Development of a roughness model for drag prediction in minichannel flows using machine learning

Roughness has been investigated for many decades because the full appreciation of the effects of wall roughness on turbulence is crucial for predicting the changes in performance due to e.g. fouling, pitting, and erosion. The roughness of surfaces affects the flow dynamics and heat transfer. The computational methods successfully used in classical flows fall short when applied to highly constricted flows, e.g. in minichannels. The elaboration of an effective numerical method dedicated to these types of flows is becoming an urgent need due to rapid progress in miniaturisation, nanotechnology, and manufacturing techniques.

Despite considerable efforts and the maturation of high-fidelity simulations, a practical approach is necessary to make predictive flow calculations for many realistic applications while minimizing the use of computational resources. In the proposed project, several numerical models will be tested and enhanced using additional methods that enable the consideration of wall roughness. These methods, while reliable in many types of flows, will require additional relations and adjustments to yield precise results without excessive computational time. The difficulty in fitting model parameters can be overcome by applying a machine learning strategy. Machine learning has been successfully used in various applications to capture complex multidimensional interactions between parameters that would otherwise be difficult to identify. To this end, different algorithms will be tested, and the procedures for using real roughness parameters to adjust the coefficients of the models will be elaborated.

Another important aspect of the project will be the creation of reliable experimental data for various flow conditions. The construction of such databases based on experiments performed on the constructed test stand, high-resolution simulations and selected literature data is an important task in the project. The experimental databases available in the literature usually concern flows in classic channels or conduits, and the lack of measurements occurring for flows in minichannels with rough walls will be supplemented within the project. The experimental campaign, prepared in a systematic way, will provide a database that will be an important benchmark for other studies conducted in the fluid mechanics community. The database will be extended with the results of numerical simulations, as well as available literature data.

The proposed models will enable more accurate prediction of roughness effects in flow for any roughness topography, and the obtained quantitative and qualitative results will expand the knowledge on the influence of friction on the flow in minichannels.