PROPOSITION DE STAGE 2017-2018

Titre : Two-way coupling between a compressible Navier-Stokes solver and an Eulerian solver and application to a 3-D Large Eddy Simulation relevant for aeronautical applications.

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Subject

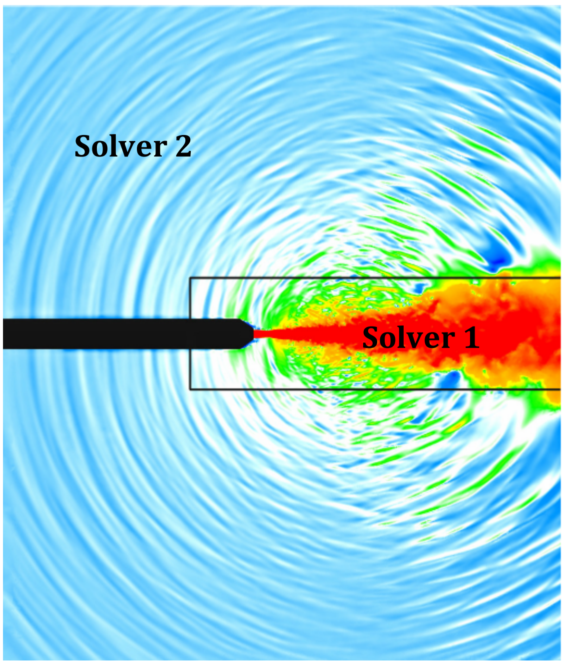
Computational aeroacoustics is a growing field that follows the recent concerns about the noise produced by aircraft, cars, wind turbines or high speed trains. For populations surrounding airports for example, it has been shown that the effect of this noise may result in health hazards and social issues. More specifically, it can lead to higher rates of heart disease [1] and waist circumference [2].

For populations surrounding airports, in order to have the noise radiated by an aircraft located far away, two solvers need to be used.

- A first solver will permit to compute the hydrodynamic and the acoustic fields in the vicinity of the airplane. To do so, a recent solver named IC3 will be used to perform high-order Large Eddy Simulations. It solves the 3-D compressible Navier-Stokes equations on unstructured grids. It should be noted that computational aeroacoustics is highly demanding in terms of accuracy since the hydrodynamic fluctuating pressure is several orders of magnitude higher (classically 3 to 5) than the sound pressure fluctuations.

- A second solver will permit to propagate the sound from near to far field. IC3 will also be used for that purpose but the viscous fluxes will not be solved and the mesh will be designed with the only purpose to be able to propagate acoustic waves.

An example of such coupling applied to a supersonic hot round jet can be seen below [3]. The regions covered with each solver are shown.



Snapshot of the instantaneous near and far acoustic fields. The coupling interface is represented by the black line.

Objectives

1/ The first objective will be to run two instances of the solver, one solving the compressible Navier-Stokes equations and the other solving the Euler equations. These two instances should be able to run simultaneously. The chosen candidate will work in close cooperation with a PhD student devoted to the code development. The two-code set-up will be tested on 2-D simple cases in order to assess the methodology and the programming of the coupling.

2/ The second objective will be to gradually damp the viscous terms at the boundary between the two solvers, in order to avoid spurious reflections. The solution will also be calibrated and validated on simple 2-D test cases.

3/ The third objective will be to apply this new coupling to a full 3-D LES simulation on a relevant geometry in the aeronautical context.

Research program

The candidate will:
- first read some literature about the subject, in order to propose the best coupling strategy at the boundary
- program the coupling (C++ programming in the solver IC3)
- test the setup on simple 2-D cases, seeking for bugs and errors
- finally apply the validated set-up on a aeronautically relevant geometry.

Références

[1] Hansell, A. L., Blangiardo, M., Fortunato, L., Floud, S., de Hoogh, K., Fecht, D., ... & Beevers, S. (2013). Aircraft noise and cardiovascular disease near Heathrow airport in London: small area study. *Bmj*, *347*, f5432.

[2] Eriksson, C., Hilding, A., Pyko, A., Bluhm, G., Pershagen, G., & Östenson, C. G. (2014). Long-term aircraft noise exposure and body mass index, waist circumference, and type 2 diabetes: a prospective study. Environmental health perspectives, 122(7), 687.

[3] Langenais, A., Vuillot, F., Troyes, J., & Bailly, C. (2017). Numerical investigation of the noise generated by a rocket engine at lift-off conditions using a two-way coupled CFD-CAA method. In 23rd AIAA/CEAS Aeroacoustics Conference.