RESEARCH INTERNSHIP

Title: Application of SPOD to denoise airflow microphone array signals

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Location: Département Aérodynamique, Energétique et Propulsion (DAEP), ISAE-SUPAERO

Duration : 6 months

Key words: aeroacoustics, modal decomposition, signal processing, numerical simulations

Context:

Global economic and demographic expansion is leading to an increase in noise pollution associated with land and air transportation as well as new energy developments (wind power). Noise pollution regulations are becoming increasingly strict and the reduction of aerodynamic noise sources, known as aeroacoustics, is therefore a major challenge. The characterization of aeroacoustic sources in the pre-project phase by means of wind tunnel tests is a key step to help understand noise generation mechanisms and to be able to develop effective noise reduction strategies.

For this purpose, various source localization techniques have been developed. The most well-known is called Beamforming and was developed by Billinglsey and Kinns[1] in 1974. This technique is based on the assumption that the sound field radiated by the sources under study follows a certain source model (usually monopole). It is then possible to localize the acoustic sources from farfield microphone array measurements by interpreting the propagation delays measured between each microphone of the antenna and by knowing the source-antenna distance. However, this methodology is based on the assumption of sound wave measurements without airflow, which might not be always the case for outdoor or wind tunnel measurements.

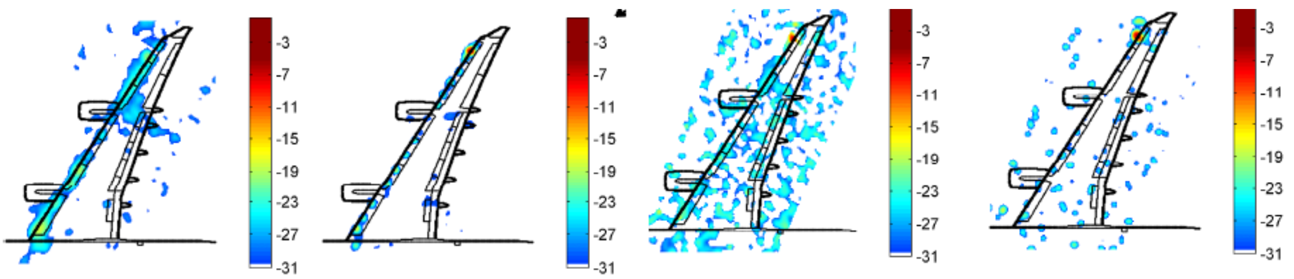

Figure 9: Source plot at 12360 Hz, CB, after coherent source removal, peak at −15.5 dB.
Figure 10: Source plot at 12360 Hz, CLEAN-SC.
Figure 11: Source plot at 12360 Hz, CLEAN-PSF.
Figure 12: Source plot at 12360 Hz, DAMAS.

Figure 1: Reconstructed source field in source plane for different beamforming algorithms: conventional beamforming, CLEAN-SC, CLEAN-PSF et DAMAS[2].

Figure 2: Localization array in ISAE-SUPAERO aeroacoustic wind tunnel.

Content:

The objective of this research internship is to study numerically the effect of an airflow on microphone array measurements and to test a methodology to extract the sound pressure from the global measured pressure fluctuation. For that, the first step will be to simulate using large eddy simulations (LES) a monopole source and its radiation on an array plane without airflow, and then with airflows of various mean and fluctuating velocities, to assess the impact on virtual microphone array measurements. The second step will be to apply spectral proper orthogonal decomposition (SPOD)[3] on virtual array signals to see if this methodology, already applied in the field of aeroacoustics[4], is able to separate the acoustic and aerodynamic components of the fluctuating pressure. Depending the advancement of the internship, the methodology could then be applied on more realistic aeroacoustic configurations (in-flow cylinder noise…).

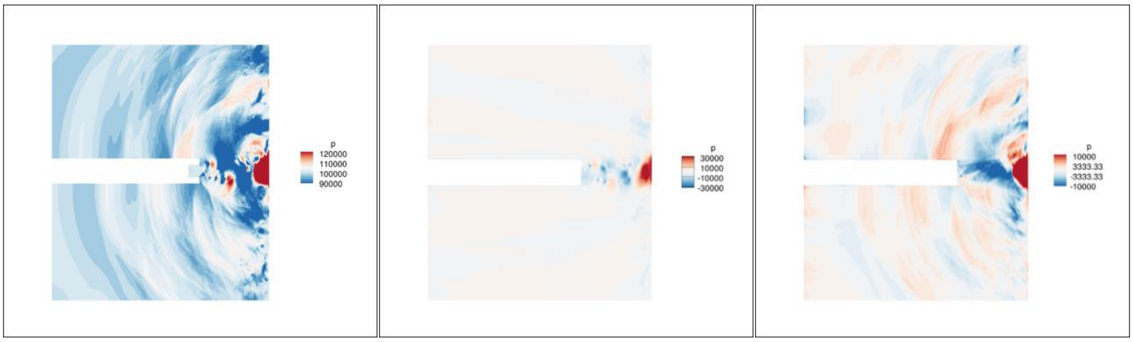

Figure 3: Fluctuating pressure field (left) decomposition into hydrodynamic (center) and acoustic (right) components using SPOD for a supersonic impinging jet[3].

References

[1] J. Billinsgley and R. Kinns, « The acoustic telescope », J. Sound Vib. 48 (4), 485-510 (1976).
[2] P. Sijtsma, CLEAN based on spatial source coherence, In 11th AIAA/CEAS Aeroacoustics Conference, AIAA 2007-3436 (2007).
[3] Towne A, Schmidt OT, Colonius T. Spectral proper orthogonal decomposition and its relationship to dynamic mode decomposition and resolvent analysis. JFluid Mech 2018;847(1):821–67. http://dx.doi.org/10.1017/jfm.2018.283.
[4] M. Fiore, H. Parisot-Dupuis, B. Etchebarne and R. Gojon, Spectral proper orthogonal decomposition of coupled hydrodynamic and acoustic fields: Application to impinging jet configurations, Computers and Fluids, 241, 105484, 2022.

Expected profile:

We are looking for candidates with a background in acoustics, aerodynamics. Knowledge in signal processing is a plus to approach this theme. Candidates will also be required to program in Matlab and/or Python.