Resolving the Roughness

Implicit Large-eddy Simulation of a Rough Turbine Cascade using the Curved Element Capabilities of a High-order Solver

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In Short

- Novel method for scale-resolving simulation of fluid flow over roughness
- Validated with channel flow simulations
- A low-pressure turbine case with Re=700K is to be simulated.
- The results will be used for validation of a RANS-based roughness model

Roughness on turbomachinery components can have a dramatic impact on the overall efficiency of the engine, and in turn, the carbon footprint thereof. The performance degradation due to roughness needs to be predicted for making decisions about component replacement. The available roughness models used in these quick RANS-based predictions still have many deficiencies. Further development of the models necessitate detailed flow information coming from the scale-resolving simulations. In this project, scale-resolving simulation of a low-pressure turbine cascade (T106C) with roughness is intended. Element curving capabilities of high-order solvers together with high-performance of a high-order solver on GPUs forms the basis of the approach. A preliminary study based on Re=80K is to be extended to Re=700K because the lack of flow complexities, such as laminar separation bubble and transition, is crucial for testing the roughness model first at its best.

A high-order compressible Navier-Stokes solver called PyFR is utilized [1]. It is a multi-platform software developed in Python, where the computationally demanding part of the job is done on the targeted backend. The code for the targeted backend is created based on the templates using Mako templating engine, and compiled on the run. This is indeed a really flexible and efficient approach where the code can be optimally compiled on the targeted backend (e.g. the CUDA backend).

A real roughness is considered using a discontinuous Galerkin scheme based on flux reconstruction (FR). Any roughness without sharp edges (i.e. any roughness that can be fit to a polynomial) is theoretically possible. Some filtering over the measured real roughness it thus essential. The devised approach not only suggests a plausible way to adopt a body-fitted grid approach as an alternative to immersed boundary method (IBM), but also enables performing LES instead of DNS without under-resolving the roughness. In addition to high efficiency of high-order methods and cost-effectiveness of GPUs, capability of doing LES over roughness could make scale-resolving simulation of real industrial cases with roughness affordable. When successfully validated, the method can even lead to a breakthrough towards modeling the roughness effect, and in turn, a small step towards designing components that comply with the challenging low-carbon-emission goals of the aviation industry.

As a preliminary study, a low-Re LPT case has already been simulated successfully [2]. Figure 1 compares the transition pattern of the smooth and rough cases. The aim of the simulations to be done in the present project is to investigate a rather high-Re LPT case (Re=700K). The high-Re results are primarily intended for validating the method in a industrially relevant case using the available experimental measurements [3]. After the validation, the results are also going to be used for testing our new RANS-based roughness model [4].

The high-Re condition is essential here due to the lack of a laminar separation bubble on the LPT blade. In fact, a laminar separation bubble with complex physics would complicate the problem for the preliminary validation of the roughness model.

WWW

http://tfd.uni-hannover.de

More Information

[1] www.pyfr.org

[2] K. Cengiz, S. Kurth, L. Wein, J.R. Seume, *Proceedings of the Global Power and Propulsion Society (GPPS)*, (2022), doi:10.33737/gpps22-tc-21

[3] M. Montis, R. Niehuis, A. Fiala, *Turbo Expo: Power for Land, Sea, and Air*, vol. 7, pp. 1535–1547, (2010). doi:10.1115/GT2010-23317

[4] S. Kurth, K. Cengiz, D. Möller, L. Wein, J.R. Seume, *Proceedings of the Global Power and Propulsion Society (GPPS)*, (2022), doi: 10.33737/gpps22-tc-38

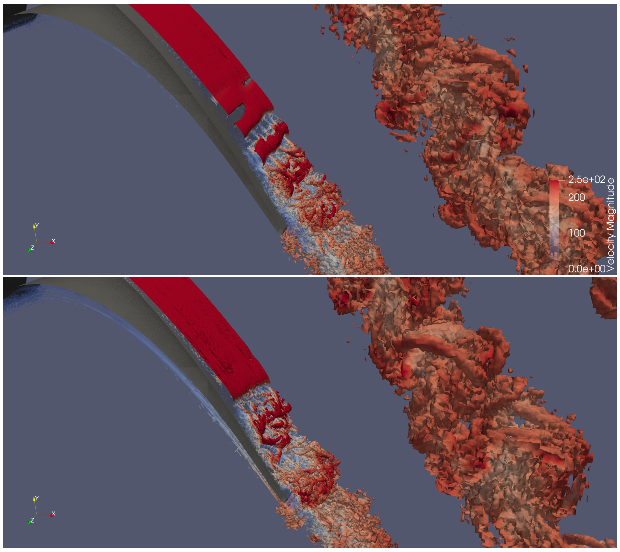

Figure 1: *Isosurface of Q-criterion coloured by the velocity magnitude. Top: smooth; bottom: rough blade*

Project Partners

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Funding

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DFG Subject Area

404-03