Steady RANS Simulation of TUDa Compressor with an In-house Code

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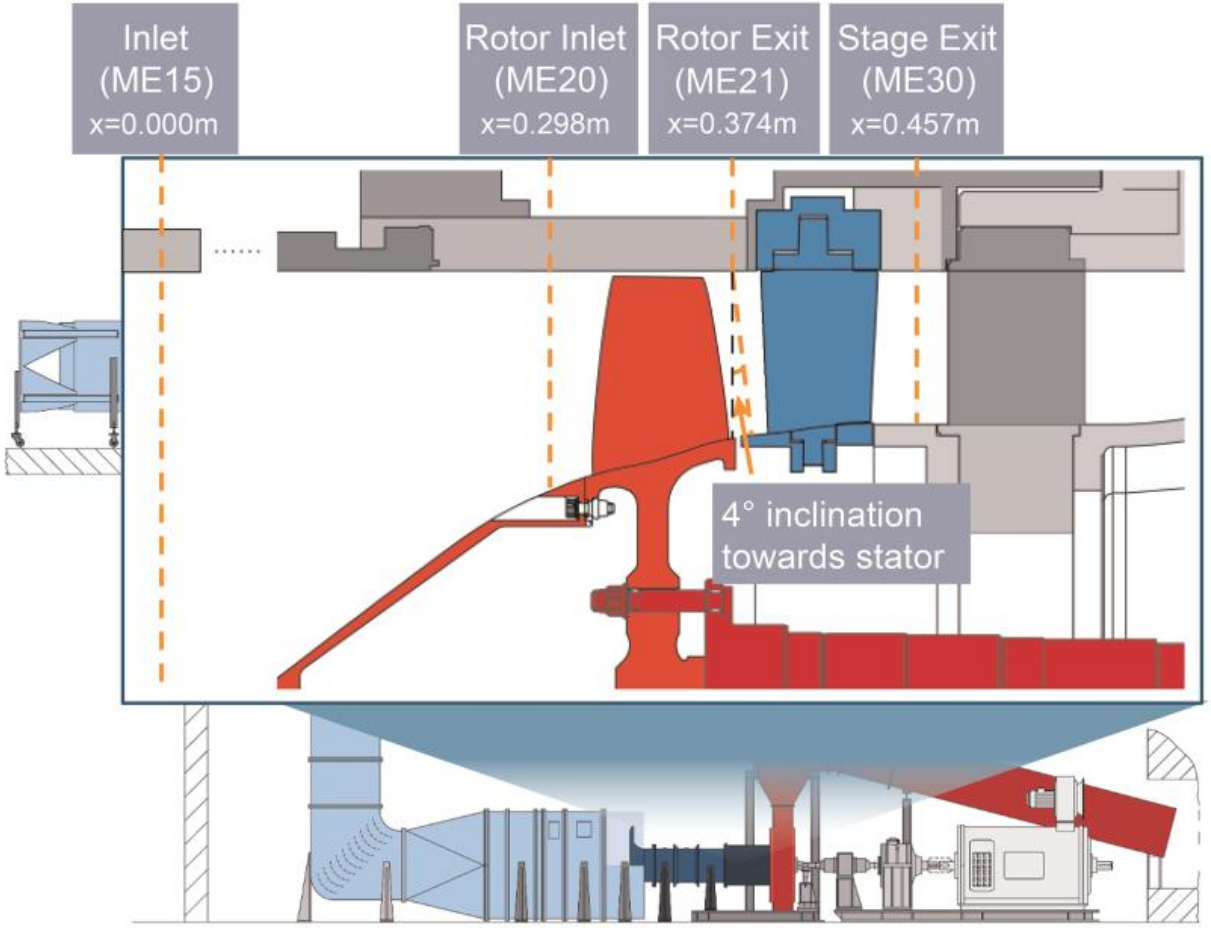
Laboratory for Advanced Simulation of Turbulence

- Research Object
- Numerical Method
- Result
- Summary

Laboratory for Advanced Simulation of Turbulence

Research Object

☐ TUDa-GLR-OpenStage



Parameters	Values
Rotor tip Mach number	1.17
Rotor mean aspect ratio	0.94
Rotor hub-to-tip ratio	0.51
Rotor tip gap-to-chord ratio	0.80%
Rotor tip radius (mm)	190
Rotor tip chord length (mm)	94
Rotor design speed (RPM)	20000
Stage flow coefficient	0.37
Stage loading coefficient	0.4
Stage mass flow (kg/s)	16
Stage total pressure ratio	1.5
Number of blades	16/29/5

He X, Zhu M, Xia K, et al. Validation and verification of RANS solvers for TUDa-GLR-OpenStage transonic axial compressor[J]. Journal of the Global Power and Propulsion Society, 2023, 7: 13-29.

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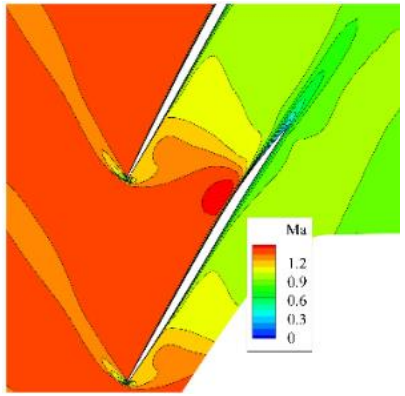
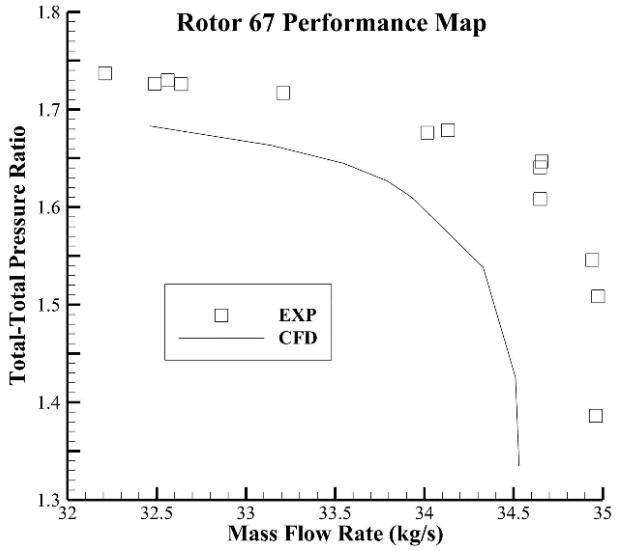
Numerical Method

