CFD Post processing of Industrial Gas Turbine Exhaust Diffuser
and
Optimization of a 1D Analysis Tool

Leolein Moualeu
Department of Mechanical Engineering
University of North Dakota
Grand Forks, ND 58203

Overview

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- Catalogue for Exhaust Diffuser
  - Content
  - Diffuser geometry
  - Diffuser inlet profiles
  - Diffuser performance
- 1D Analysis Tool
  - Definition & Content
  - 1D tool calculations
  - Results
  - Problems with the tool
  - Approach for result improvement
- Acknowledgement

Catalogue Content

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Objective: Define a catalogue summarizing performances and other information for exhaust diffuser

Geometry Section

- Longitudinal views with cold dimensions (CAD data)
- Views of 2D CFD profiles
- Area plots (Area vs. x, AR vs. x/L)

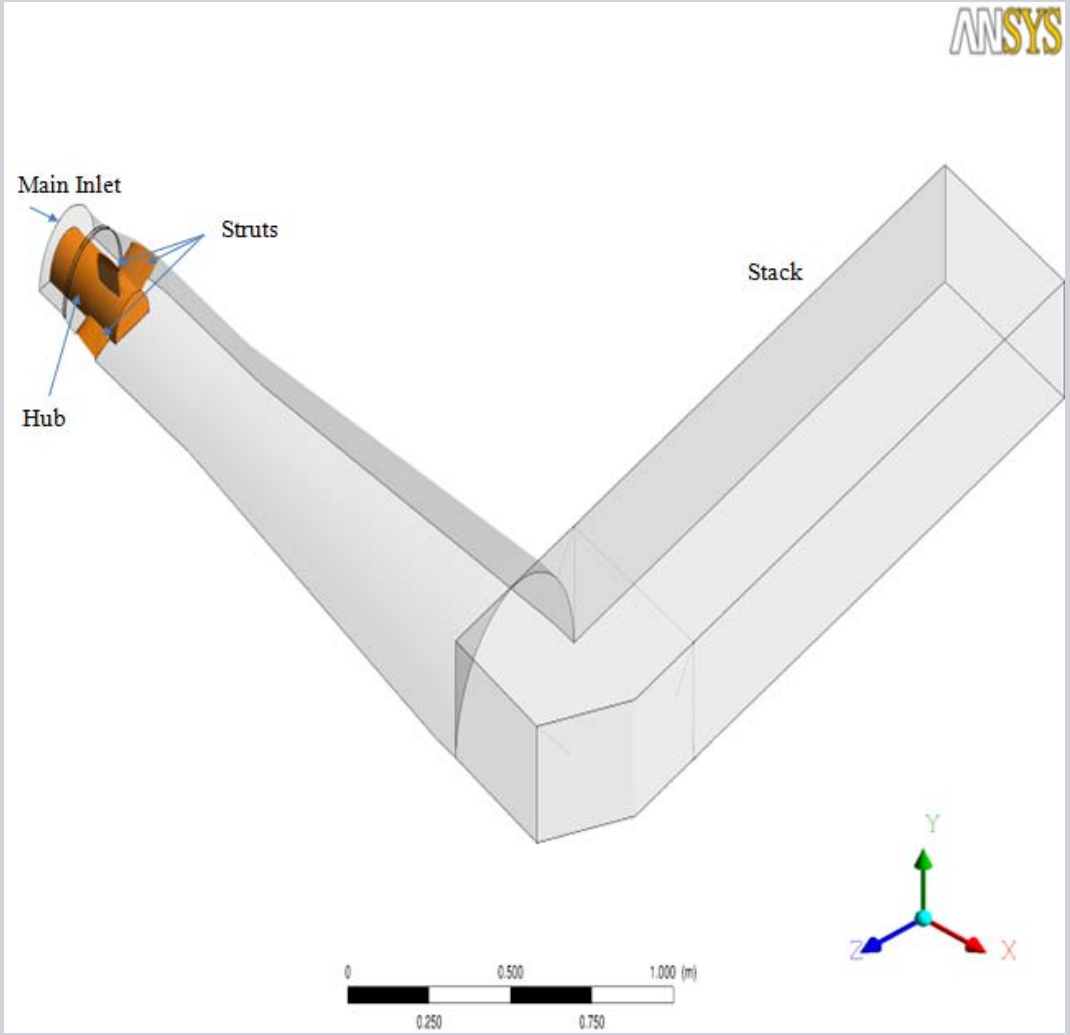
Performance

- Area vs. x/L (with strut blockage)
- Dimensionless plots: Cp, Loss, kinetic energy coef, P_t, and P

