Master project - Surrogate Modeling of a Radial Turbine with Artificial Neural Networks for Modular and Robust Fuel Cell Applications

November 24, 2022

General information

- Laboratory: Laboratory of Applied Mechanical Design (LAMD)
- Supervisor: Soheyl Massoudi, Prof. J. Schiffmann
- Location: Lausanne or Neuchâtel (travel allowance offered)
- Starting date: ASAP
- Duration: Semester
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Background

Gas-bearings supported micro-turbomachinery is an emerging field in fuel cell applications. They allow for the deployment of compact, oil-free, maintenance free turbine-driven compressors for mobility applications [1]. However, their efficiency is highly dependent on that of the turbine and compressor being used. Should the manufacturing processes deviate from the nominal design point, or its operating conditions change to adapt to a different load, or varying atmospheric conditions, best performance may no longer be guaranteed. This is why robustness against deviations from the nominal design point, and modularity with respect to operating conditions, are among the design goals of a fuel cell turbocompressor.

Systems are often engineered by evaluating their performance exclusively at nominal conditions. Robustness and modularity are sometimes evaluated a-posteriori through a sensitivity analysis, which does not guarantee an optimal design. These sensitivity analysis could be introduced in the early stage of the design process as objectives and/or constraints of the optimization.

While a surrogate model has been developed to allow for fast design of the compressor wheel [2], the current numerical turbine model available is too slow for this task.

Objective

The objective of this project is the surrogate model of the experimentally validated 1D radial turbine model with feed-forward neural networks. This has already been successfully done for the 1D radial compressor model. You will extend generate data by calling the turbine model and train the neural networks. (Master project only) You will deploy the model in multi-objective optimization and identify the parameters impacting robustness and modularity.

Tasks (working plan guideline)

1. Literature review on artificial neural networks, data sampling, radial turbines, (master thesis only) multi-objective optimization and feature selection
2. Generate data with the 1D turbine model
3. Train new neural networks for state classification and efficiency prediction
4. Validate the surrogate model by performing a time and relative error comparison with the 1D code
5. (master thesis only) Further validate the model by performing a nominal multi-objective optimization with the 1D code and the surrogate model
6. (master thesis only) Perform a multi-objective optimization and find a suitable robust and modular compressor wheel for an existing experimental test-bench of the LAMD
7. (master thesis only) Identify main parameters impacting nominal performance, robustness and modularity

References

[1] Patrick H Wagner, Jürg Schiffmann, et al. "Theoretical and Experimental Investigation of a Small-Scale, High-Speed, and Oil-Free Radial Anode Off-Gas Recirculation Fan for Solid Oxide Fuel Cell Systems". In: *Journal of Engineering for Gas Turbines and Power* 142.4 (2020).

[2] Soheyl Massoudi, Cyril Picard, and Jürg Schiffmann. “Robust design using multiobjective optimisation and artificial neural networks with application to a heat pump radial compressor”. In: *Design Science* 8 (2022).