6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
June 11- 15, 2018, Glasgow, UK

Turbulent Flows over Rough Walls: DNS and Modelling

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Key Words: *Roughness modeling, Direct Numerical Simulation*

Walls are predominantly rough in a variety of industrial devices. In combustion systems roughness is mainly genreated through depositions and the related influence on flow, heat transfer and combustion itself is important to understand.

High fidelity numerical approaches such as Direct Numerical Simulation (DNS) and Large Eddy Simulation (LES) are increasingly used for such application-oriented problems thanks to the growth of High Performance Computing (HPC) resources. However, the simulation of flow over a rough wall is significantly more demanding in terms of computational cost than that over a smooth wall at the same Reynolds number since finer grids are required in order to capture not only all the flow structures but also the small scales of the surface geometry. In addition, use of either a body conforming grid or an Immersed Boundary Method (IBM) for the reproduction of the rough surface involves extra effort on code development, parallelization and/or grid generation.

In order to estimate the roughness effect a priori, engineering correlations that relate the roughness geometry to flow quantities are required. For a refined analyis of the roughness effect with limited computational effort, a roughness model is required that allows capturing the effect on turbulence statistics correctly.

Within the context of the present state of the literature, we present results of a parametric DNS study in which the surface geometry is fully resolved with IBM and discuss which implications for engineering correlations that allow an a priori estimation of the roughness effect can be deduced. In addition, an extension of the Parametric Forcing Approach suggested by Busse and Sandham (2012) is presented, in which the roughness is effectively modeled by adding source terms to the governing equations. In the present model, the functions required for the calculation of the soure terms can be found deterministically based on the geometry of the roughness; therefore, except for the use of scalar 'model constants', the model is a priori. The capability of this model in reproducting the integral flow quantities is demonstrated by direct comparison to the DNS results.

[1] A. Busse, N. D. Sandham, 2012. Parametric forcing approach to rough-wall turbulent channel flow, Journal of Fluid Mechanics 712 169-202.