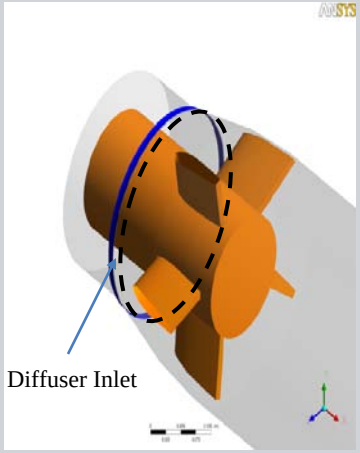
Aerodynamics

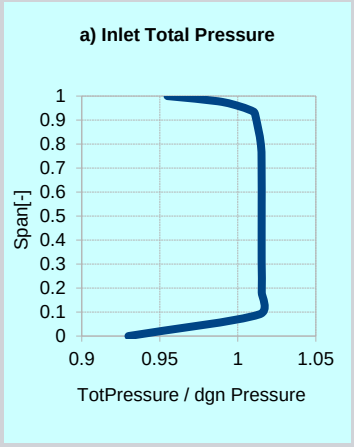
- Radial plots: Inlet P_t, T_t, Swirl, Pitch, V components, and Ma
- Struts: 2D profiles, Pressure Coef vs. Chord @ Hub, mid-span, and Shroud

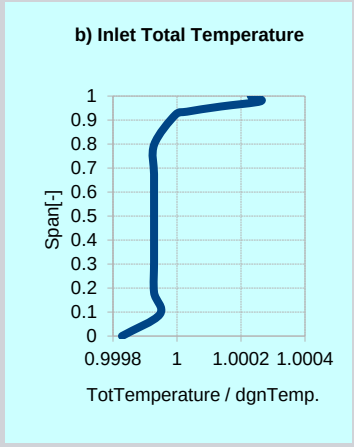
ITSM Baseline Configuration: Geometry

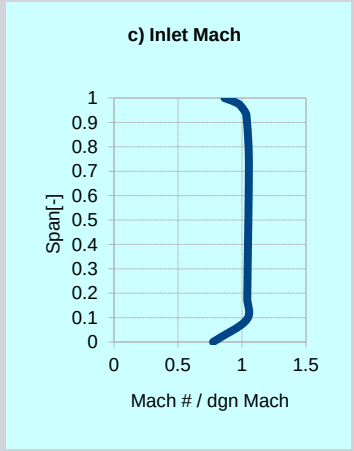


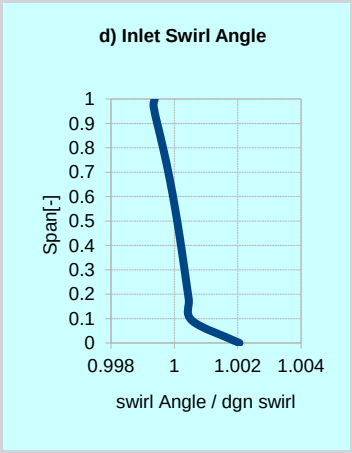
ITSM Baseline Configuration: Inlet Profiles

