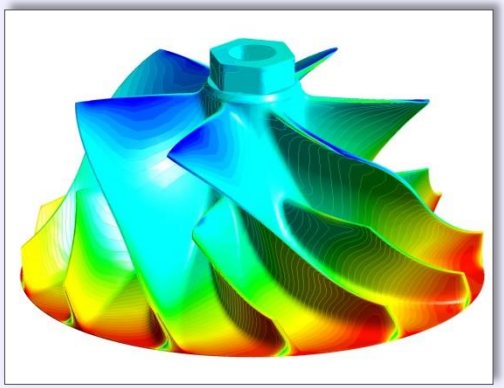
❶ CFturbo® Software

- Design software for turbomachinery
- Training courses
- Workflows



❷ CAE Consulting

- Turbomachinery conceptual design
- CFD/FEA simulation
- Optimization



❸ CAD & Prototyping

- 3D-CAD modeling
- Prototyping (with partners)

1. Company overview

Software customers (extract)

2. Aerodynamic compressor design

What is CFturbo?

CFturbo = conceptual turbomachinery design (radial, mixed-flow, axial) for impellers, stators and volutes

Machine design point
m, H/Δp, n,
Fluid properties,
Inlet boundary conditions

Fundamental fluid equations
Euler's equation of turbom.,
Continuity,
Momentum equation,
Velocity triangles, …

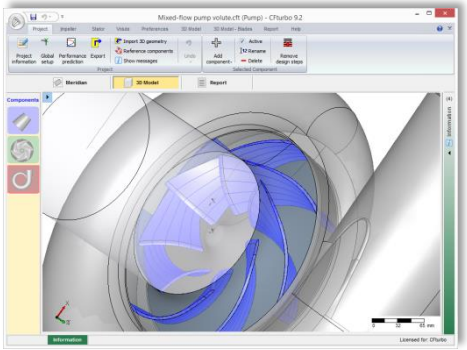
Empirical functions
Publicly available experiences,
In-house know-How

High geometrical flexibility, many checks, information

CFturbo®

Geometry import, redesign optionally

New / improved 3D geometry



2. Aerodynamic compressor design

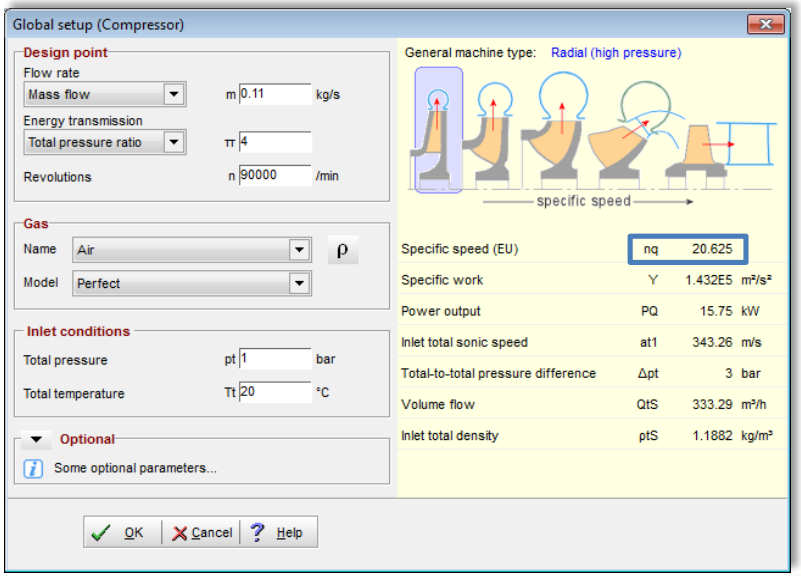
CFturbo input

Design point

- Total pressure ratio π_{tt} = 4
- Mass flow $\dot{m}$ = 0.11 kg/s
- Rotational speed n = 90 000 RPM
- Max. motor power P_M < 30 kW
- Max. available power P_i = 25.5 kW

