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Abstract: Direct numerical simulation of turbulent flow in rough pipes
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Title

DNS of flow inside pipes with large relative roughness height

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Abstract

In recent years, technological advancements in rocket thrust chambers allowed the use of innovative designs and materials of the cooling channels, which also mandate the use of advanced numerical simulations as design tool. For example, additive manufacturing allows to machine cooling channels with more complex geometry and smaller size, however it also yields large relative roughness, which significantly affects both frictional drag and heat transfer [1].
The present study is focused on understanding the behaviour of flows inside circular pipes with irregular rough walls, whose relative roughness is higher than the one studied so far in most experiments [2].
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, where the skin friction coefficient does not depend on the Reynolds number anymore.
Past studies have already noticed that the increases in the heat transfer due to the presence of the roughness are accompanied by even larger increases in the skin friction coefficient with respect to the smooth-wall case [3]. They also noticed that the Reynolds analogy is less accurate with increasing wall roughness height, meaning that the efficiency in heat transfer decreases.
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. higher decrease in heat transfer efficiency, lower transitional Reynolds from laminar to turbulent flow, higher friction factor in the laminar region).
Moreover, we compare the results with those obtained in plane channels. The small differences point to the influence of the duct cross-sectional shape in the presence of relatively large roughness. This outcome can not be neglected since the ducts in cooling systems are generally designed with a square cross-section.
Last, a comparison of the computed equivalent sand-grain roughness height 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.

References

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