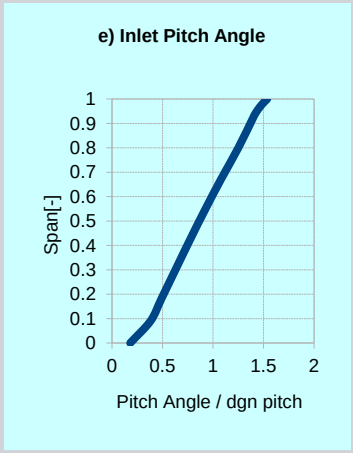


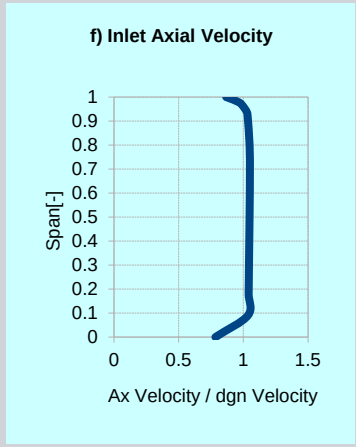


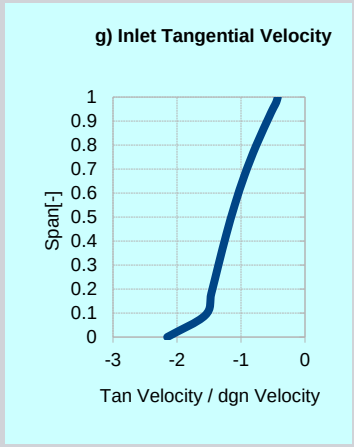


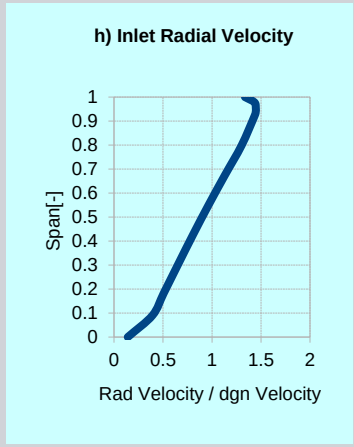




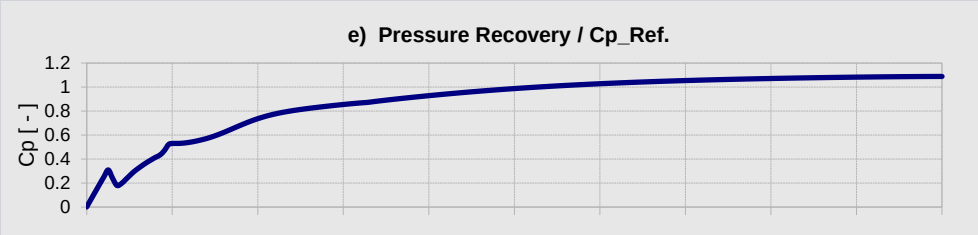


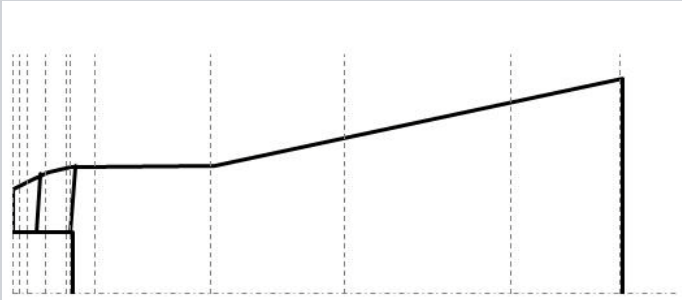


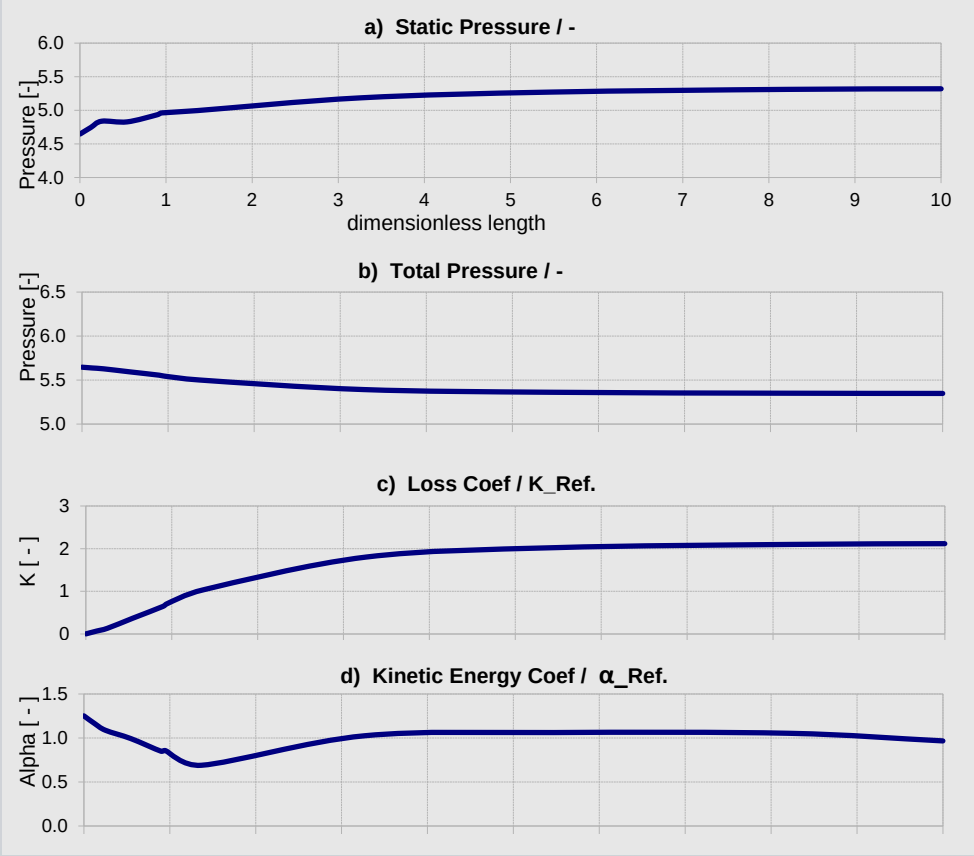




ITSM Baseline Configuration: Performance







1D Analysis Tool

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Definition: Mean line code developed to evaluate the performance of the diffuser and validate design for further CFD and experimental analyses

Content:

- Inlet boundary condition inputs
- Geometry inputs
- Sections of the segmented diffuser (4 main regions) and calculations for each section
