Heat and mass transfer of flow inside pipes with large relative roughness height

Mariangela De Maio[a], 2nd Beatrice Latini[b], 3rd Francesco Nasuti[c] and 4th Sergio Pirozzoli[d]

The present study is focused on flows inside circular pipes with irregular rough walls, which significantly affects both frictional drag and heat transfer. Past experimental studies have focused on relative low roughness [1]. Other researches performed direct numerical simulations of flows inside rough channels, with infinite extension in the spanwise direction and many of them are focused on structured geometrical roughness [2]. For what concerns heat transfer, past studies have already mainly noticed that roughness augments mass transfer more than heat transfer with respect to the smooth-wall case [3,4], meaning that the efficiency decreases.

The present study is focused on flow inside pipes with higher roughness than the one studied so far. Some direct numerical simulations are carried out, and a wide range of Reynolds numbers is tested, from the laminar up to the fully-rough regime.

In the present simulations, the larger relative roughness has the role of altering the geometry of the pipe, determining some differences with respect to the previous studies (i.e. lower transitional Reynolds from laminar to turbulent flow, higher friction factor in the laminar region, higher decrease in heat transfer efficiency). We also show the differences between the velocity and temperature fields, in order to highlight that the Reynolds analogy does not hold at high Reynolds number and large relative roughness.

Moreover, the high relative roughness determines a dependence of the duct cross-sectional shape, when the present results are compared to those obtained in plane channels with the same roughness.

Last, a comparison of the computed heat transfer coefficient with the existing correlations in literature shows that the latter suffer from poor predictive power for surfaces with large relative roughness, meaning that new correlations should be defined.

[a,b,c,d] Dep. Mechanical and Aerospace Engineering, Sapienza, via Eudossiana 18, Rome, Italy

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