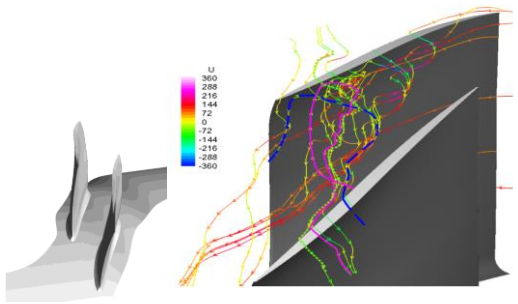
☐ CFD solver: TRANS (in-house)

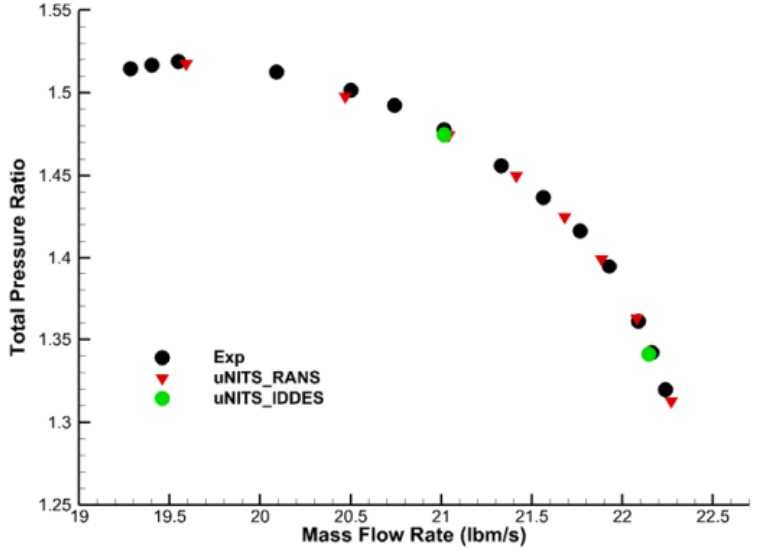
1. Axial Compressor Rotor
Single Passage, RANS
NASA Rotor 67



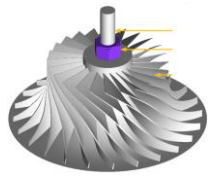


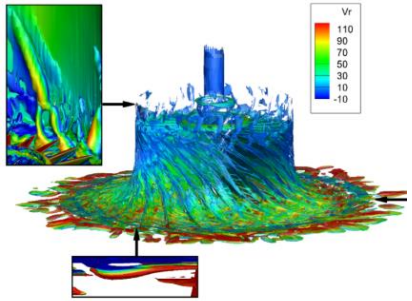
2. Axial Compressor Rotor
Single Passage, IDDES
Designed by University of
Notre Dame

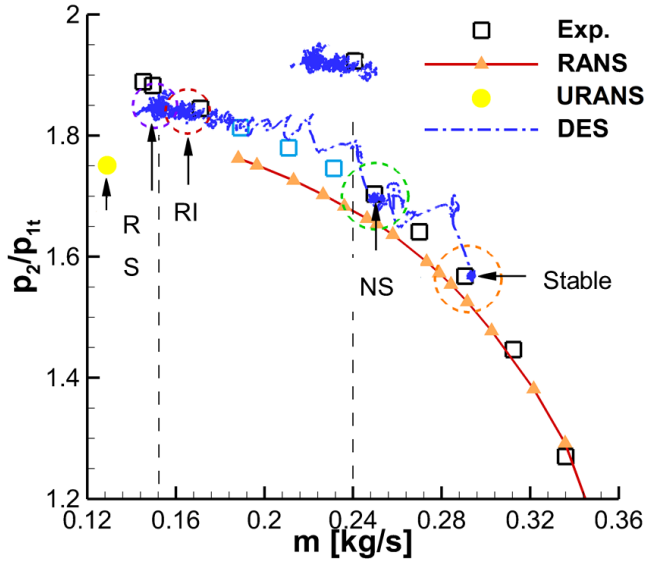




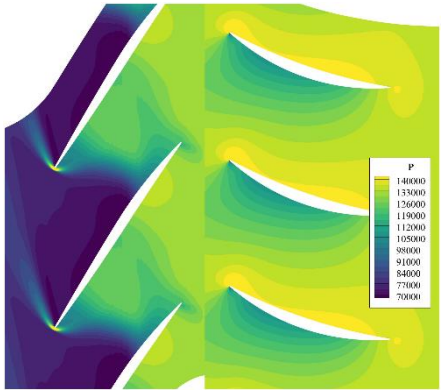
3. Centrifugal Impeller
Annulus, IDDES
Designed by Tsinghua University