- Developed correlations for drags on struts
- Results and comparison to CFD predictions

1D-tool Calculations

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Assumptions:

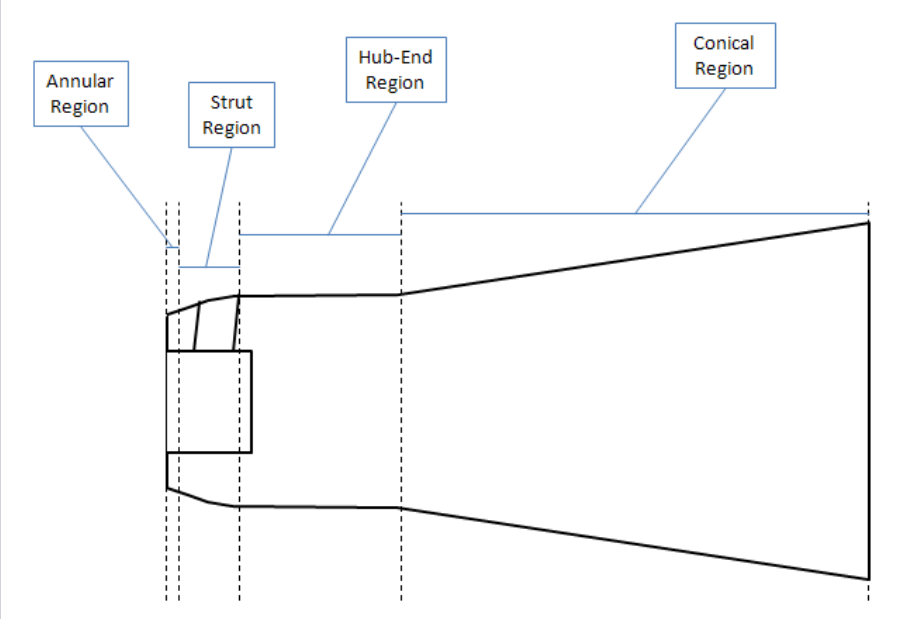
- Steady flow
- Incompressible
- No heat transfer

$$A_1 \cdot c_{x,1} = A_2 \cdot c_{x,2}$$

$$p_1 \cdot A_1 - p_2 \cdot A_2 - \sum F_{drag} + F_p = \rho \cdot \left(- A_1 \cdot c_{x,1}^2 + A_2 \cdot c_{x,2}^2 \right)$$

$$C_p = \frac{p_2 - p_1}{p_{t,1} - p_1}$$

$$K = \frac{p_{t,1} - p_{t,2}}{p_{t,1} - p_1}$$



- Skin-friction drag applied in all regions
- Base drag added in Hub-end region
- Incremental, interference, and profile drags added in Strut region