Constraints

- Max. casing extension
- Manufacturing by flank milling

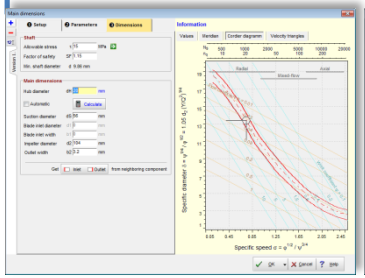


2. Aerodynamic compressor design

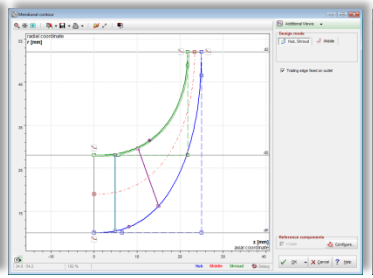
CFturbo design steps

Impeller

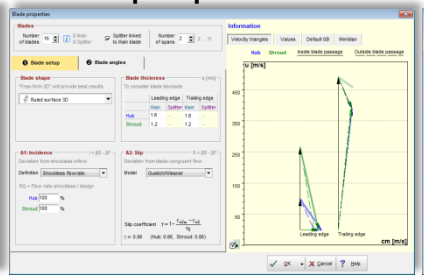
Main dimensions



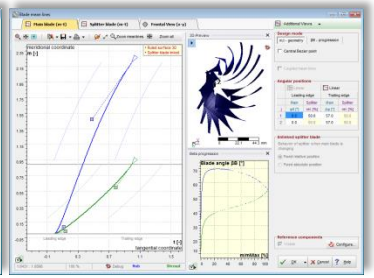
Meridian contour



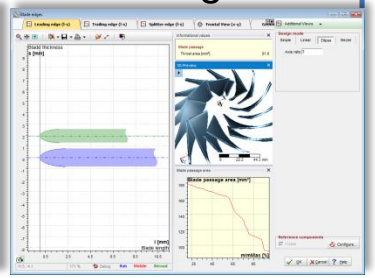
Blade properties



Mean lines

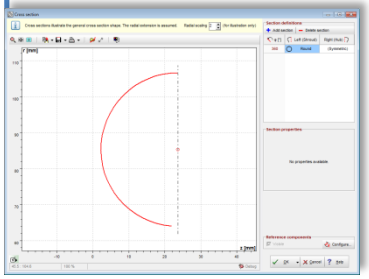


Blades edges

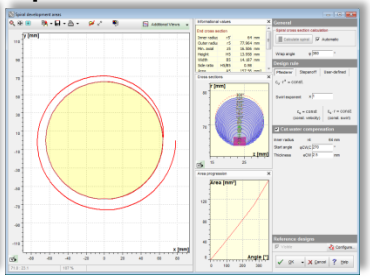


Volute

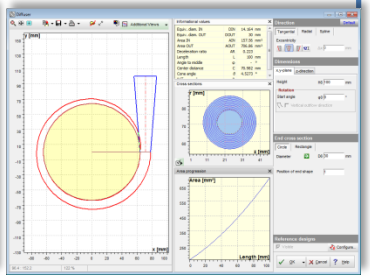
Cross section



Spiral areas

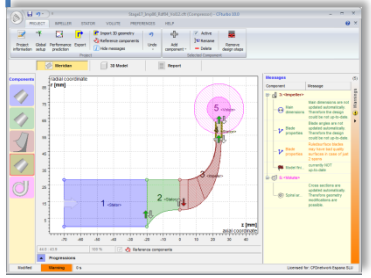


Diffuser, Cutwater

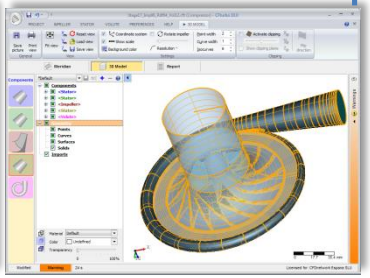


General

Meridian view



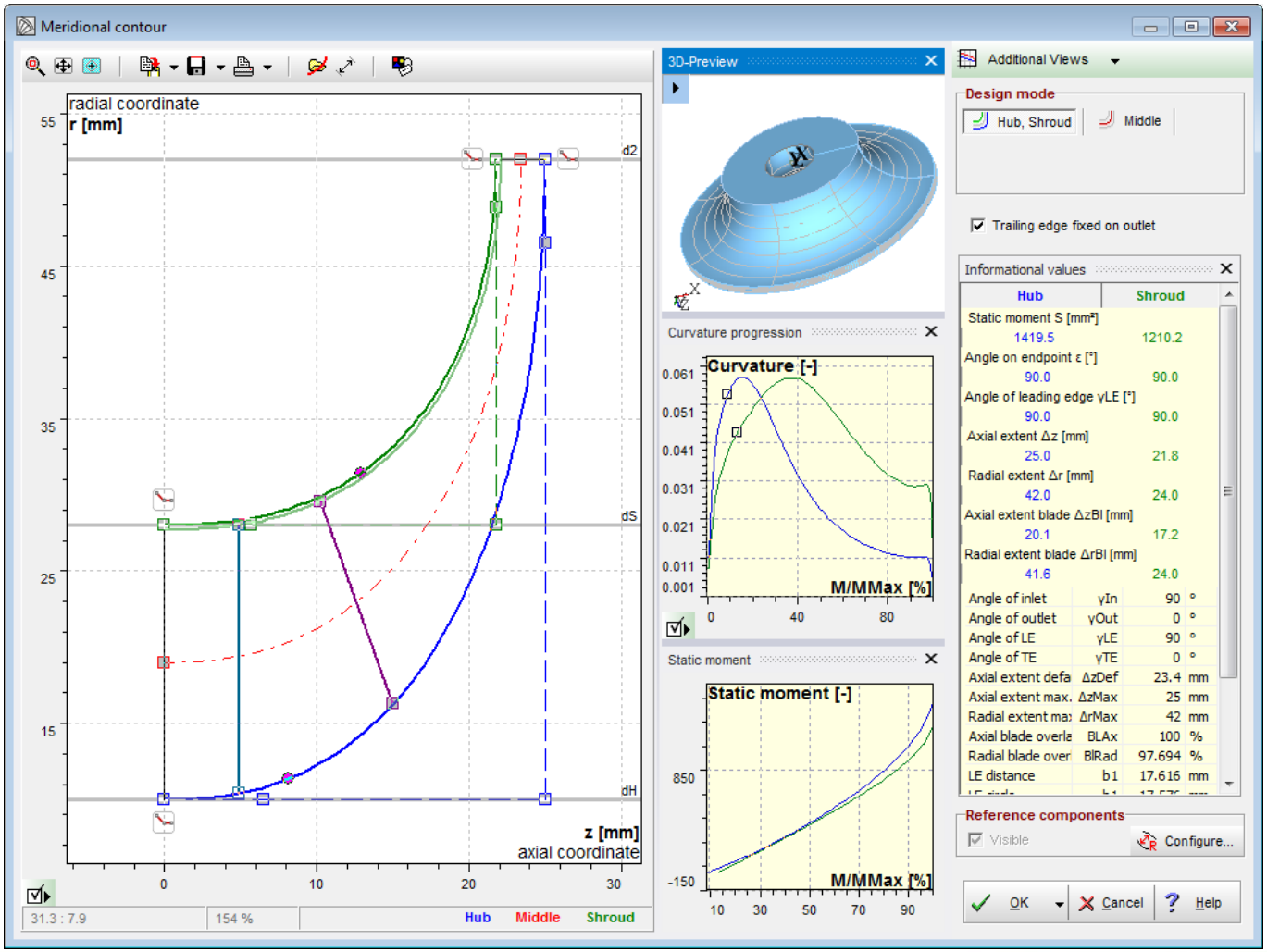
3D-Model



2. Aerodynamic compressor design

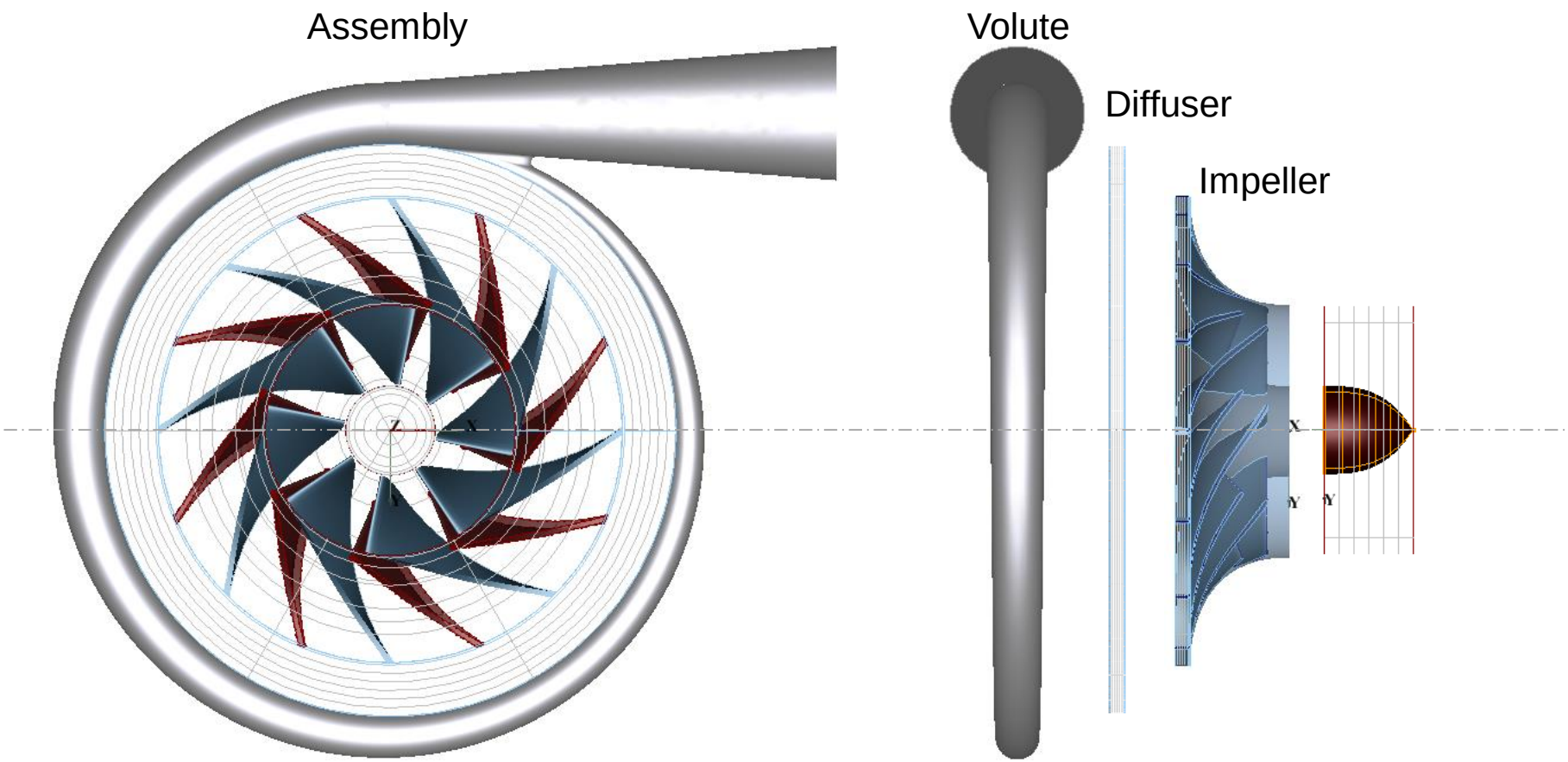
CFturbo design steps

Design step example



2. Aerodynamic compressor design

Components



3. Automated simulation process

Overview

Design point, requirements

Optimization

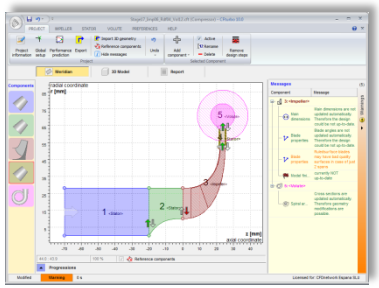
interactive or automatic

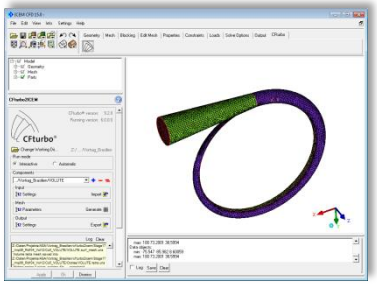
Product

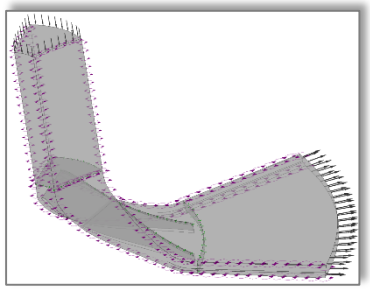
Conceptual Design
CFturbo

Grid generation
ANSYS ICEM-CFD

Simulation
ANSYS CFX







3. Automated simulation process

Meshing in ICEM-CFD

Export in **CFturbo**

ICEM-CFD parameters in **CFturbo**

Export

Interfaces

- Basic
- CAD
  - AutoCAD
  - BladeGen
  - CATIA
  - Creo Parametric
  - Inventor
  - NX
  - SOLIDWORKS
- CFD
  - ANSA
  - AutoGrid
  - ICEM-CFD
  - IGG
  - Pointwise
  - PumpLinx
  - SimericsMP
  - STAR-CCM+
  - TurboGrid
  - Vista TF

Components

ICEM-CFD: multi component selection supported.

- <Stator>
- <Stator>
- <Impeller>
- <Stator>
- <Volute>

Settings

Export destination

Path

Z:\Daten\Projekte\ASA\cad\Stage17\

Base file name

Stage17_Imp06_Rdf04_Vol12

Parameters

Define additional parameters if available for the selected interface

Set parameters ...

Export

Export data

Open exported file(s)

Version 150 (Win64)

Log

Export path: Z:\Daten\Projekte\ASA\cad\Stage17\

Export ICEM-CFD

General

Topology: Full (360°) / Single blade passage