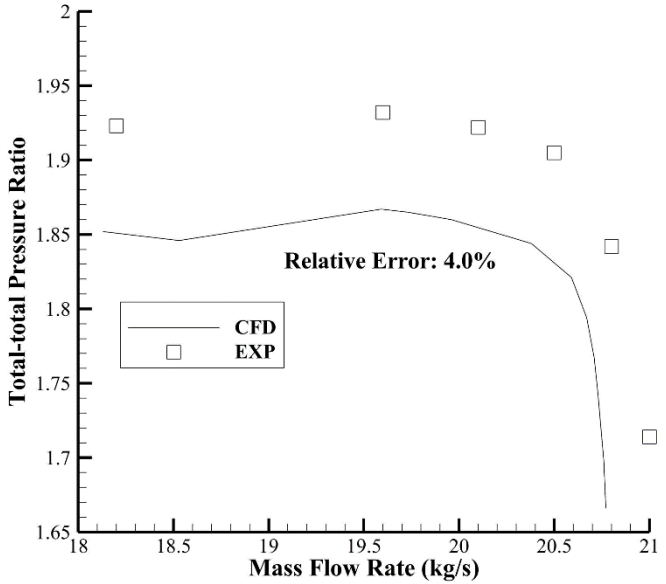






4. Axial Compressor Stage
Single Passage, RANS
NASA Stage 35

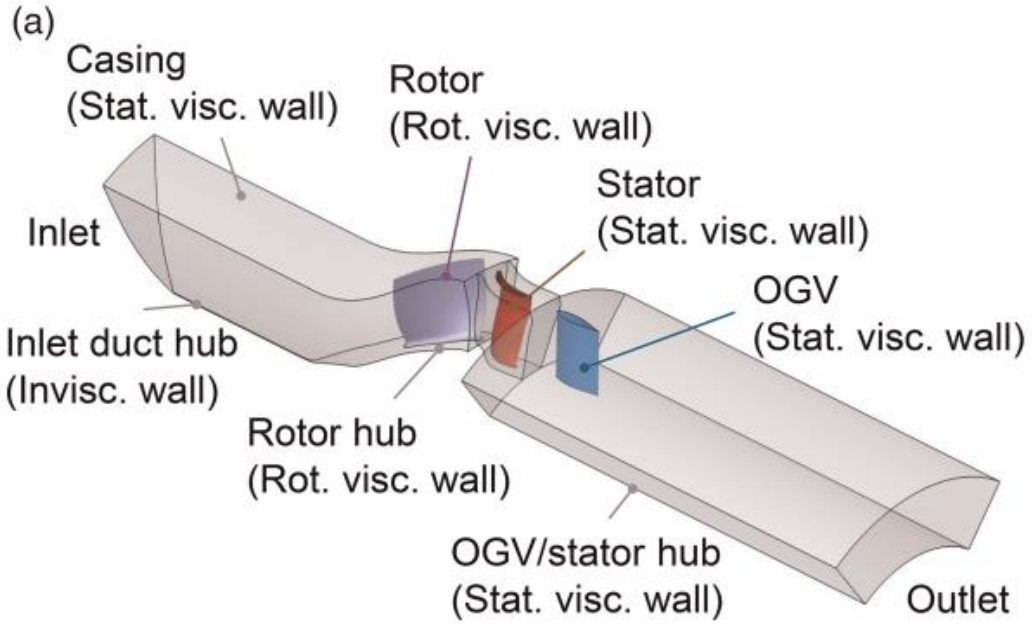




Numerical Method

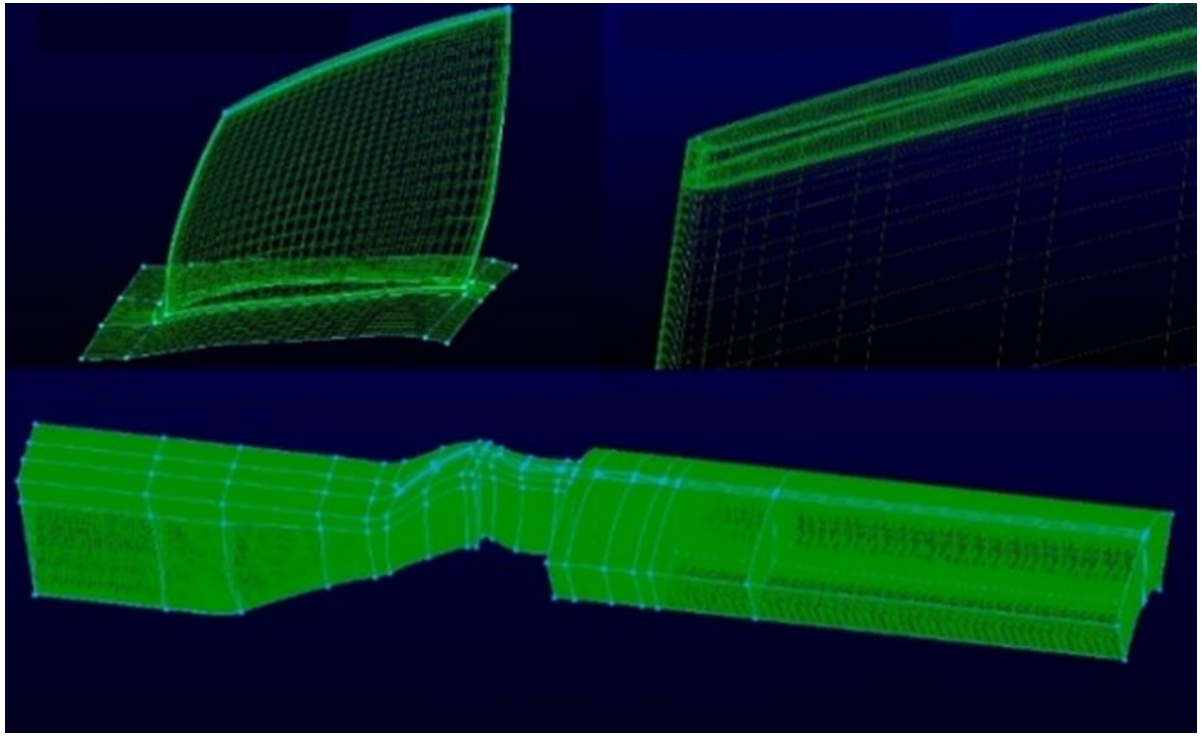
☐ Mesh for CFD

- Offical grid: fine
- No pinched rotor casing
- No stator hub cavity
- Rotor + Stator + OGV, Single passage



