Out of alignment

Orientation dependency of turbulent flow over irregular anisotropic roughness

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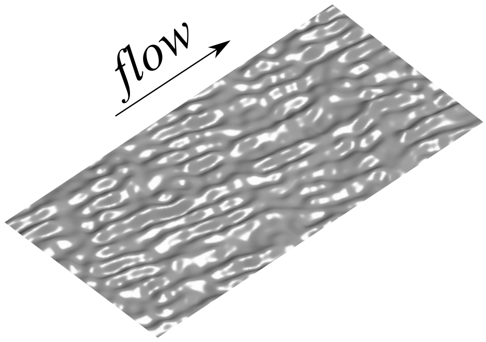

***Figure 1:** An example of an anisotropic surface with elongated roughness features that are not aligned with the mean flow direction.*

In Short

- Investigation of orientation effects of anisotropic irregular roughness on mean flow, turbulence statistics, and flow structure.
- DNS of turbulent channel flow over anisotropic multiscale roughness at friction Reynolds number $Re_\tau = 550$ for a series of surfaces with systematic varied orientation with respect to the mean flow.
- Two different degrees of surface anisotropy are considered to explore common trends in their behaviour with the change of orientation and highlight differences.

Surface roughness is ubiquitous in natural and engineered flows, influencing drag, turbulence structure, and momentum and scalar transport. While considerable progress has been made in characterising isotropic and aligned anisotropic rough surfaces, the orientation dependence of anisotropic roughness effects remains poorly understood [1]. In realistic applications, such as flow over turbine blades, ship hulls, or atmospheric and oceanic boundary layers, the roughness features are rarely perfectly aligned with the mean flow direction, and their orientation may vary in space and time. Understanding how the orientation of anisotropic roughness modifies mean flow and turbulence statistics is therefore crucial for accurate prediction of drag and modelling near-wall in situations where the mean flow direction and the dominant direction of an anisotropic surface are not aligned.

The overarching goal of this project is to explore the orientation dependency of mean flow and turbulence statistics in wall-bounded turbulent flows over anisotropic irregular rough surfaces, using high-fidelity direct numerical simulations. These simulations will provide a systematic dataset covering two degrees of anisotropy (mild and strong anisotropy) and multiple surface orientations, revealing how directional roughness modifies near-wall turbulence.

To date, research [2, 3] on anisotropic roughness considered surfaces where elongated roughness features are either aligned with the mean flow direction (e.g., ridge-type roughness) or are normal to it (e.g., square bar roughness, ratchet-type surfaces). The proposed project represents a novel and timely contribution to wall-bounded turbulence research by conducing the first systematic DNS study of anisotropic irregular roughness with systematically varied orientation relative to the mean flow (figure 1), rather than fixed streamwise or spanwise alignment as in most previous studies. The use of the MARS algorithm [4] will allow to generate realistic multiscale rough surfaces with controlled degree anisotropy, orientation, and statistical properties. High-fidelity DNS data and detailed statistical and spectral analysis will help to reveal how anisotropic surface orientation affects turbulence structure and secondary motions. In addition, the generated results will have direct applicability for improving fluid dynamic roughness characterisation and can inform the development of improved wall models for Reynolds-averaged Navier-Stokes (RANS) and wall-modelled large-eddy simulations (LES).

WWW

https://www.tu.berlin/nfd

More Information

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[3] P. Forooghi, A. Stroh, F. Magagnato, S. Jakirlic, B. Frohnapfel, Toward a universal roughness correlation, Journal of Fluids Engineering. *Journal of Fluids Engineering, 139(12), p. 121201 (2017)* doi:10.1115/1.4037280

[4] T.O. Jelly, A. Busse, Multi-scale anisotropic rough surface algorithm: technical documentation and user guide. *Tech. Rep.*, (2019). https://eprints.gla.ac.uk/198278/

DFG Subject Area

404-03 Fluid Mechanics