Brandenburgische Technische Universität Cottbus - Senftenberg

Possible Topic for a MASTER THESIS OR STUDY PROJECT

at Brandenburg University of Technology (BTU) in Cottbus, Germany

Parametric forcing for roughness in turbulent channel flows

Synopsis – Proper characterization of rough walls is an ongoing research issue [1]. Although ample experimental and empirical work has been carried out, a fundamental understanding of how the roughness geometry is related to the flow dynamics is still missing. An example are the different ways in which the roughness can be parameterized in the mean velocity profile [1]. All of the different ways in which roughness can be represented give rise to a very large parameter space which needs to be evaluated, if progress in understanding is expected from the hand of numerical simulation research. One natural way to represent roughness, at least homogeneous roughness, is by considering an horizontal plane, in which a volume-average is applied for the fluid flow governing equations, i.e., considering simplified macroscale equations for porous media flows [2]. Here again, very little is understood regarding the nature of the closure problem arising from the application of the volume-average operator, since a handful of approximations and asymptotic theory is generally used to arrive at simplified models such as the Darcy-Brinkman-Forchheimer's law [3]. Recently, a novel approach is being suggested to correlate physical features of a rough surface with the roughness function, one of the ways in which roughness can be represented at the fluid-dynamical level; the approach involves the use of neural networks to obtain a nonlinear regression for the roughness function dependent on the surface geometry [4,5]. In this work, it is desired to use a reduced order stochastic turbulence model with the purpose of evaluating different forms in which roughness can be parameterized. These results should be compared to those obtained with Direct Numerical Simulations of minimal channels, and the previously referenced neural network model [4,5]. Applications of this parametric approach to roughness could be considered for atmospheric flows [6,7]. The suggested investigation can be carried out in any of the following modalities:

- **a) Master Thesis (1 semester):** The student should focus on variations of a previously published parametric forcing form within the reduced order stochastic turbulence model (in-house developed software).
- **b) Study Project (2 semesters):** Same as a), but the student should also develop a new forcing model or modify the suggested parametric forcing based on the results of classical volume-averaging theory, or other novel approaches.
- **c) Study Project and Master Thesis (3 semesters):** Same as b). Additionally, the student will evaluate rough wall channel flows with open source CFD software using the method of Large Eddy Simulations (LES), in order to have additional validation for the results.

[1] Jiménez (2004), *Annu. Rev. Fluid Mech.* **36**, 173-196 — [2] Whitaker (1996), *Transp. Porous Media* **25**, 27-61 — [3] Wood *et al.* (2020), *Annu. Rev. Fluid Mech.* **52**, 171-203 — [4] Yang *et al.* (2022), *J. Fluid Mech.* **941**:A47 — [5] Lee *et al.* (2022), *J. Fluid Mech.* **933**:A18 — [6] Finnigan (2000), *Annu. Rev. Fluid Mech.* **32**, 519-571 — [7] Freire and Chamecki (2021), *Comput. Fluids* **230**:105135

Tasks

- Review of relevant literature and theoretical foundations
- Code development, compilation and testing
- Visualization, post-processing, and data analysis of numerical simulation data
- Comparison of simulation results with relevant reference data

Desired skills and requisites

- Solid knowledge of fundamentals of fluid mechanics
- Affinity to programming (preferably Python and C/C++)
- Scientific attitude (curiosity, self-motivation, and critical reasoning)
- Experience with data analysis, numerical simulation and modeling, or CFD is an asset
- **For the intended take of the Master Thesis:** The student must have approved the modules of Turbulence Modeling and CFD 1.
- **For the intended take of the Study Project:** The student is required to take the modules of Turbulence Modeling and CFD 1 in parallel to the project time frame.

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