- Total grid: 5.68M

Blade Row Name	Grid Number
Rotor	3.18 M
Stator	1.62 M
Outlet Guide Vane (OGV)	0.88 M



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Numerical Method

Numerical Scheme (2nd Order Accuracy)

- Cell-centered finite-volume scheme on structured grid
- Inviscid flux: 3rd-order MUSCL reconstruction + rotated Roe scheme
- Viscid flux: 2nd-order central scheme
- Steady simulation: implicit LU-SGS scheme with iterations in pseudo time

Rotor/Stator Interface

- Rotor in rotating frame, Stator in static frame
- Interface: Mixing Plane

Rotational Speed

- 100% (20000 rpm)

Mixing Plane Method

- 2021 An Liu, Yaping Ju, Chuhua Zhang
- Characteristic variable perturbations

Boundary Conditions

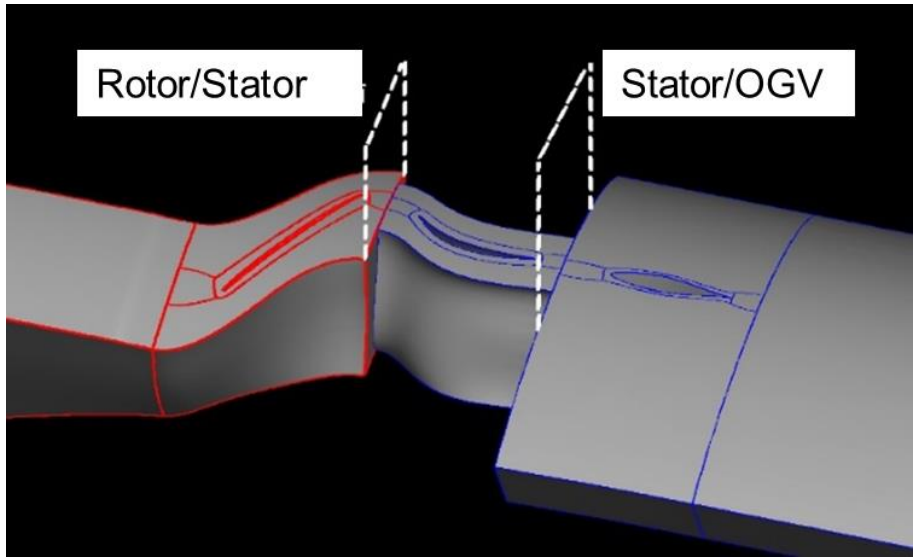
- Solid walls: no-slip and adiabatic condition
- Inlet: P_0=101325 Pa, T_0=288 K, pure axial; Turbulent intensity=0.1, μ_t/μ=100.0
- Outlet: radial equilibrium backpressure
- Rotational period boundary

Turbulence Model

- Standard SST k-ω Model

Fluid Model

- Ideal gas



$$dc_1 = -\bar{a}^2 d\rho + dp$$
$$dc_2 = \bar{\rho}\bar{a} dv_\theta$$
$$dc_3 = \bar{\rho}\bar{a} dv_t$$
$$dc_4 = \bar{\rho}\bar{a} dv_n + dp$$
$$dc_5 = -\bar{\rho}\bar{a} dv_n + dp$$

