A comparison between different wall pressure measurement devices for the separation and analysis of TBL and acoustic contributions

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Microphone array measurements are commonly used for the characterisation of aeroacoustic sources in wind tunnels. The object of interest (or a mockup of it) is installed in the tunnel and a flow is established so as to generate aeroacoustic sources. The difficulty, in these conditions, is that the pressure fluctuations observed at one given point in the tunnel result from the acoustic pressure, radiated by the aeroacoustic source of interest, but also from fluctuations caused by the flow itself. For practical reasons, microphones are often installed on a wall of the tunnel. The acoustic pressure radiated by the source of interest is then disturbed by the pressure due to the turbulent boundary layer developed on the wall, with often strongly negative signal to noise ratios. The post-processing of such data, for acoustic imaging purpose, requires the separation of these two contributions (acoustic and TBL). This separation relies on statistical and/or physical properties of these two components.

Statistically, correlation lengths of the TBL are very short, the resulting coherence between different sensors of the array being very low. The contribution of the TBL to averaged cross-spectral quantities is thus limited (except for auto-spectra). Many acoustic imaging techniques are based on the post-processing of averaged cross-spectral quantities, either excluding [1] or reconstructing [2] auto-spectra. These approaches require sufficiently converged cross-spectra, which in turn requires quite long time records. Moreover, transient acoustic events cannot be analyzed using such averaged spectral quantities.

Other separation techniques rely on the different physical properties of the TBL and acoustic fields, more specifically their properties in the wavenumber domain. The acoustic part is by definition limited to the low wavenumber domain (lower or equal to the acoustic wavenumber). The support of the TBL is much wider, with a maximum around the convective wavenumber in the direction of the flow. A separation of acoustic and TBL contributions can thus be processed by a filtering operation in the wavenumber domain. This filtering can be operated either by post-processing parietal pressure fields sampled using high density microphone arrays, or alternatively using a low-pass physical filtering operating before data acquisition. Post-processing filtering requires high density microphone arrays to avoid aliasing problems at the stage of spatial sampling, the high number of required microphones is often reached using multi-pass measurements [3]. Physical filtering is achieved by various ways, using surface or remote microphones, the filtering being realized by an averaging of the pressure over a surface determined by the sensor area or by the section of the tube connected to remote sensors [3, 4]. Another possibility is to use filtering properties of thin structures: a thin plate submitted to a parietal pressure field will act as a low pass filter, with a cut-off frequency equal to its natural wavenumber. The vibration of the plate can be used to recover the low wavenumber part of the incident pressure field using inverse methods [5, 6].

The aim of the present contribution is to compare different experimental approaches to separate TBL and acoustic contributions in the frame of a unique academic experiment. The experimental setup has been realized in the frame of the ADAPT Cleansky EU project, in a small wind tunnel at Ecole Centrale de Lyon. Some acoustic sources are mounted in the roof of the tunnel, and 3 different parietal pressure field

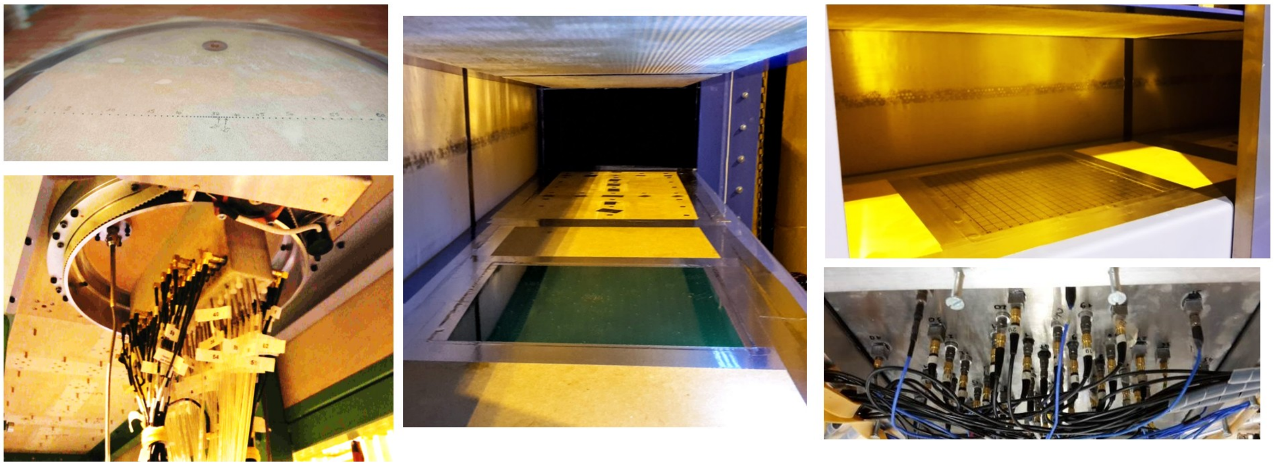

Figure 1: Tested experimental devices : rotating array of 63 remote microphones (upper and back sides), 75 mems microphone array, thin plate with 49 accelerometer array on the back side (upper and back sides).

measurement devices are successively tested (see Fig. 1):
- a rotating array of 63 remote microphones,
- a fixed array of 75 flush-mounted mems microphones,
- a fixed array of 49 accelerometers mounted on a thin plate.

Measurements have been realized for different flow speeds and acoustic source configurations. The different separation approaches will then be processed, and results will be confronted to illustrate advantages and drawbacks of all methods.

References

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