Surface mesh: Export STL; STL parameters ...

Mesh method: Robust (Octree) / Quick (Delaunay)

Miscellaneous: Component caption: Impeller; Triangulation tolerance: 1E-6

Information

Mesh element size may not match the geometry (see marked cells).

Max. size at interfaces of adjacent components should have similar values.

Mesh

Tetrahedra: Coarse | Middle | Fine

Global element scale factor 1

Global element seed size 2

Min. size limit 0.25

Edge criterion 0.15

Prism layers: Coarse | Middle | Fine

Number of layers 7

Growth law Linear

Height ratio 1.2

Part	Max. size	Max. deviation	Layers	Height	Height ratio	End height	Total height	Height factor
Hub	2	0.20095	7	0.0055804	1.2	0.012277	0.0625	0.03125
Shroud	2	0.20095	7	0.0055804	1.2	0.012277	0.0625	0.03125
Blade	1	0.20095	7	0.0055804	1.2	0.012277	0.0625	0.0625
Blade LE	0.5	0.13397	7	0.0055804	1.2	0.012277	0.0625	0.125
Blade TE	1	0.13397	7	0.0055804	1.2	0.012277	0.0625	0.0625
Blade Fillets	0.25	-	7	0.0055804	1.2	0.012277	0.0625	0.25
Blade Tip	0.25	-	7	0.0055804	1.2	0.012277	0.0625	0.25
Inflow	2	-	7	0.0055804	1.2	0.012277	0.0625	0.03125
Outflow	1	-	7	0.0055804	1.2	0.012277	0.0625	0.0625

OK | Cancel | Help

3. Automated simulation process

Meshing in ICEM-CFD

CFturbo2ICEM panels in ICEM-CFD

ICEM CFD 15.0 :

File Edit View Info Settings Help

Geometry | Mesh | Blocking | Edit Mesh | Properties | Constraints | Loads | Solve Options | Output | CFturbo

Model

CFturbo2ICEM

CFturbo® version: 9.2.0
Running version: 6.0.0.0

CFturbo®

Change Working Dir... Z:/Daten/ASA/Vortrag_Brasilien

Run mode: Interactive / Automatic

Components: .../Vortrag_Brasilien/VOLUTE

Input: 12 Settings — Import

Mesh: 12 Parameters — Generate

Output: 12 Settings — Export

Test | Load procs | Log | Clear

Session started on Wednesday, 06 of May of 2015 at 16:46:07

Components added to the project:
.../Vortrag_Brasilien/ZULAUF
.../Vortrag_Brasilien/STATOR1
.../Vortrag_Brasilien/IMPELLER
.../Vortrag_Brasilien/STATOR3
.../Vortrag_Brasilien/VOLUTE

Apply | Ok | Dismiss

Modify mesh parameters for the component .../Vortrag_Brasilien/VOLUTE

Input mesh: Load from STL

Tetra mesh method: Robust (Octree) / Quick (Delaunay)

