M2 Internship proposal: Parametric study of oscillating boundary condition in turbulent anisothermal channel flow using Thermal-Large Eddy Simulation (T-LES)

Context

This internship is part of the SOLAIRE ANR project which includes 2 Ph.D. students. The SOLAIRE project aims to improve the efficiency of converting concentrated solar energy into electricity using artificial intelligence. The key component of these power plants is the solar receiver, which converts concentrated solar energy into thermal energy and transfers it to a heat-carrying fluid, pressured air in our case. The project focuses on maximizing thermal transfers between the gas and the wall of the solar receiver, while minimizing pressure losses. This is done through optimization of thermal transfers and the development of strategies for controlling near-wall turbulence in the solar receiver using machine learning. For more context, see this POLYPHEM project video explaining challenges with solar receiver research. To best assess different types of Thermal-Large Eddy Simulation (T-LES) models in our study case, it is necessary to run simulations with different types of models on different meshes to obtain the most accurate assessment of these models. This type of simulation offers a good perspective as it's comparatively much cheaper than Direct Numerical Simulation (DNS). A visual representation of DNS can be seen here simulation visualisation.

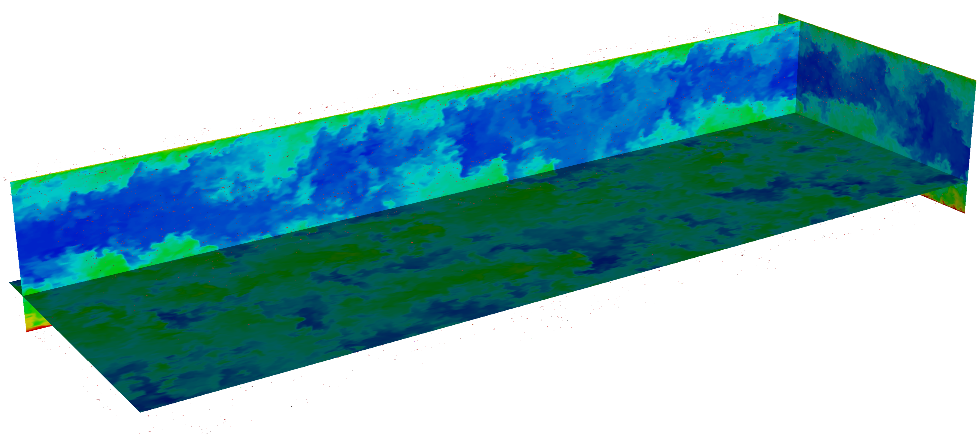

Figure 1: Representation of temperature field, with small structures with asymmetrical heating, at high

Description

As said before, the control of turbulence by oscillating the wall has the potential to intensify the heat transfer to the hot wall. The method used to realize this oscillating wall is the addition of a volume force in the fluid, in the spanwise direction of the channel. This choice is based on extensive studies dealing with drag reduction (e.g., Quadrio *et al.* (2009) [6], Gatti and Quadrio (2013) [5] or Agostini *et al.* (2014) [1]). These studies showed that drag could be reduced or significantly increased, depending on the control parameters, in particular the period and amplitude of oscillations. The mechanism by which these oscillations control drag is complex and has been the subject of numerous studies (e.g., Agostini *et al.* (2014) [1], Agostini *et al.* (2015) [2], Agostini & Leschziner (2018) [3] or Ricco *et al.* (2021) [7]). In essence, the oscillations produce a Stokes layer that weakens or strengthens near-wall turbulent structures wall, as well as associated vortices, thereby reducing or enhancing near-wall turbulent exchange.

In a first phase, the intern will get familiar with TrioCFD [4], the CFD code we use to run our channel flow simulations, and the post-treatment code we use. In the mean time, they will read the bibliography around this subject and gather information on the effects of different amplitudes and oscillation periods on the flow.

In a second phase, the intern will run Themal-Large Eddy Simulations (T-LES) for different amplitudes and periods in a simplified case representing the flow inside a solar receiver. Finally, the intern will conduct exploratory T-LES in conditions close to the operating conditions of a solar receiver. For all of these simulations, the intern will study the effects on the wall heat flux ϕ_ω, as well as the wall sheer τ_ω. These simulations will be done on the TGCC's cluster, called Irene.

Skill requirements

Second year of Master's degree or last year of Engineering School student, with a fluid mechanics background. Programming knowledge and the use of languages like C/C++ Python or Shell is a plus but isn't required. Some understanding of English is appreciated.

Location

PROMES-CNRS Perpignan : Rambla de la thermodynamique, Tecnosud, 66100 Perpignan

Duration

5 to 6 months starting anywhere from February to March 2024

Salary

Current CNRS flat rate gratification (≈ 615 €/month)

Supervisors

- Adrien Toutant (Associate professor, Université de Perpignan Via Domitia - 04 68 68 27 09 adrien.toutant@univ-perp.fr)
- Yanis Zatout (Ph.D. Student, PROMES-CNRS - LISN, yanis.zatout@promes.cnrs.fr)

Application process

Email every supervisor in the same email with:

- Your resume
- Your transcript of Bachelor's and Master's degree grades
- Recommendation letters (optional)

References

[1] L. Agostini, E. Touber, and M. Leschziner. Spanwise oscillatory wall motion in channel flow: drag-reduction mechanisms inferred from DNS-predicted phase-wise property variations at. *Journal of Fluid Mechanics*, 743:606–635, March 2014.

[2] L Agostini, E Touber, and MA Leschziner. The turbulence vorticity as a window to the physics of friction-drag reduction by oscillatory wall motion. *International Journal of Heat and Fluid Flow*, 51:3–15, 2015.

[3] Lionel Agostini and Michael Leschziner. The impact of footprints of large-scale outer structures on the near-wall layer in the presence of drag-reducing spanwise wall motion. *Flow, Turbulence and Combustion*, 100(4):1037–1061, 2018.

[4] Christophe Calvin, Olga Cueto, and Philippe Emonot. An object-oriented approach to the design of fluid mechanics software. *ESAIM: Mathematical Modelling and Numerical Analysis - Modélisation Mathématique et Analyse Numérique*, 36(5):907–921, 2002.

[5] Davide Gatti and Maurizio Quadrio. Performance losses of drag-reducing spanwise forcing at moderate values of the reynolds number. *Physics of Fluids*, 25(12):125109, 2013.

[6] Maurizio Quadrio, Pierre Ricco, and Claudio Viotti. Streamwise-travelling waves of spanwise wall velocity for turbulent drag reduction. *Journal of Fluid Mechanics*, 627:161–178, 2009.

[7] Pierre Ricco, Martin Skote, and Michael A Leschziner. A review of turbulent skin-friction drag reduction by near-wall transverse forcing. *Progress in Aerospace Sciences*, 123:100713, 2021.