2019 Doctoral research projects for PhD recruitment
Institut P'

Wake modelling for aeroacoustic design

Institute/Department : P' / FTC
Research team : 2AT
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3-year contract: 1768 € raw monthly salary (to be modified if complementary funding)

Key-words: Aeroacoustics, Fluid dynamics, Turbulence, Airframe noise

Framework and objectives.

Subject

The Ph.D. project will involve development of a reduced-order **modelling framework for airframe noise,** tailored for exploration of the acoustic impact of geometrical changes to airframe components. The use of such an approach early in the aeroacoustic design process can lead to gains in design efficiency by reducing dependence on time-consuming activities such as high-fidelity simulation and trial-and-error testing. The work will involve a combination of **non-linear numerical simulation**, **experiment** and **hydrodynamic stability theory**, emphasis being placed on the exploration of flow physics underpinning the generation of aerodynamic sound.

State of the art

Numerical simulation, experimental diagnostics and theoretical frameworks for the study of unsteady flow and acoustics have progressed considerably in recent years. Our group pursues research activities in all three domains and has recently begun to combine them with a view to developing novel analysis and modelling methodologies.

One such methodology predicts **the acoustic field radiated by flow over rigid bodies of various shapes**[1]. Curle's analogy is coupled with a homemade, open-source CFD tool (Incompact3D) using an immersed boundary method (IBM) that ensures flexibility with respect to body shape. It has been used to generate a rich database, for numerous geometrical configurations (cylinders with rectangular, elliptical or round cross section, etc.). Thanks to storage of the entire flow and acoustic fields, identification of the flow motions that underpin the radiated sound is possible. Also, **shape optimisation** is possible, and one such optimisation led to a 16dB reduction[2] for a 2D flow with a highly constrained parameter space (Figure 1).

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[1] F. Margnat, *Hybrid prediction of the aerodynamic noise radiated by a rectangular cylinder at incidence*, Computers and Fluids, 109, 13-26, (2015)

[2] W. Pinto, F. Margnat, *A shape optimization procedure for cylinders aeolian tone*, 2018, hal-01844771

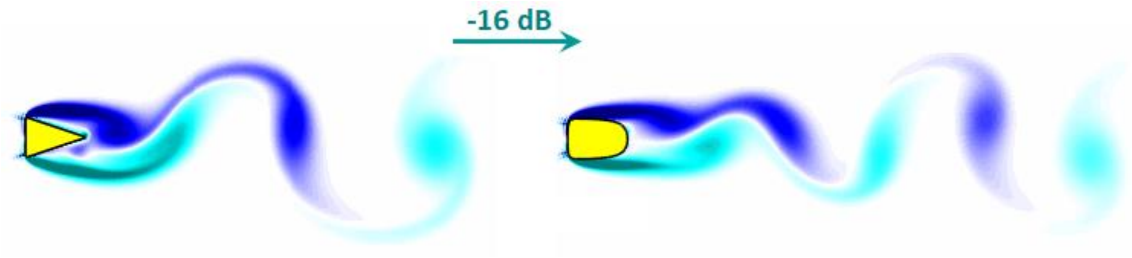

Figure 1: optimal shapes for aeroacoustics: Vorticity field in the laminar flow over 2D bodies. The left geometry radiates 45 times more acoustic power[2].

Another methodology, based on consideration of the stability properties of the linearised Navier-Stokes equations—linearisation being performed with respect to the time-averaged, turbulent mean—is used to understand, model and control **coherent structures and their sound radiation** in turbulent shear flows[3,4]. Recent developments include the inclusion of non-linearity as an external force that drives the linearised system[5,6].

Dedicated experimental methodologies[7] are also developed for analysis of aeroacoustic phenomena in the numerous anechoïc windtunnels of the PPRIME Institute (Figure 2). The methodologies, which permit highly resolved, synchronous acquisition of pressure and velocity data using multi-probe antennae and time-resolved field-measurement techniques, are guided by the theoretical frameworks mentioned above. They thus provide, in addition to **empirical input** and **validation data** for a given model, the **physical insight** necessary for model improvement.

Proposed innovation

Aimed at merging the three approaches cited above, the Ph.-D. work will involve development of a tool that provides fast-return, first-order approximations of **how changes in the geometry of airframe components impact the sound they radiate**. Mean flow data for a given configuration will be obtained both experimentally and via non-linear numerical simulation, the former being used to validate the latter. Two-point experimental measurements will then be used to provide amplitudes of the acoustically relevant wake dynamics (low-order spanwise Fourier modes). The amplitudes will be used to calibrate global modes obtained from a mean-flow stability analysis; the calibrated modes will then be used to compute the radiated sound using Curle's analogy. In addition to development of the design tool, the Ph.D. work is expected to provide new understanding of the flow physics that underpin the generation of airframe noise.

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[3] P. Jordan & T. Colonius, *Wavepackets and turbulent jet noise*. Annual Review of Fluid Mechanics. Vo. 45 (2013)

[4] K. Sasaki, G. Tissot, A.V.G. Cavalieri, F.J. Silvestre, P. Jordan & D. Biau, *Closed-loop control of a free shear flow a framework using the parabolised stability equations.* Theor. Comput. Fluid Dyn. (2018)

[5] G. Tissot, M. Zhang, F. C. Lajus, A.V.G. Cavalieri, P. Jordan, *Sensitivity of wavepackets in jets to nonlinear effects.* Jnl. Fluid Mech., Vol 811 (2017)

[6] L. Lesshafft, O. Semeraro, V. Jaunet, A.V.G. Cavalieri, P. Jordan, *Resolvent-based modelling of wavepackets in turbulent jets.* ArXiV (2018)

[7] W. Pinto, F. Margnat, *Measurements of spanwise coherence in flow around prismatic bluff bodies*, submitted to Journal of Fluid and Structures, 2018.