Prism layers control: Fix ratio / Fix initial height

Re-mesh options: Use existing volume tetra-mesh / Use only surface mesh

Information

Global

Tetra		Prism			
Global element scale factor	1	Number of layers	5	One layer and split	
Global element seed size	4	Height	0.03571	Total height	0.0
Min. size limit	0.5	Height ratio	1.2	Height factor	0.0
Edge criterion	0.15	Growth law	Linear		

Local

Part	Max. size	Max. deviation	☑	Layers	Height	Height ratio	Total height	Height factor
Inflow	4	0	☐	5	0.03571	1.2	0.2500	0.0625
Outflow	4	0.28398	☐	5	0.03571	1.2	0.2500	0.0625
Spiral	4	0.28398	☑	5	0.03571	1.2	0.2500	0.0625
CutWater	0.5	0.13288	☑	5	0.03571	1.2	0.2500	0.5000
Outlet_Diffuser	2	0.28398	☐	5	0.03571	1.2	0.2500	0.1250

Handle settings | Open | Save | Save As | No parameters file recently saved for this component | Reset | OK | Cancel

Input settings

STEP Reader: Workbench reader / CFturbo2ICEM reader / Use version 5.1

Options — Units: [mm] Millimeter / [in] Inch / [cm] Centimeter / [ft] Feet / [m] Meter

Names with prefix

OK

Information: CFturbo2ICEM reader: based on ICEM Step Translator with additional names recognition

Output settings

Export format: CFX5 (Ansys CFX)