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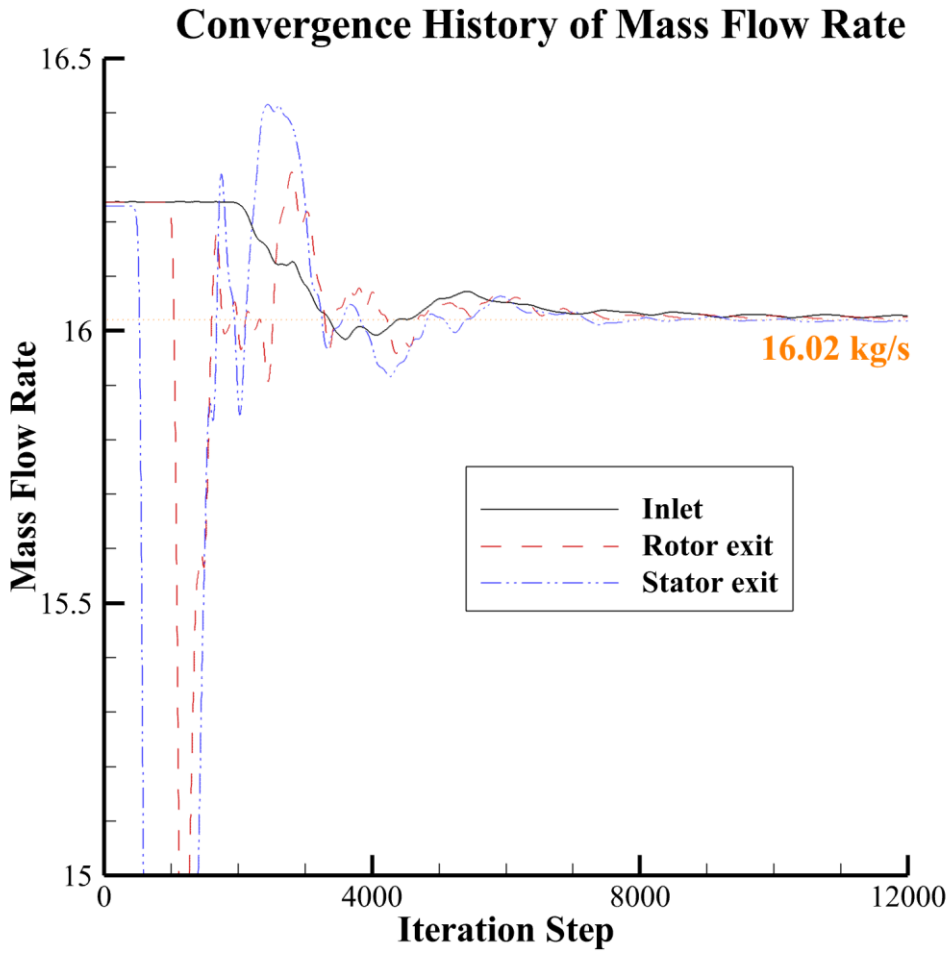
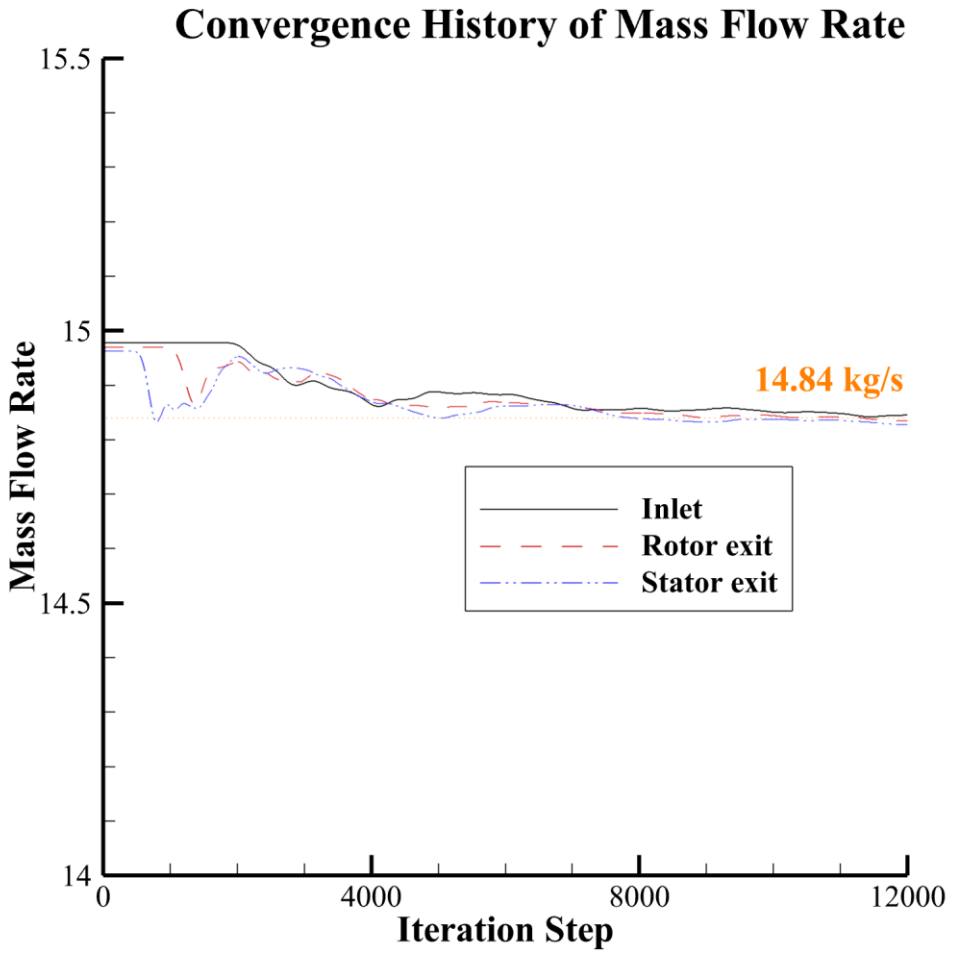
Result

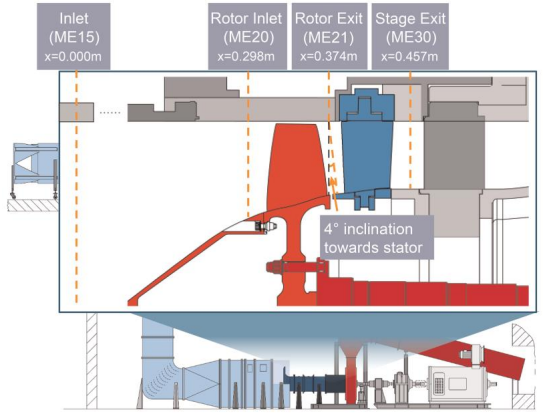
☐ Convergence History (Mass Flow Rate)



Peak Efficiency



Near Stall



Inlet: ME15

Rotor exit: ME21

Stator exit: ME30

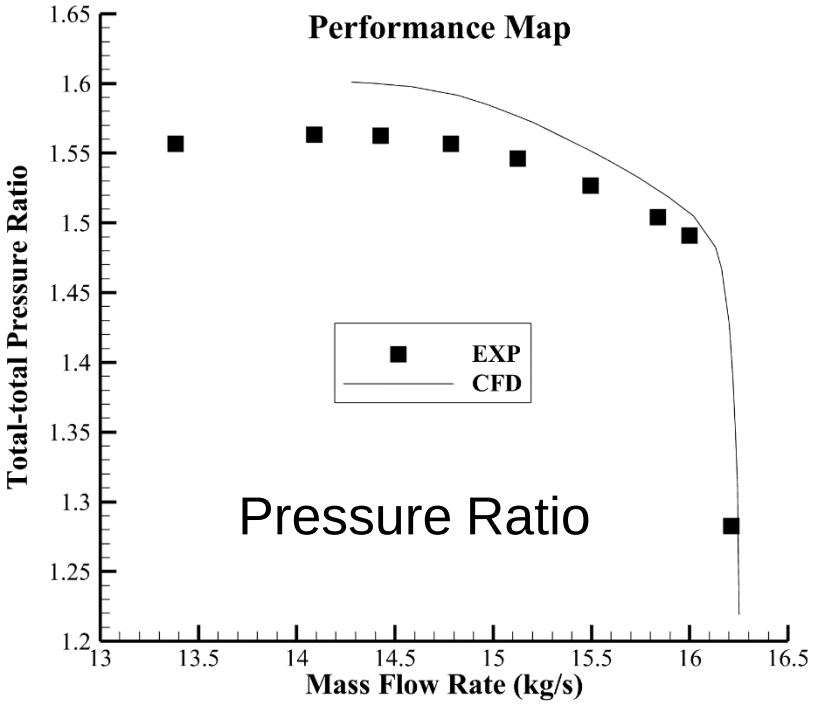
Rotational Speed:
100% (20000 rpm)

