Towards Understanding Roughness

Influence of Complex Rough Structures on the Aerodynamic Loss of Blades

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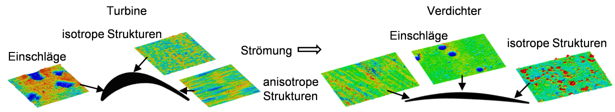

***Figure 1:** Measurements of operationally stressed surfaces of turbine and compressor samples.*

In Short

- Operation-related surface roughness of turbomachinery blades cause degradation of efficiency.
- Regeneration or renewal of the aged blades is essential for sustaining the efficiency of machine operation, which is a costly process. Thus, when to take such an action should be based on solid understanding of the influences of roughness on the flow.
- Our direct numerical simulation approach powered by immersed boundary method enables us to collect detailed information of flow over complex rough surfaces.
- The collected information is planned to be used on building and shaping of a combined RANS-based model that simultaneously takes into account effects of isotropic and anisotropic roughness structures.

In many technical applications the effect of surface roughness on the local flow as well as on the integral characteristics is significant. Understanding and modeling their effect is an ongoing challenge as there are plenty of surface structures caused by intention, manufacturing, or wear (Figure 1) which have various effects on the boundary layer flow [1,2]. Direct numerical simulations are worthy tools in this context as they provide highly-resolved view of the local effect of roughness on the flow. However, complex surface structures pose challenges to the generation of commonly used body-fitted structured computational grids. Immersed boundary methods (IBM), on the other hand, are promising tools towards this challenge [5]. In this project a custom IBM solver implemented in “foam-extend” fork of the CFD suite OpenFOAM is utilized for scale-resolving simulations of turbulent channel flows over rough surfaces. The method proved success in preliminary validation cases with smooth channel, as well as with a synthetic roughness, being quite a challenge for the method. In addition, results obtained for a real rough surface is also compared with another DNS study [6], being in good agreement (Figure **??**). Consequently, thanks to its flexibility, the method is considered more suitable for the simulation of turbulent flows over arbitrary complex rough surfaces, as compared to classical body-fitted grid approaches.

A set of tests on real roughness geometries supplied by the industry is designed covering a range of roughness from hydraulically smooth regime to fully turbulent regime. The integral values and the local flow field obtained from these DNS results are priceless for correlating the roughness geometry parameters with their effects on the flow. These correlations are planned to be utilized in devising of a combined roughness model designed for the $k-\omega$ RANS model, such that an affordable prediction tool for a broader range of roughness types is achieved. The combined model is expected to work for a mixture of isotropic and anisotropic roughness over blades, by combining features of a riblet model [3] and an isotropic (k_s-based) roughness model. The DNS results are also going to be supplemented by PIV measurements in the water channel setup of Institute of Turbomachinery and Fluid Dynamics, not only to gain confidence over the results, but also to supply an extension of knowledge up to inaccessible Reynolds numbers by DNS.

WWW

`http://www.tfd.uni-hannover.de`

More Information

[1] Bons JP. A Review of Surface Roughness Effects in Gas Turbines. *ASME. J. Turbomach.* 2010;132(2):021004-021004-16. doi: 10.1115/1.3066315

[2] Gilge, P., Mulleners, K. (2016). Resulting Aerodynamic Losses of Combinations of Localized Roughness Patches on Turbine Blades. *AIAA Journal*, 2552-2555. doi:10.2514/1.J054602

[3] V. Koepplin, F. Herbst, J.R. Seume (2017): Correlation-Based Riblet Model for Turbomachinery Applications, *ASME. J. Turbomach.* 2017;139(7):071006-071006-10. doi: 10.1115/1.4035605

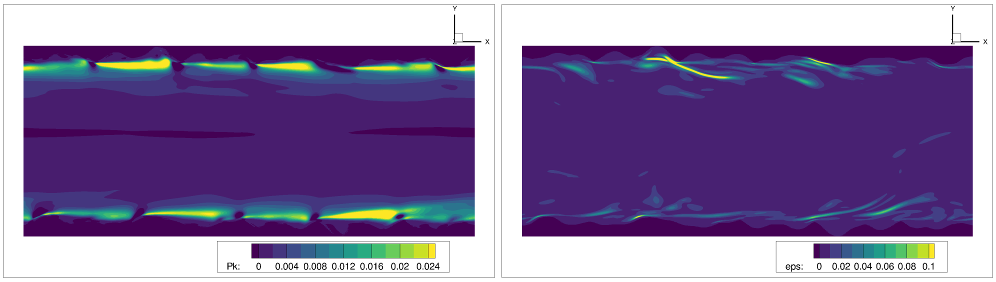

Figure 2: *Turbulence production and dissipation over the rough surface "Thakkar S8" [6].*

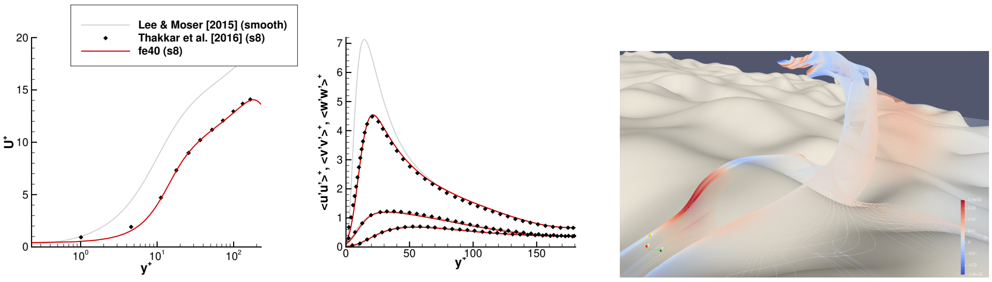

Figure 3: *Comparison of mean velocity and Reynolds stress components, and streamlines over the rough surface "Thakkar S8" [6].*

[4] Müller-Schindewolffs C, Baier RD, Seume JR, Herbst F. Direct Numerical Simulation Based Analysis of RANS Predictions of a Low-Pressure Turbine Cascade. *ASME. J. Turbomach.* 2017;139(8):081006-081006-11. doi:10.1115/1.4035834

[5] Hartung, K.; Gilge, P.; Herbst, F. (2018): Towards Immersed Boundary Methods for Complex Roughness Structures in Scale-Resolving Simulations, *ECMS 2018*, 22-25 May 2018, Wilhelmshaven, Germany

[6] Thakkar, M., Busse, A., Sandham, N. (2018): Direct numerical simulation of turbulent channel flow over a surrogate for Nikuradse-type roughness. Journal of Fluid Mechanics, 837, R1

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LuFo V-3: Virtualles Triebwerk - Hochgenaue Modellierung von Turbokomponenten