Topology: Full (360°) / Single blade passage

Units: [mm] Millimeter / [in] Inch / [cm] Centimeter / [ft] Feet / [m] Meter

File encoding: Ascii / Binary

Family names: Export original families

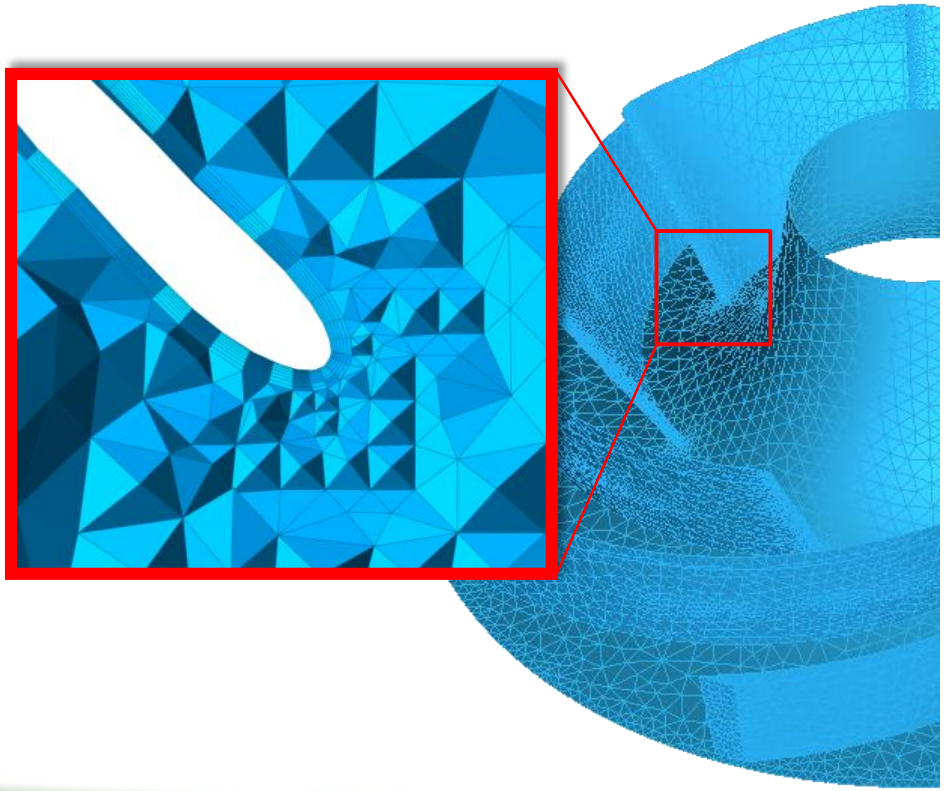
OK

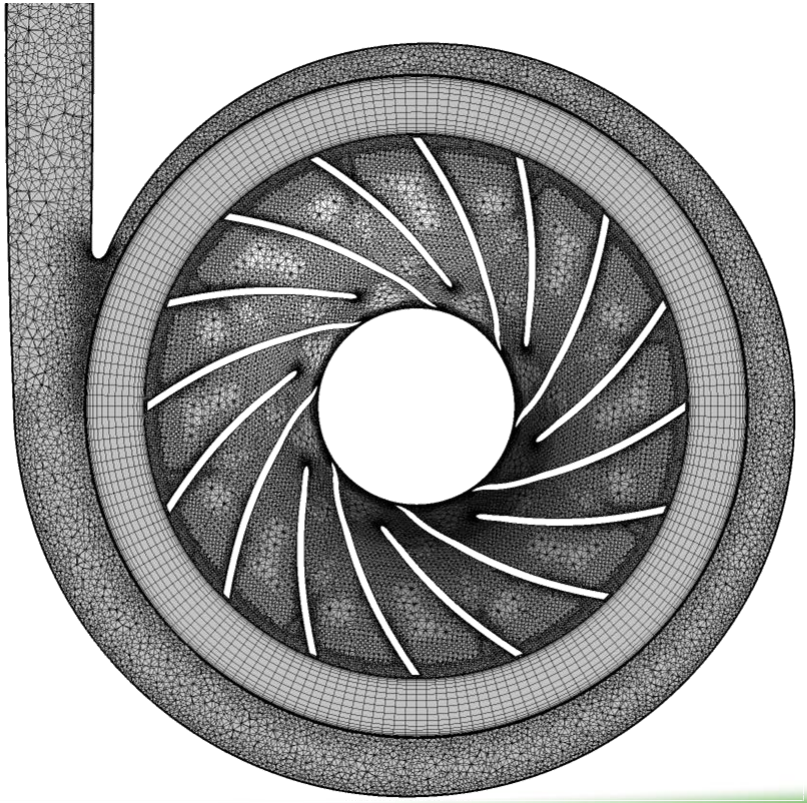
Information

3. Automated simulation process

Meshing in ICEM-CFD

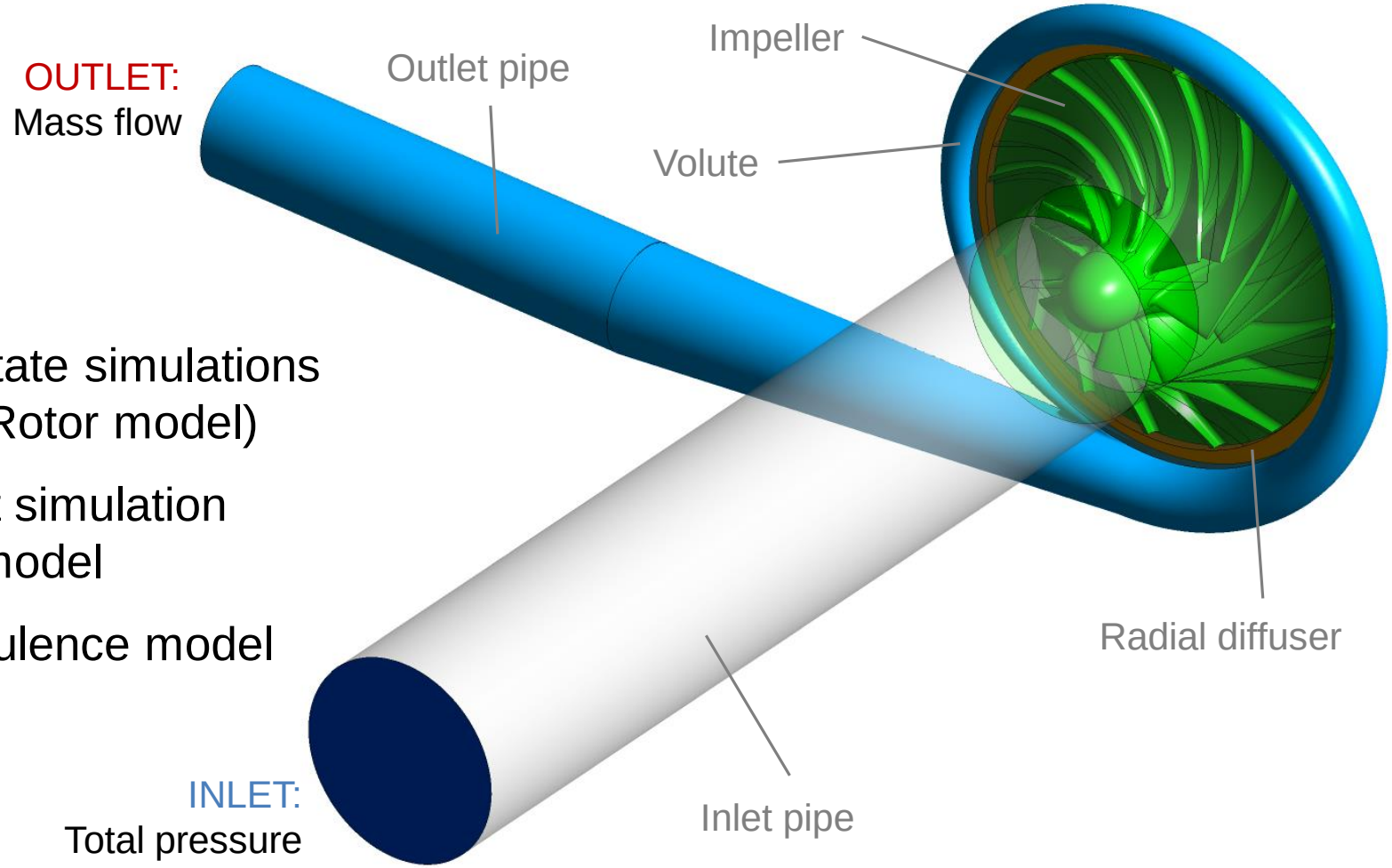
- Fully automated, script based meshing with Tet/Prism, Hexa
- Mesh size: 4.6 Mill. nodes
- Design modifications and meshing within 1 hour





3. Automated simulation process

CFX settings

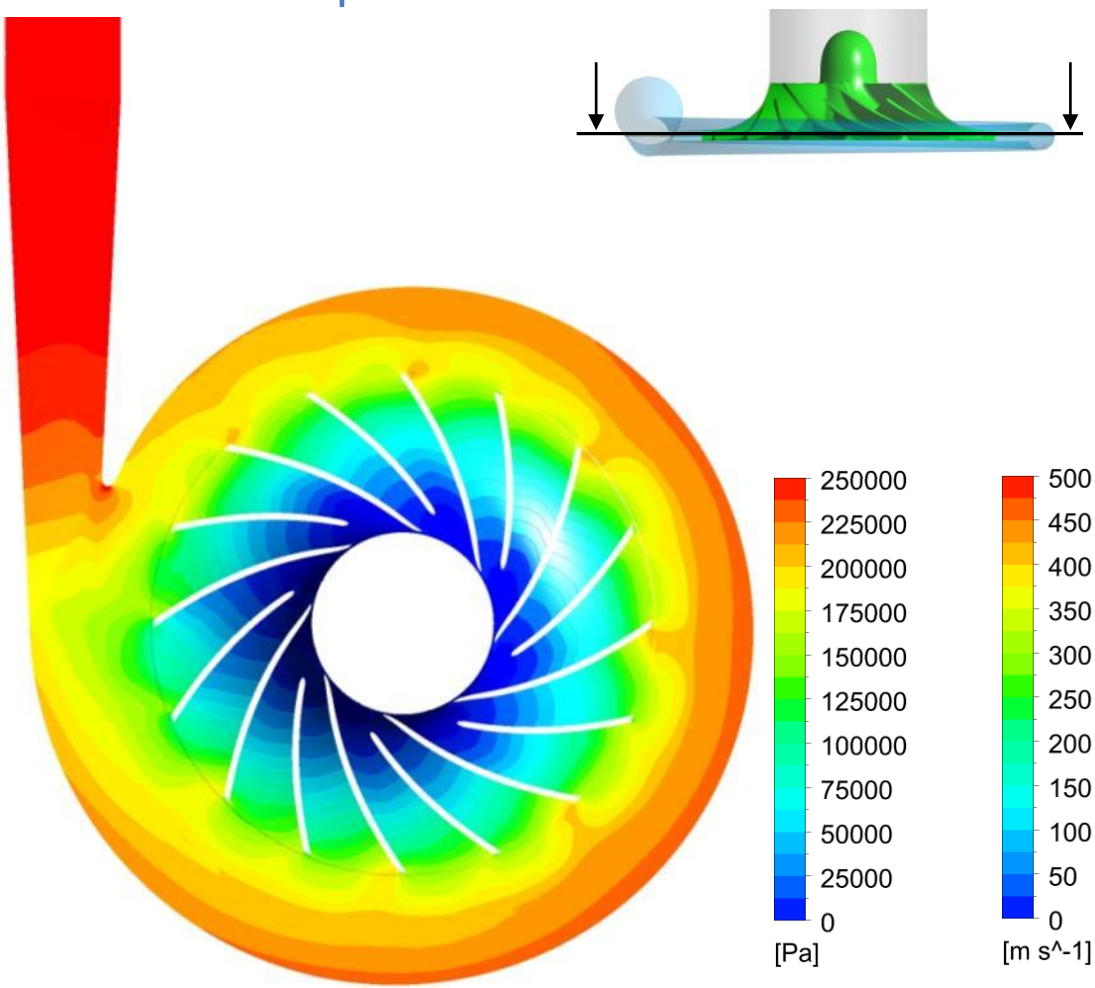


- Steady-state simulations (Frozen-Rotor model)
- Transient simulation for final model
- SST turbulence model

