Internship opportunity 2022

Title: Spectral Proper Orthogonal Decomposition methods for aeroacoustic analysis

Responsable(s):
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Duration: 6 months
Salary: statutory minimum pay

Key words: aeroacoustics, signal processing, programming

Background

The aero-acoustic study of industrial applications (jet flow, fan-Outlet Guide Vane interaction for example) is generally made difficult by the complexity of the aerodynamic phenomena and the acoustic radiated. Some paths are then investigated in order to decompose these fields and make the analysis of these systems easier. Spectral Proper Orthogonal Decomposition (SPOD) is a process based on the Proper Orthogonal Decomposition (POD) and the Discrete Fourier Transform (DFT). The major advantage by using this technique is to be able to make appear several coherent structures organised in a decreasing order of energy at each observation frequency.

Program of internship

The SPOD **[1]** method has been widely used and tailored to study hydrodynamic phenomena and much less aeroacoustic ones. In general, the majority of the applications have both hydrodynamic and acoustic phenomena that coexist and interact with each other. The hydrodynamic fluctuations are generally several orders of magnitude larger than the acoustic fluctuations. As a consequence, when performing a SPOD treatment without additional treatment, mainly the hydrodynamic modes emerge and the acoustic ones are not captured. A SPOD program has been developed during a previous internship in Matlab and a Python code from the literature **[2]** is also available. Based on one of these two codes already available, the purpose of this internship would be to improve the normalizations and weighting in the SPOD in order to have a reliable method to study fluctuating pressure fields, taking into account both aerodynamic and acoustic footprints. The input data will be based on well validated Large-Eddy Simulations (LES) consisting of planar/round jets, impacting jets with different angles **[3]** and FAN-Outlet Guide Vane interactions configurations **[4]**. An experimental test case consisting of microphone array measurements in a wind tunnel will also be available (see Figure 1).

Figure 1: Microphone array measurements in ISAE-SUPAERO aeroacoustic wind tunnel.

During the previous internship, a normalization was proposed for the SPOD so that the hydrodynamic and acoustic fluctuations could be of comparable magnitudes and the hydrodynamic and acoustic phenomena would be compared at the same time. An interesting result can be seen in Figure 2 below where the fluctuating pressure inside the studied impinging jet and the fluctuating pressure outside of it have been normalized differently in order to recover a mode consisting of its hydrodynamic footprint inside the jet and its acoustic footprint outside.

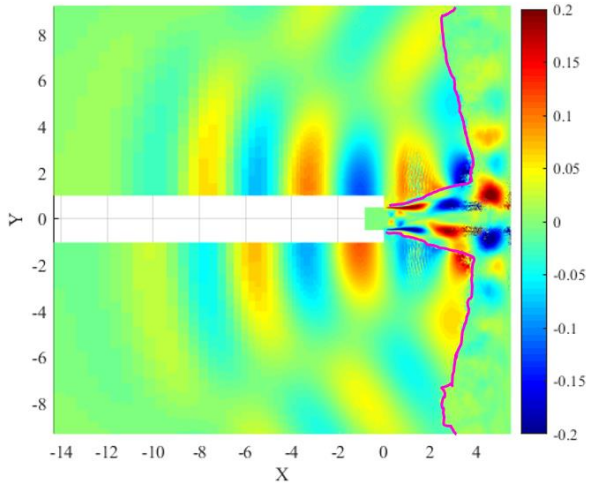

Figure 2: Main SPOD mode of an impacting jet configuration (LES) showing its hydrodynamic (in the mixing region and recirculation) and acoustic footprints (in the region corresponding to the acoustic waves propagation).

Bibliography

[1] Schmidt, O. T., & Towne, A. (2019). An efficient streaming algorithm for spectral proper orthogonal decomposition. *Computer Physics Communications*, *237*, 98-109.

[2] Mengaldo, G., & Maulik, R. (2021). PySPOD: A Python package for Spectral Proper Orthogonal Decomposition (SPOD). *Journal of Open Source Software*, *6*(60), 2862.

[3] Gojon, R., Bogey, C., & Marsden, O. (2016). Investigation of tone generation in ideally expanded supersonic planar impinging jets using large-eddy simulation. *Journal of Fluid Mechanics*, *808*, 90-115.

[4] M. Fiore, M. Daroukh, M. Montagnac (2021). Broadband noise prediction of a counter rotating open rotor based on LES simulation with phase-lagged assumption, *Journal of Sound and Vibration*, Volume 514.

Required profile

We are looking for a candidate with a good training in fluid mechanics and/or applied mathematics and with an experience in programming (Python, Matlab). Knowledge in aeroacoustics and/or signal processing would be appreciated.