Results

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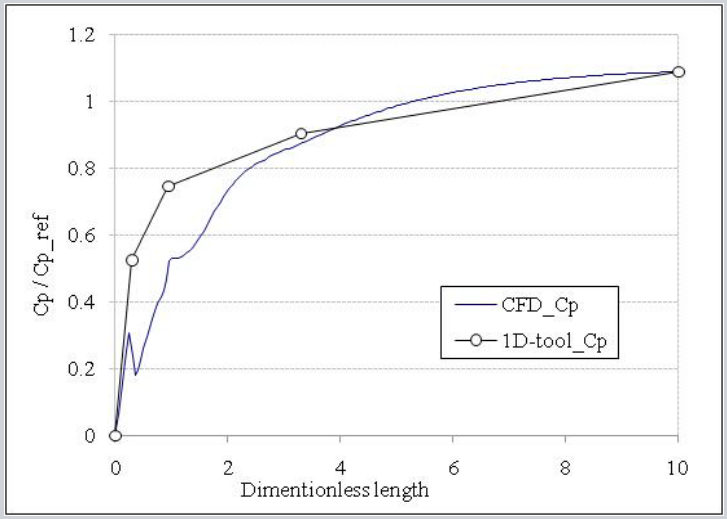

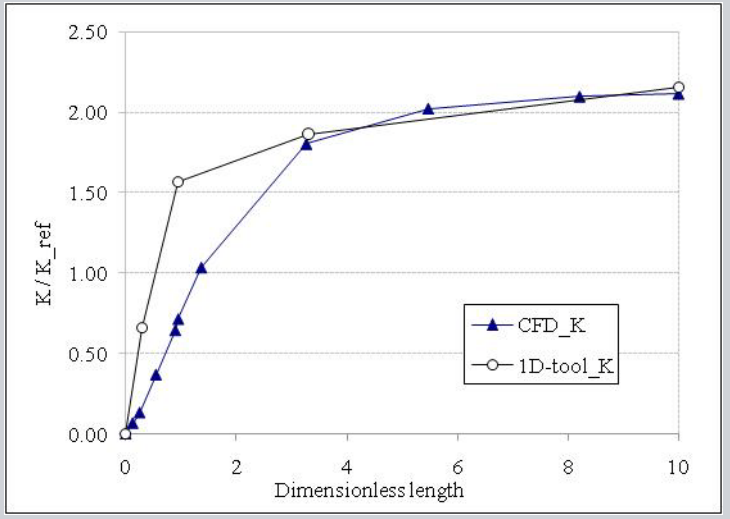

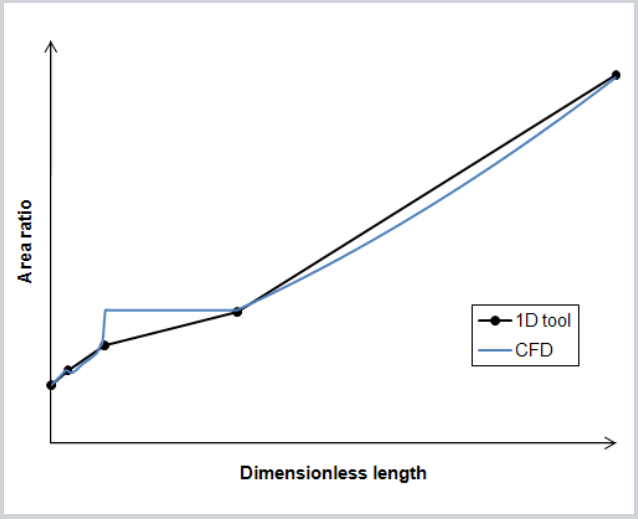

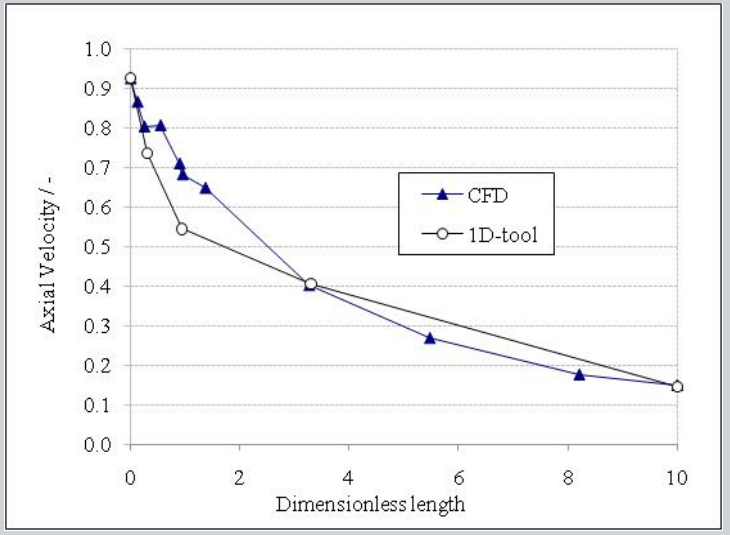

Problems with the Tool

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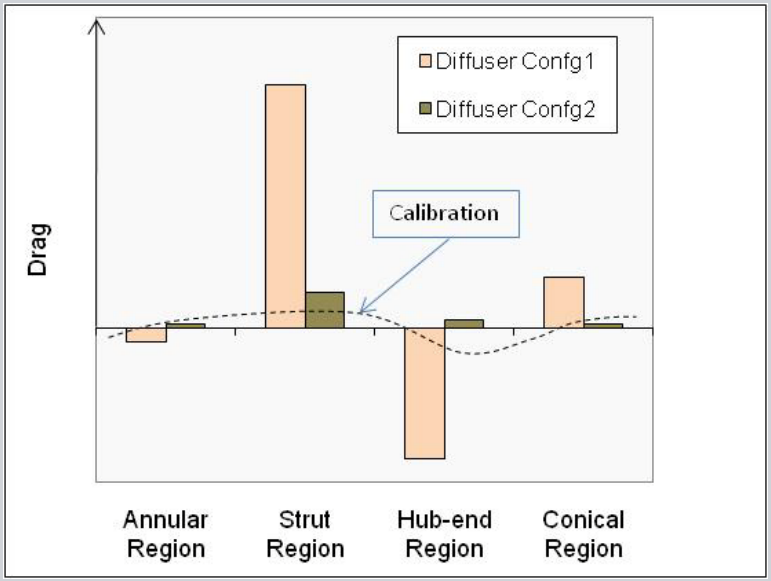
$$p_1 \cdot A_1 - p_2 \cdot A_2 - \sum F_{drag} + F_p = \rho \cdot \left(- A_1 \cdot c_{x,1}^2 + A_2 \cdot c_{x,2}^2 \right)$$

- Skin-friction drag prediction are based on flat-plate assumption
- Interference and profile drag correlations were developed for NACA struts
- Contributions of different drags are inconsistent with CFD
- Airfoil maximum thickness location in 1D tool differs from CFD model
- Profile drag correlations only account for struts in turbine exit casing

Approach for Solution Improvement

Updating drag predictions in all regions

- Match 1D-tool and CFD static pressure predictions
- Evaluate new drags to CFD predictions
- Plot new drags for different diffuser configurations to obtain calibration coefficients



Conclusion

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- Locations for 1D tool calculations should be properly chosen
- Boundary layer calculation can be added in regions with minimum flow complexity
- Contributions of different drags in Strut and Hub-end regions are underpredicted
- Drag calibrations for all the regions can be obtained
- More CFD diffuser configurations would need to be evaluated
- Improvement of drag predictions will result in better pressure recovery prediction for each region

Acknowledgement

THANK YOU…

SIEMENS & UTSR University Turbine Systems Research