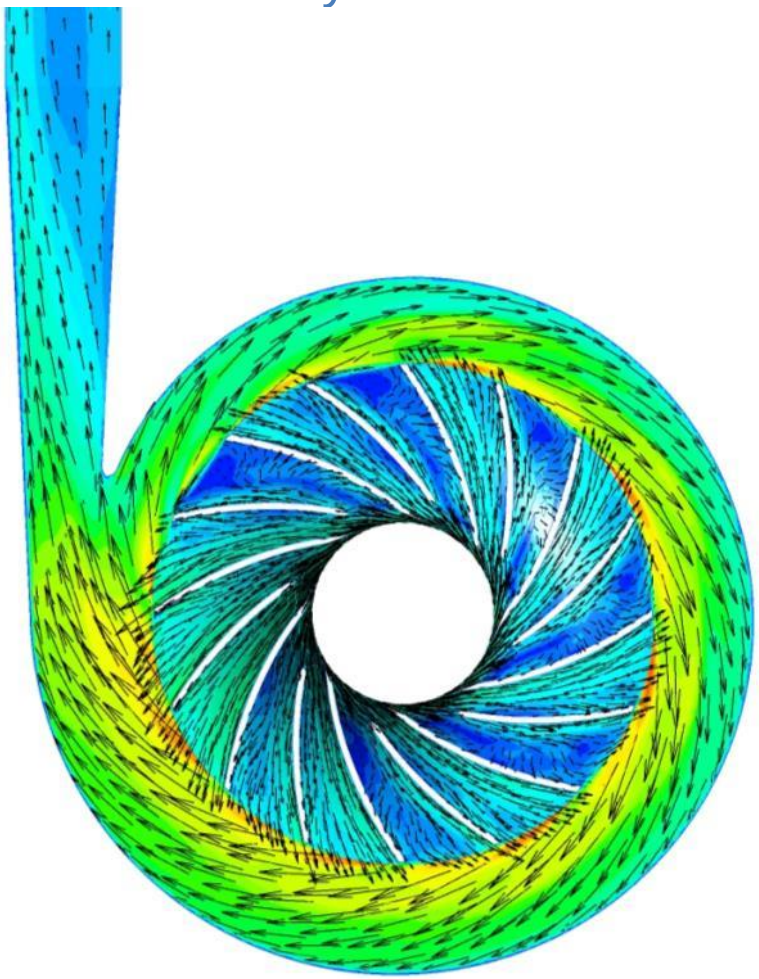
4. Results

Impeller and Volute

Static pressure



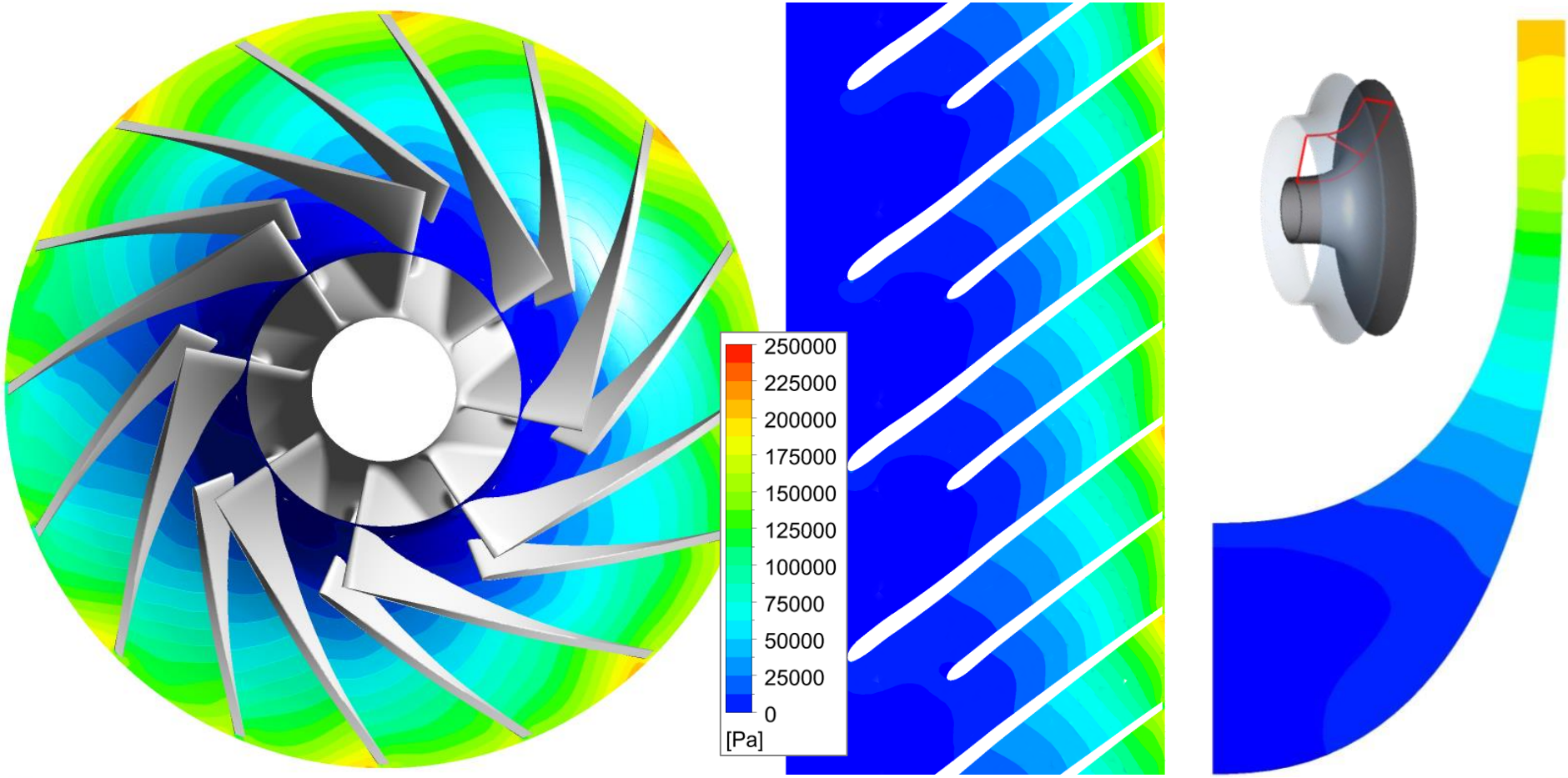
Velocity



4. Results

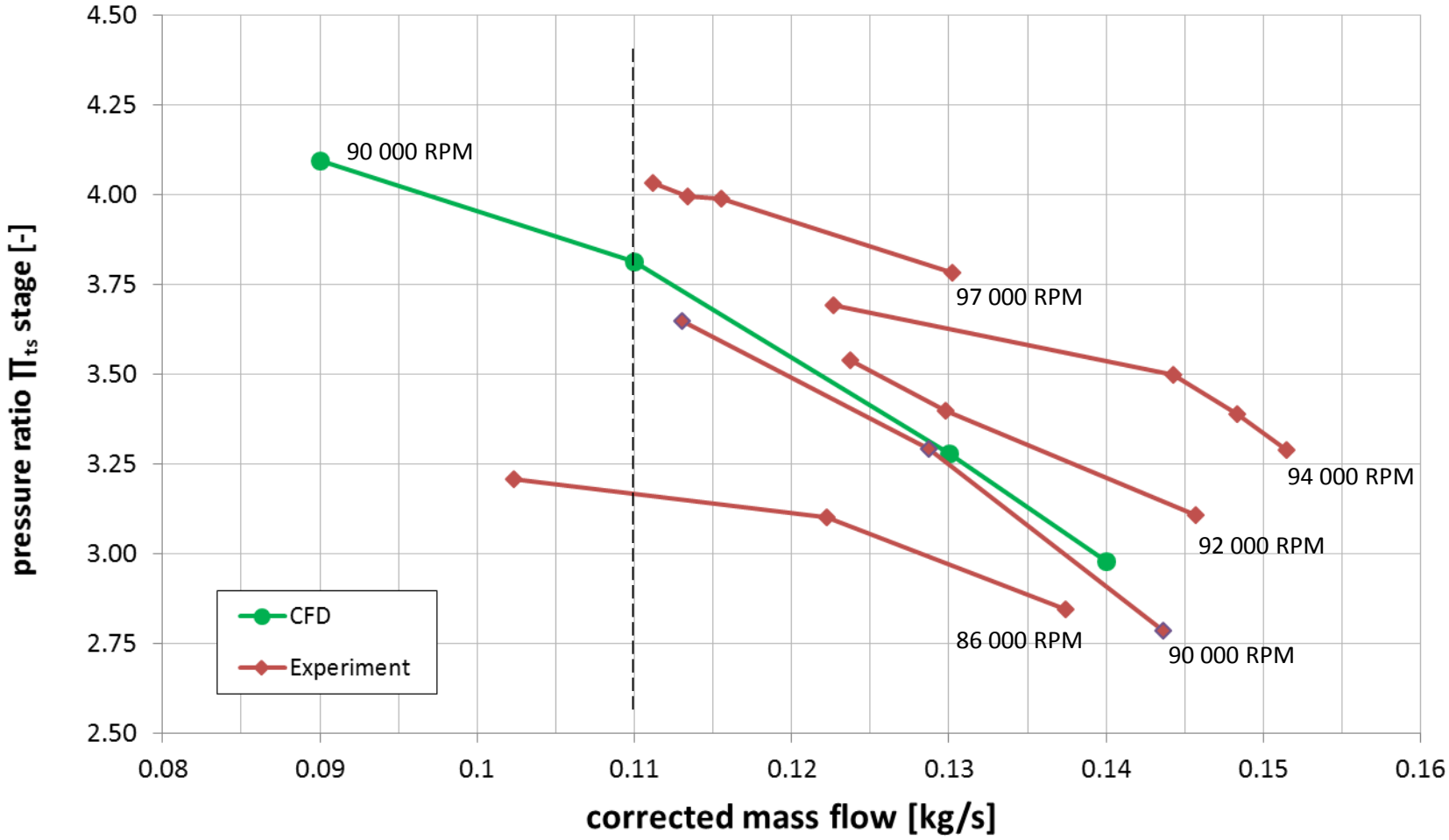
Impeller

Static pressure (mid-span) (blade-to-blade) (meridian)



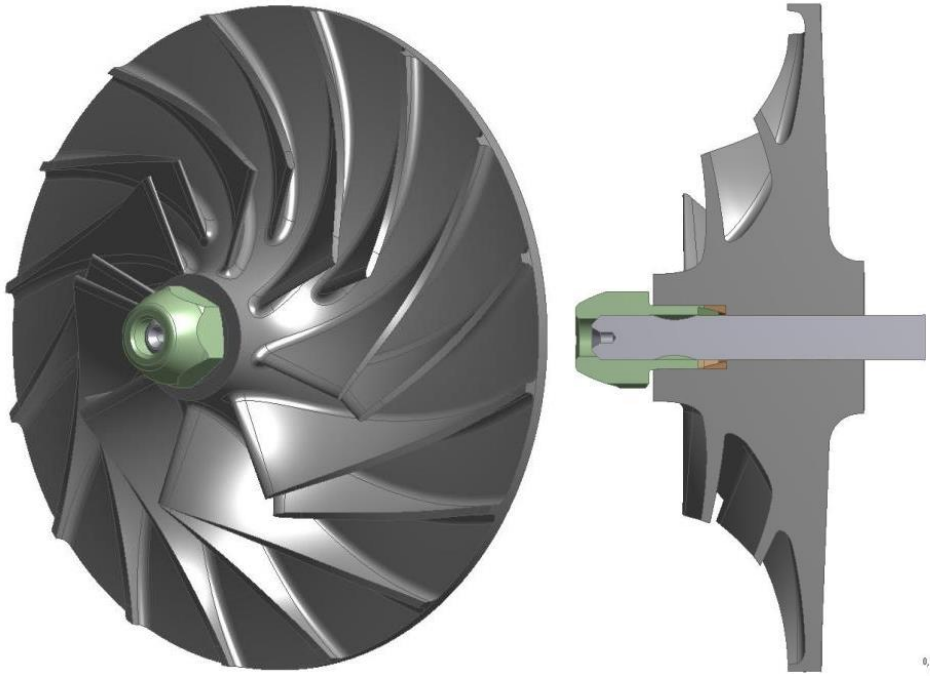
4. Results

Performance map



4. Results

Prototype



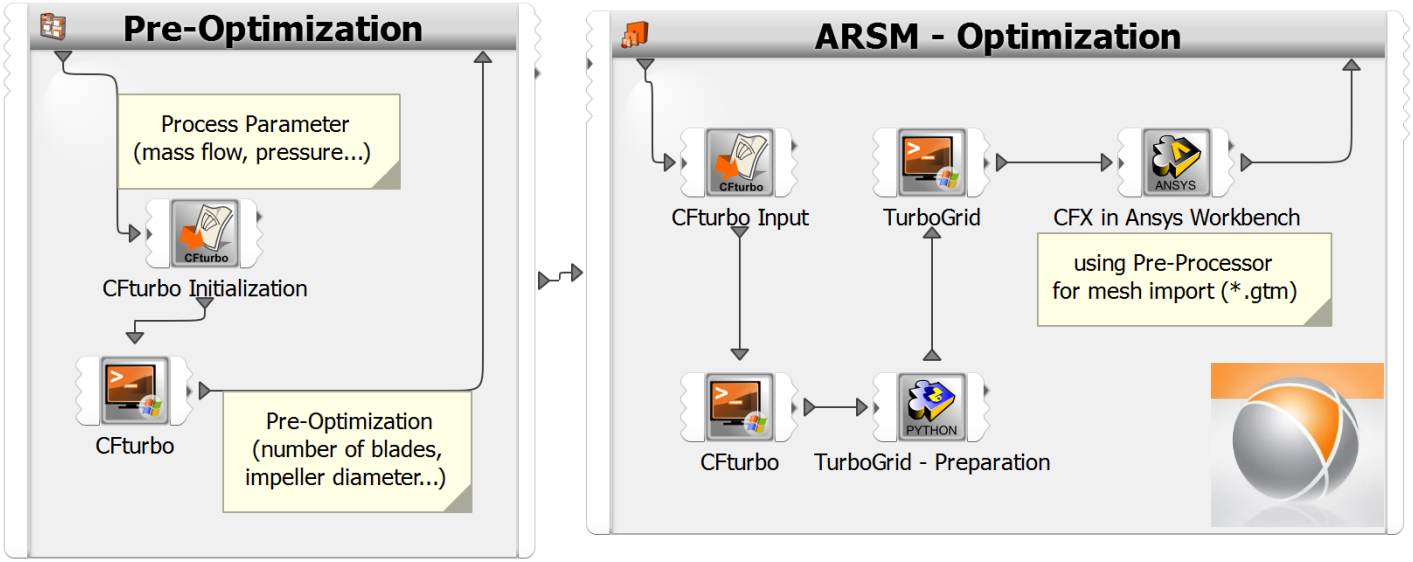
5. Conclusion and next steps

- CFD based design procedure for compressor stage
  - comfortable, easy-to-use
  - reliable results
  - very fast design and analysis
- 10 different compressors designed to get best compromise between efficiency, power requirements and geometrical constraints
- Project was running within 4 weeks
- Stage efficiency η_{St} = 67 %
  Impeller efficiency η_{Imp} = 84 %
  Power consumption P_i = 25 kW

