Rapid Design of an optimized Radial Compressor using CFturbo and ANSYS

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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)

1. CFturbo® Software
   - Design software for turbomachinery
   - Training courses
   - Workflows

2. CAE Consulting
   - Turbomachinery conceptual design
   - CFD/FEA simulation
   - Optimization

3. 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

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

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

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

- **High geometrical flexibility, many checks, information**

- **Geometry import, redesign optionally**

- **New / improved 3D geometry**
2. Aerodynamic compressor design

CFturbo input

Design point

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

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

- Assembly
- Volute
- Diffuser
- Impeller
3. Automated simulation process

Overview

- **Conceptual Design**: CFturbo
- **Grid generation**: ANSYS ICEM-CFD
- **Simulation**: ANSYS CFX

Optimization
- Interactive or automatic

Design point, requirements → Optimization

Product

- ANSYS
- CFturbo
3. Automated simulation process
Meshing in ICEM-CFD

Export in CFturbo

ICEM-CFD parameters in CFturbo
3. Automated simulation process
Meshing in ICEM-CFD

CFturbo2ICEM panels in ICEM-CFD
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

[Graph showing performance map with various RPM values]
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 $\eta_{St} = 67\%$
- Impeller efficiency $\eta_{Imp} = 84\%$
- 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 $\approx 100$ simulations on Desktop PC ($< 24$ h)
5. Conclusion and next steps

Optimization

Initial design: $\eta_{\text{Imp}} = 78\%$

Optimized design: $\eta_{\text{Imp}} = 84.5\%$

... will be continued for the whole compressor stage ...