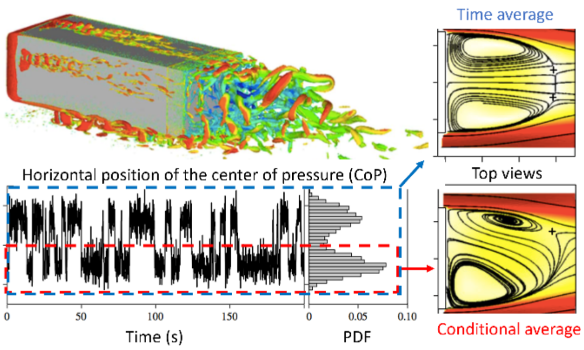
PhD theses proposal:
Analysis and modelling of 3D bluff body wakes

Description:

Fluid flows past bluff bodies arise in many natural and engineering situations: (i) ground vehicles, crucially in need of improved aerodynamics in order to reduce emissions of CO_2, in order to mitigate climate change; (ii) civil engineering, where unsteady vortex shedding past slender structures induce mechanical fatigue and failure; (iii) energy-harvesting systems exploiting fluid-structure interaction in natural streams like rivers/oceans to produce electricity; and (iv) freely falling objects like tree seeds (relevant to biological population) and industrial particles (in food and chemical processes). Decades of extensive studies on bluff body wakes have yielded results of great significance on flow stability, reduced-order models, and flow control. Yet, unexplored areas still exist in the laminar and turbulent regimes alike.

The objective of these two SNSF-funded PhD theses is to combine theoretical and numerical tools to address some of the gaps existing in the understanding and modelling of 3D bluff body wakes. A particular focus will be put on wakes exhibiting bistability (e.g. 3D rectangular prisms and Ahmed bodies) or multistability (e.g. axisymmetric bodies) related to planar or azimuthal symmetry breaking, and induced either by stochastic forcing in the laminar regime or by turbulent fluctuations in the turbulent regime.



Example of symmetry-breaking stochastic dynamics: turbulent wake of an Ahmed body (Re=92000) jumping randomly between left and right static deflections. Time averaging restores symmetry.

Some of the topics of interest include: (i) study the effect of misalignment (yaw and pitch) and ground proximity on the laminar flow past Ahmed bodies, using linear and weakly nonlinear stability analysis; (ii) develop amplitude equations for stochastically forced laminar flows near symmetry-breaking bifurcations; (iv) develop reduced-order models especially designed for stochastic flows with symmetries; (iv) develop amplitude equations for turbulent wakes.

Profile:

Essential: the candidates must hold a Master's degree (e.g. physics, engineering, or applied mathematics) and be highly motivated about theoretical/numerical aspects of fluid mechanics.

Desired: the candidates should have experience with flow stability, dynamical systems, weakly nonlinear analysis, reduced-order modelling, stochastic analysis, or CFD.

Additional information:

The candidates will be part of the Laboratory of Fluid Mechanics and Instabilities (LFMI), which has a long experience in using hydrodynamic stability to study a wide range of topics from separated flows to jets and from microfluidics to thin-film flows. The group will grow significantly in the coming months with 5 new expected PhD candidates.

The candidates will have to apply to EPFL's doctoral program in Mechanics. More information on admission at EPFL here. Applications of candidates with excellent files may be exceptionally considered outside of the formal deadlines found in these documents.

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Selected references:

[1] G. Bonnavion and O. Cadot. Unstable wake dynamics of rectangular flat-backed bluff bodies with inclination and ground proximity. *Journal of Fluid Mechanics,* 854:196–232, 2018.

[2] Y.-M. Ducimetière, E. Boujo, and F. Gallaire. Noise-induced transitions past the onset of a steady symmetry-breaking bifurcation: The case of the sudden expansion. *Physical Review Fluids,* 9, 053905, 2024.

[3] M. Grandemange, M. Gohlke and O. Cadot. Bi-stability in the turbulent wake past parallelepiped bodies with various aspect ratios and wall effects. *Physics of Fluids*, 25, 095103, 2013.

[4] P. Meliga, J.-M. Chomaz, and D. Sipp. Global mode interaction and pattern selection in the wake of a disk: a weakly nonlinear expansion. *Journal of Fluid Mechanics*, 633:159–189, 2009.

[5] G. Rigas, A. S. Morgans, R. D. Brackston, and J. F. Morrison. Diffusive dynamics and stochastic models of turbulent axisymmetric wakes. *Journal of Fluid Mechanics*, 778:R2, 2015.