5. Conclusion and next steps

Optimization

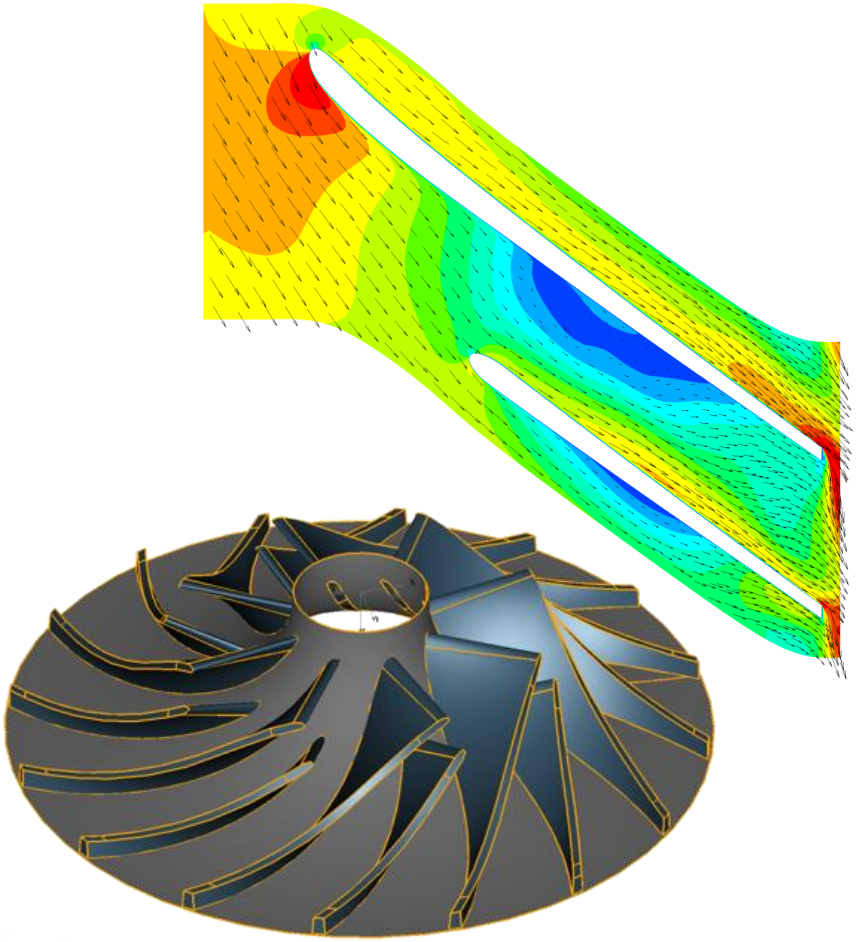
- Efficiency optimization (impeller only) using optiSLang
- CFturbo for initial design and Pre-Optimization
- ANSYS TurboGrid for single passage meshing
- ANSYS CFX for flow simulation
- Adaptive Response Surface Method (ARSM): only ≈ 100 simulations on Desktop PC (< 24 h)



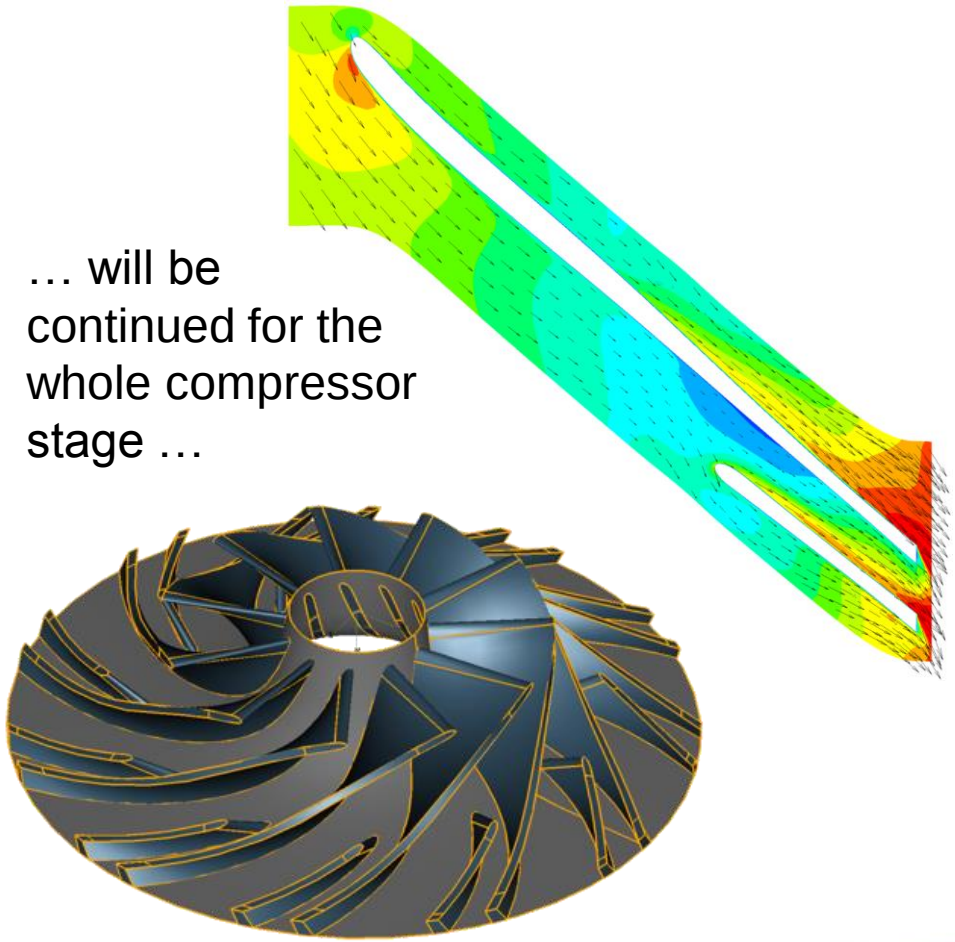
5. Conclusion and next steps

Optimization

Initial design: η_{Imp} = 78 %



Optimized design: η_{Imp} = 84.5 %



… will be continued for the whole compressor stage …