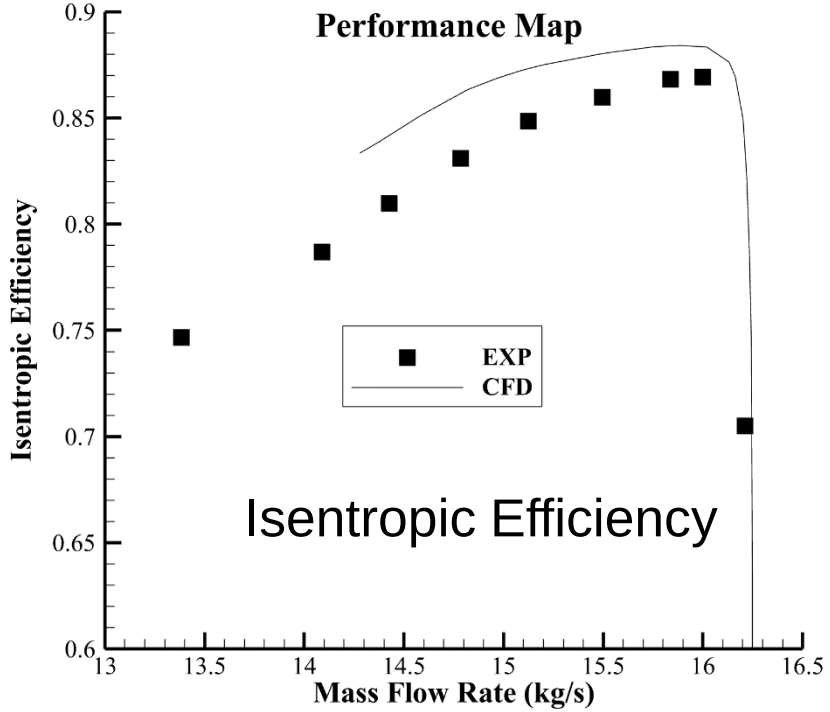
Result

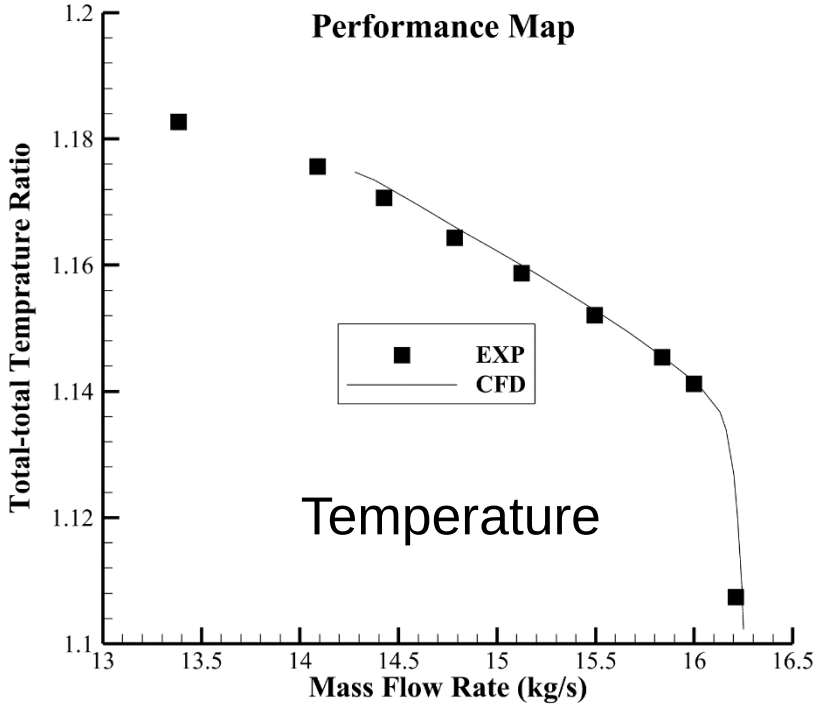
Rotational Speed: 100% (20000 rpm)

