Data-driven optimization of rough surfaces for convective heat transfer enhancement

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Turbulent flows past rough surfaces can be found in many engineering applications. In most cases, the presence of rough surfaces can significantly increase drag resistance, leading to higher energy losses and fuel consumption. However, certain rough surfaces can yield favorable results, such as enhancing heat transfer, while producing only a modest increase in pressure losses. In this work, we combine a previously developed convolutional neural network (CNN) with an optimization strategy to find rough surfaces with optimal Nusselt numbers. As it can be observed in Figure 1, this neural network is capable of predicting detailed 2-D maps for the local skin friction factors and Nusselt numbers of a rough surface[1]. Unlike traditional correlations, which are based on standard surface metrics, the neural network is able to perform predictions taking into account both the detailed shape of every roughness element, as well as their spatial organization. The optimization procedure to generate new rough surfaces is described hereafter. First, a CNN is trained using existing DNS data. Then, the weights of the neural network are held fixed, and the input rough surface is parameterized, such that its underlying topological features can be optimized to maximize heat transfer. To avoid local minima, the optimization procedure for every rough surface considers random variations in its topological features, as well as a robust line search procedure in every optimization direction. Once a new design for a rough surface has been created, a GPU-accelerated DNS solver is employed to verify the predicted Nusselt numbers. Subsequently, these DNS results are used as new training data for the CNN. Finally, the previous steps are repeated until convergence is achieved. Preliminary results indicate that the combination of the CNN and the optimization methods employed can find rough surfaces with enhanced Nusselt numbers.

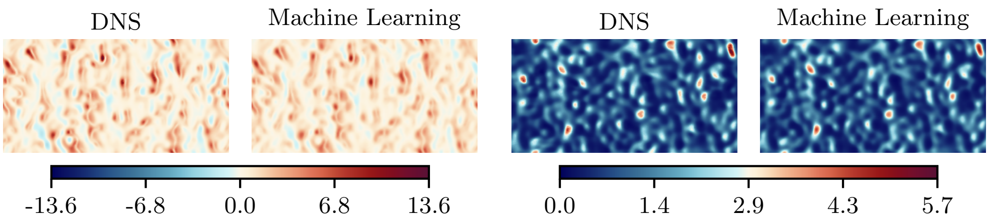

Figure 1: Comparison between the local skin friction factors (left) and Nusselt numbers (right) obtained using DNS simulations and machine learning. The values in the colormaps are scaled with respect to the average DNS values for every quantity.

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[1] Diez et al., *TSFP12 International Symposium*, Osaka, Japan (2022).