Loss Models Extraction from CFD Datasets

General Information

Type:	Master Thesis (30 ECTS) or Semester Project (10 ECTS)
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1 Background

The design of a turbomachine relies on different simulation tools, which differ in terms of accuracy and computational cost. Balje maps [1] offer a useful pre-design strategy both in terms of type and size of the machine. Nonetheless, for a rigorous assessment of the aerodynamics, CFD or mean-line models should be employed. CFD is a high-fidelity model and it is usually dedicated to the refinement of the 3D geometry given the computational cost associated to it. On the other hand, in the context of design optimization, a mean-line model [2] is a desirable option in terms of both accuracy and computational cost.

The philosophy behind mean-line modeling consists of dividing the machine into control volumes on which balance laws (concerning mass, energy and rothalpy) can be imposed to deduce the respective outlet properties (both thermodynamic and kinematic). The procedure is carried out sequentially, moving from the inducer to the volute (in the case of a turbocompressor), since the outlet of one control volume serves as the inlet of the next. The quality of the aerodynamics taking place, depending on the geometry of the machine and operating conditions, is accounted for by loss correlations which quantify the impact on performance of undesirable flow phenomena (skin friction, tip leakage, incidence, trailing edge mixing, etc.). Nonetheless, these correlations are obtained for a limited number of scenarios and have a range of validity which might not be suitable for certain types of application (e.g., small-scale turbomachinery).

In our laboratory, research efforts have been already done to extract (from a dataset of CFD simulations) losses and other mean-line aerodynamic variables (such as blockage and slip coefficients) so that, in a future step, the associated correlations can be calibrated to obtain a new model combining the accuracy of data-driven methods with the interpretive and generalization strengths of traditional mean-line models.

2 Objective

The objective of this study is to develop new correlations from the losses and other mean-line aerodynamic variables (such as blockage and slip coefficients) extracted from datasets of CFD simulations of both turbocompressors and turbines.

Tasks

1. Familiarize yourself with aerodynamics and mean-line models of turbomachines.
2. Conduct a literature review on correlations concerning losses and other mean-line aerodynamic variables (such as blockage and slip coefficients).
3. Fit and compare data-driven (e.g., [3, 4]) and physics-based loss correlations.

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[1]The possibility to work from the EPFL main campus in Lausanne can be discussed (semester project only)

4. Optional: investigate model architectures to accelerate large-scale computations for design optimization.

NB: adjustments may be required according to progress, results, and project duration.

Prerequisite knowledge

1. Fluid Mechanics and Thermodynamics
2. CFD (experience in Ansys CFX is a plus)
3. Python
4. MATLAB

References

[1] Otto E. Balje. *Turbomachines: A Guide to Design, Selection, and Theory.* John Wiley & Sons, New York, 1981.

[2] Ronald H. Aungier. *Centrifugal Compressors: A Strategy for Aerodynamic Design and Analysis.* ASME Press, New York, 2000.

[3] J. Brind. Data-driven radial compressor design space mapping. *Journal of Turbomachinery*, 147(2):021001, 09 2024.

[4] A. C. Senior and R. J. Miller. A data-centric approach to loss mechanisms. *Journal of Turbomachinery*, 146(4):041007, 12 2023.