MUR
Dipartimento
di Eccellenza
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Research project

Name and Surname: Stefania Cherubini
Title: Reducing drag in wall-bounded shear flows by controlling large-scale structures
Description:
Since the beginning of the XX century, pattern and coherent structure formation in wall-bounded turbulent flows were studied by fluid dynamicists. The dynamics of near-wall structures was studied in detail employing numerical simulations and experiments, leading to the development of the self-sustaining wall cycle theory [1-2]. Nevertheless, when larger domains and high Reynolds numbers are considered, the picture of wall turbulence becomes much more complex [3], due to the presence of coherent structures having size reaching more than 10 times the reference length of the considered flow (i.e., pipe radius, channel half-height or boundary layer thickness). The origin of large-scale structures is still uncertain, although many authors advanced the hypothesis that such structures may be the result of large-scale instability of smaller wall structures [4].

Investigations on large-scale and very-large-scale motions are becoming increasingly relevant for drag reduction of wall-bounded turbulent flows, since these structures carry a large fraction of the turbulent kinetic energy and of the turbulent shear stress. Their control may thus be important for effective drag reduction in these flows [5]. The existence of a bottom-up mechanism that from near-wall structures brings to large-scale motions leads to the idea that modifying by passive or active actuators the coherent structures in the wall region may lead to a damping of large-scale structures, with a consequent drop of the total drag. This research project pursue this idea through the development of passive and active control strategies able to hinder the growth of large-scale structures through the damping of the secondary large-scale instability of wall coherent structures.

The work will be carried out via direct numerical simulations with the numerical code ChannelFlow [6]. Several flows configurations will be considered, such as the pipe, the channel, and the boundary layer flow. Passive controllers (wall roughnesses, wall curvature, compliant walls, etc.) as well as active ones (small fans, blowing and suction holes etc.) will be considered. Adjoint methods will be used to evaluate the sensitivity regions of the unstable modes and/or to optimize the actuations for an optimal drag reduction.

References
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[2] J. M. Hamilton, J. Kim, and F. Waleffe, Regeneration mechanisms of near-wall turbulence structures Journal of Fluid Mechanics 287, 317 (1995)
[3] A. J. Smits, B. J. McKeon, and I. Marusic, High–reynolds number wall turbulence, Annual Review of Fluid Mechanics 43, 353 (2011)
[4] N. Ciola N, P. De Palma, J.-C. Robinet, S. Cherubini, Large-scale coherent structures in turbulent channel flow: a detuned instability of wall streaks. Journal of Fluid Mechanics. A18 (2024)
[5] I. Marusic, D. Chandran, A. Rouhi, M. Fu, D. Wine, B. Holloway, D. Chung, & A. Smits, An energy-efficient pathway to turbulent drag reduction. Nature Communications 12 (1), 5805 (2021)
[6] J. Gibson, F. Reetz, S. Azimi, A. Ferraro, T. Kreilos, H. Schrobsdorff, M. Farano, A. Yesil, S. Schutz, M. Culpo & T. Schneider, Channelflow2.0. https://www.channelflow.ch/ (2021)

Candidates should provide detailed CV

Contacts

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