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Modelling Of Additive Manufacturing-Like Rough Walls from Roughness-Resolved LES Database

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Extended Abstract

Recent development of additive manufacturing (AM) in the past decade paves the way for breakthrough designs of heat exchangers and especially for compact ones (CHX). However, the surface roughness generated with AM is larger compared to conventional manufacturing processes. In addition, the roughness is basically anisotropic. The impact of this type of roughness on pressure drop and heat transfer coefficient cannot be neglected during the design process.

Numerical RANS and LES simulations have proven to be efficient tools for optimization purposes and are appropriate candidates to fulfill this need. Nonetheless, for realistic cases, required computational resources to conduct simulations with roughness are not affordable in general. Thus, the modeling of the effects of the rough elements on the flow without explicit representation of the surface details is compulsory. Common approaches for RANS/LES rough wall modeling rely on the prediction of the mean wall stress through a modified smooth law of the wall. The modification of the law of the wall mainly follows empirical correlations obtained from experimental data and roughness resolved simulations. In line with this philosophy, a first objective at our concern is to enrich the empirical correlations with data from typical AM roughness. This kind of approach is theoretically designed to predict the mean value of the wall stress. Thus, a second objective that we seek is to complete this prediction by reproducing the statistical behavior of the wall stress fluctuations, given its mean value and the surface properties.

This is why, the creation of a Roughness-Resolved Large-Eddy Simulation (RRLES) database of representative rough channel flow appears to be a worthwhile process. Parametric RRLES from a limited set of relevant surface and flow parameters have been performed using rough surface (RSG) and body-fitted unstructured mesh (RRMG) generators, which have been developed for this purpose. The computational domains are periodic channels of size 8h x 3h x 2h in the streamwise, spanwise and crosswise directions with h the half height of the channel. Periodicity in the streamwise direction is applied at 6h from the inlet on velocity and temperature via recycling conditions. Then, the turbulent and rough wall stress statistics have been extracted from the simulations.

From results analysis, a stochastic model that reproduces the statistical behavior of the wall stress vector is proposed. We show that this modeled wall stress allows a better prediction of the pressure drop in Roughness-Modeled Large-Eddy SImulation (RMLES, i.e. the rough surface is not explicitly described by the geometry) compared to the use of the mean value of the wall stress measured in RRLES alone. Calibration of the model and comparison of its performances with standard approaches are finally addressed.