☐ Compressor Characteristic

Stator Exit ME30 / Inlet ME15





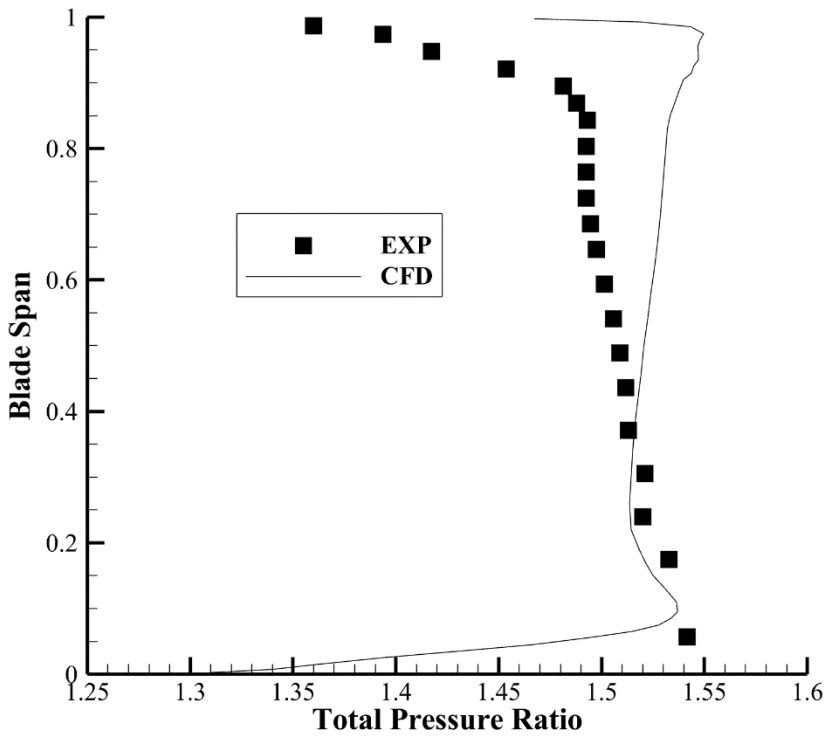


Operating Point	Peak Efficiency			Near Stall		
Characteristic	Pressure	Efficiency	Temperature	Pressure	Efficiency	Temperature
EXP	1.491	0.869	1.141	1.557	0.831	1.164
CFD	1.505	0.883	1.141	1.591	0.864	1.165
Relative Error	0.94%	1.63%	0.00%	2.22%	3.90%	0.09%

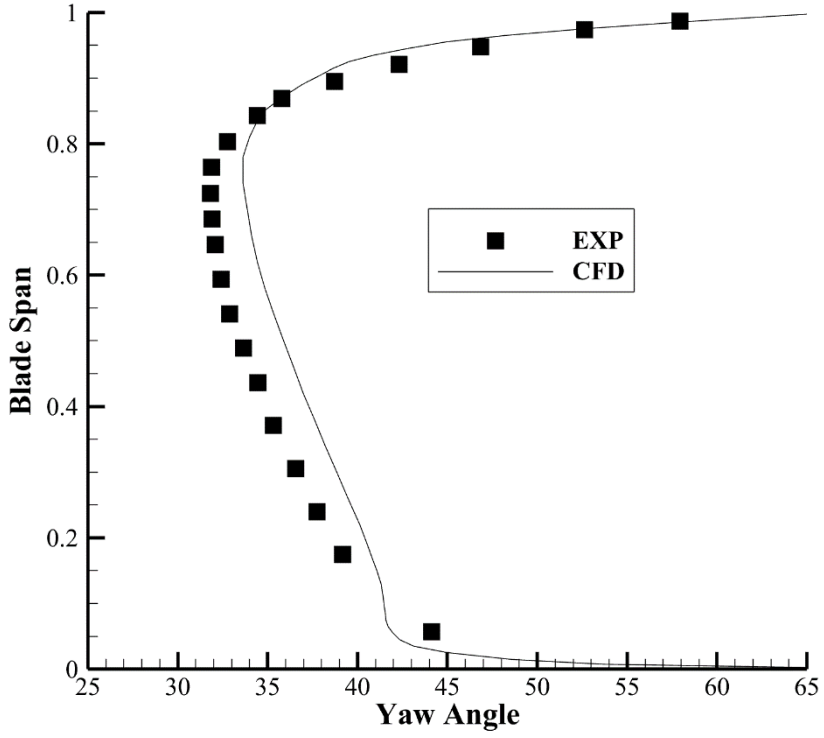
Result

☐ Radial Profile at ME21 (rotor exit)