Work program and means.

Laboratory

PPRIME Institute, Poitiers, France (http://www.pprime.fr/)

The PPRIME Institute is one of the largest CNRS laboratories in France. Research in the fields of transport and energy, motivated largely by environmental issues, is supported by a broad range of experimental and computational facilities. The **Department of Fluids, Thermal and Combustion Sciences** is concerned with fundamental research in fluid mechanics and energetics. The **2AT group** focuses on the aerodynamics and aeroacoustics of transitional and turbulent shear flows, with the goal of providing understanding and models of the underlying mechanisms.

Ph.-D. progress – Activities – Steps

[These steps may not be successive and can mostly be conducted with parallel parts. Moreover, depending on the applicant background and likings, some of them could be further deepen while other ones can be brought in.]

- **Literature review** focusing on the dynamics of wakes, in the frameworks of aerodynamic, linear-stability and aeroacoustic theories.
- Development and validation of a **global stability solver** using OpenFOAM.
- **Experimental measurements** using hot-wire rakes in order to provide mean-flow and multi-point correlation information.
- Steady and unsteady, 2D, **non-linear simulations**.
- Computation of the **sound radiation** via combination of data provided by experiment, stability computation and non-linear simulation.
- Analysis of the effects of geometry; proposition and experimental testing **of low-noise configurations**.
- **Communication** of results (conferences, journal articles) / Thesis / Final presentation

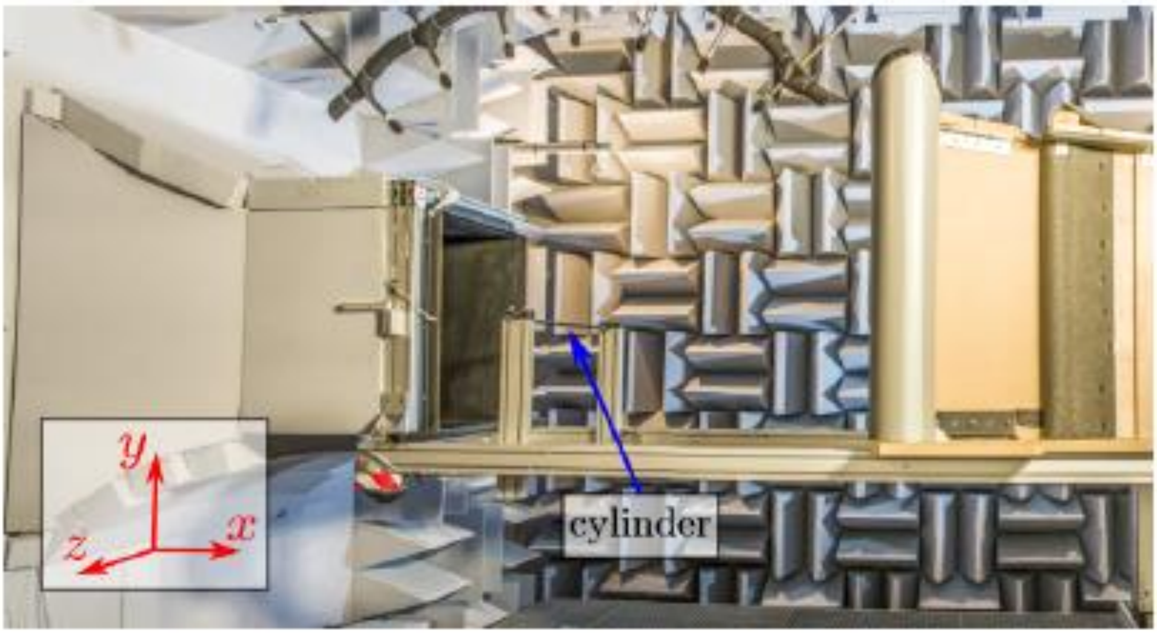

Figure 2: Anechoïc wind tunnel facility BETI at Institut PPRIME. Acoustic antenna at the top.

Applicant profile, prerequisites.

The applicant should have a Master of Science (or equivalent degree) including high-level courses in fluid mechanics. Background in the following fields would be appreciated: aeroacoustics, stability, aerodynamics, turbulence, signal processing. Skills in applied mathematics and programming are also required.

Practical information

- Place of work: **Poitiers southern campus**, at the following address:
  Institut Pprime – UPR 3346
  CNRS – Université de Poitiers – ENSMA
  ENSIP - Batiment B17 - 6 rue Marcel Doré
  TSA 41105
  86073 POITIERS Cedex 9 - France
- The PhD candidate may **supervise student projects** which will be proposed to support the work, such as MSc thesis or shorter-term studies.
- Within Institut Pprime, PhD candidates joined together to form an **organisation with several activities** and events.
- **Working language**: French or English; French skills are a plus for relationship with the technical staff and everyday life.
- Starting date: **October 2019**
- Net salary: approx. **1350€/month** (possibly complemented by teaching activity)
- Applications must first be sent to florent.margnat@univ-poitiers.fr including CV, motivation letter and MSc marksheets. A second step will be online, starting in April.