Karlsruhe Institute of Technology

Institute of Fluid Mechanics

9. Februar 2026

Bachelor thesis / Master thesis / HiWi – numerical

Turbulent flow over rough surfaces

Background

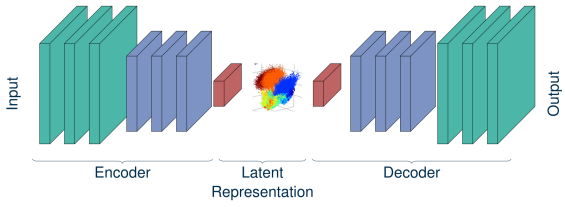
Rough surfaces are omnipresent in everyday life: from the macroscopic scale of mountains on Earth's surface to microscopic scales found on technical surfaces due to manufacturing processes. In particular, drag, representing the resistance force opposing fluid motion, and heat transfer, the exchange of thermal energy between a wall and a fluid.

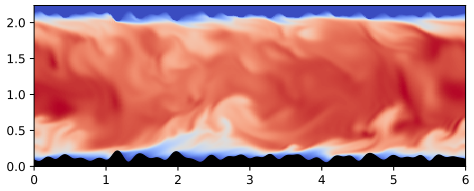
A central challenge is to predict the influence of arbitrary rough surfaces without the use of high-fidelity, computationally expensive simulations. While direct numerical simulation can capture the detailed interaction between turbulence and roughness, such approaches are impractical for design-space exploration or industrial analysis. Consequently, there is a need for fast, reliable models that can estimate the roughness-induced modifications of drag and heat transfer. In addition, it is well established that surface roughness can break the Reynolds analogy, which for smooth walls links momentum transport to the transport of passive scalars such as temperature. The degree to which specific roughness geometries modify this dissimilarity remains largely unknown and fast predictive tools can help to further investigate this dissimilarity.

Content of the Thesis

Possible topics for a thesis (by agreement):

- Direct numerical simulation (Implementing higher order immersed boundary method, conjugated heat transfer, performing simulations)
- Fast predictive tools using machine learning (Bayesian neural networks, Diffusion models, Physic-informed neural networks, Explainable AI)
- Modelling heterogeneous and anisotropic roughness





Requirements

basic knowledge in fluid mechanics and numerical methods

Beneficial Skills Bash, Linux, Python, Fortran

Start Date: flexible

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