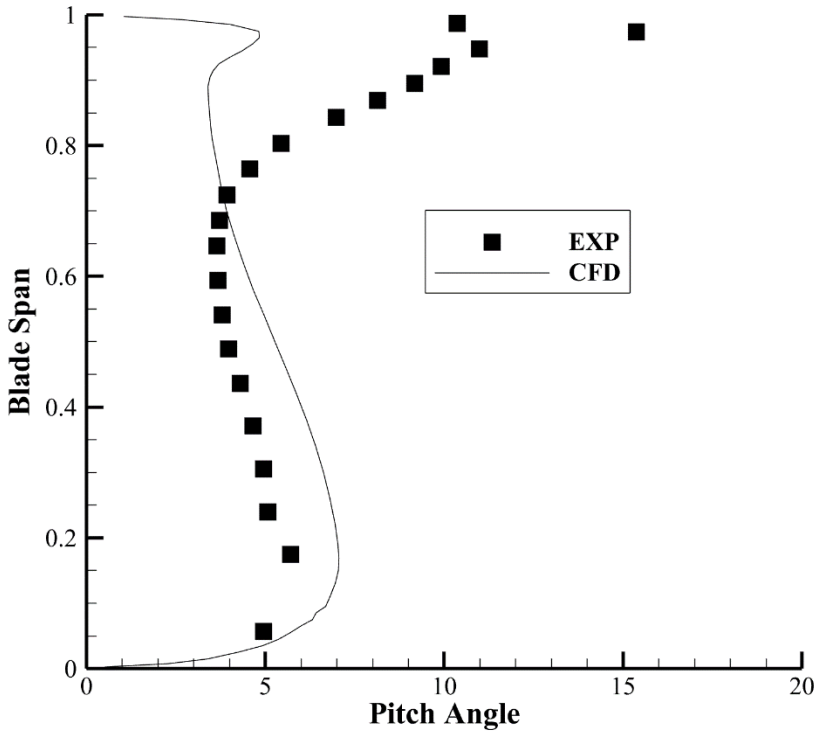
CFD: No pinched rotor casing



Total Pressure Ratio



Yaw Angle



Pitch Angle

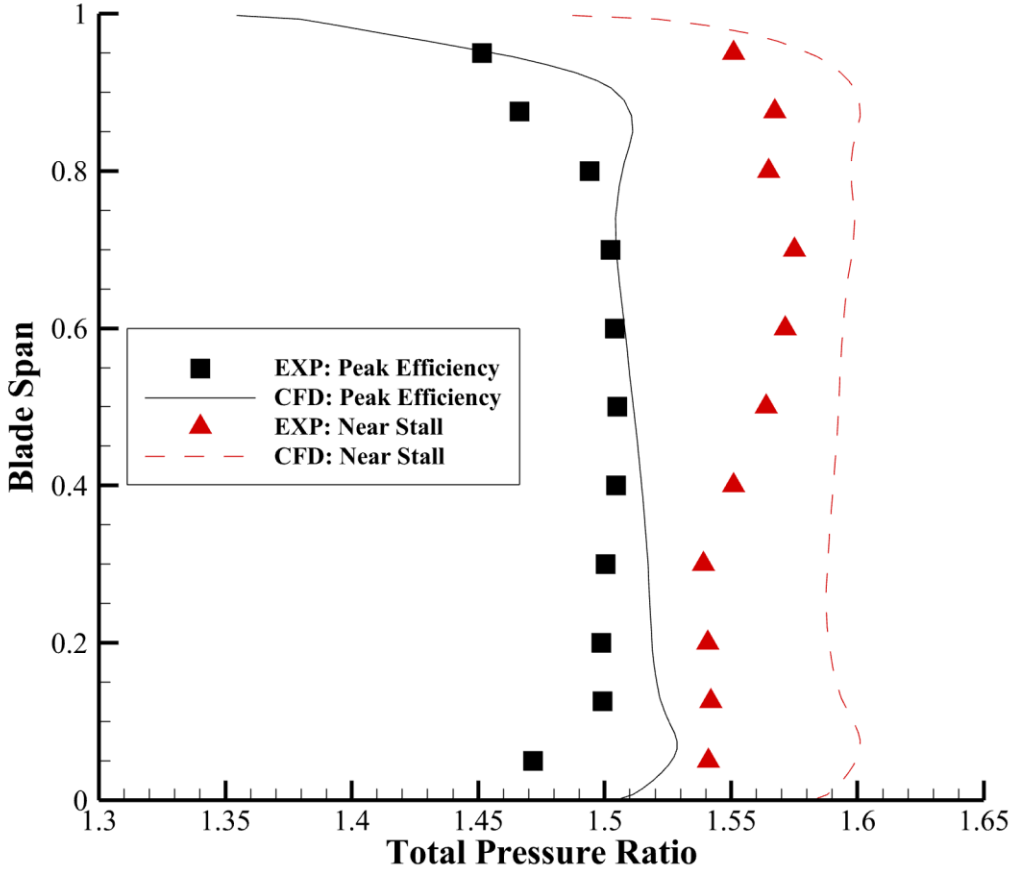
Operating Point: Peak Efficiency

Rotational Speed:
100% (20000 rpm)

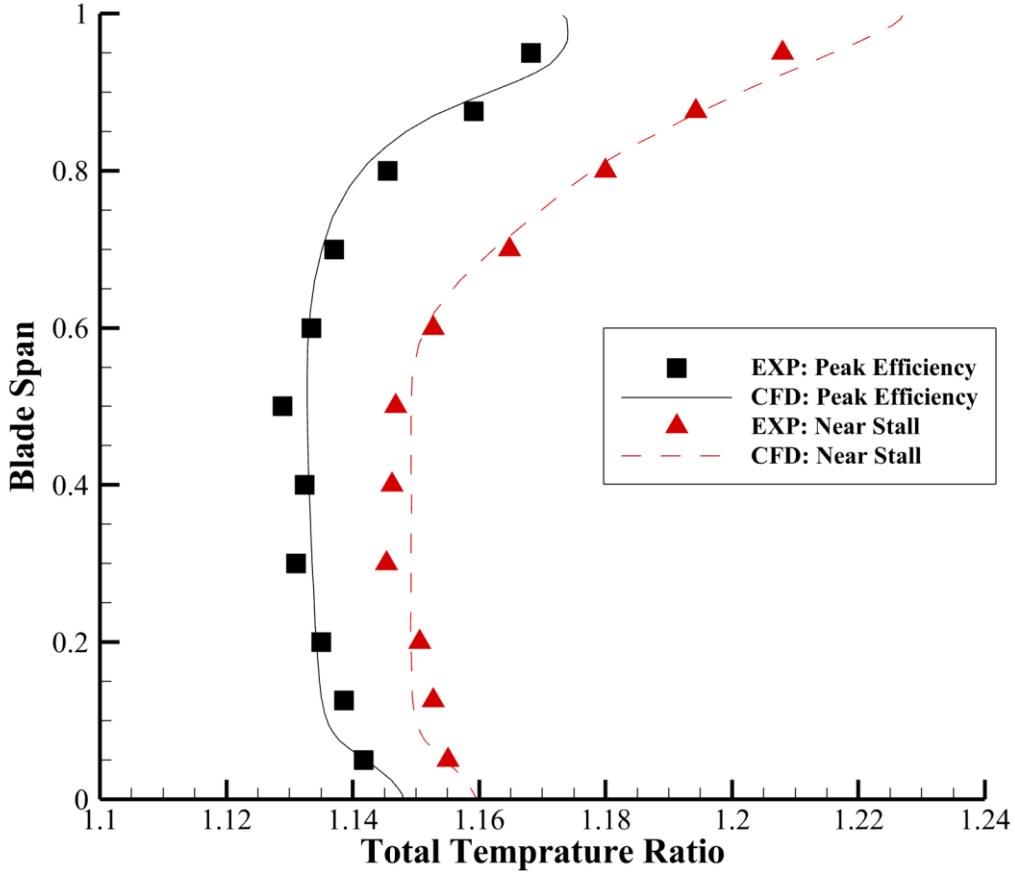
Result

Rotational Speed: 100% (20000 rpm)

☐ Radial Profile at ME30 (stator exit)



Total Pressure Ratio



Total Temperature Ratio

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Summary

- In-house CFD code “TRANS”
- Steady RANS of TUDa compressor, mixing plane
- Rotational Speed: 100% (20000 rpm)
- Official fine grid, no pinched rotor casing, no stator hub cavity
- 2nd-order accuracy numerical scheme, MUSCL+Roe+LUSGS, SST model
- Relative error in characteristic (Near Stall)

For pressure ratio: 2.2%

For isentropic efficiency: 3.9%

THANKS FOR LISTRENING!

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