Post-doc offer (24 months)

Title : Propagation of aircraft noise at ground level

Supervision: D. Dragna (assistant professor), didier.dragna@ec-lyon.fr
P. Blanc-Benon (senior researcher), philippe.blanc-benon@ec-lyon.fr

Location: Laboratoire de Mécanique des Fluides et d'Acoustique, UMR CNRS 5509,
Ecole Centrale de Lyon, 69134 Ecully Cedex, FRANCE
acoustique.ec-lyon.fr

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This post-doc is part of the MAMBO project and will be done in collaboration with AIRBUS.

Background presentation:

Civilian aircraft must meet ICAO noise certification standards. For this purpose, the noise generated by the flyover of an aircraft under different conditions is measured using a reference microphone placed at a height of 1.2 m above the ground. The microphone receives the direct field emitted by the aircraft and the field reflected by the ground, and the spectra show typical constructive and destructive interference patterns. The measure is thus sensitive to the absorption characteristics of the ground, which may vary depending on the certification site. In order to reduce this variability, aircraft manufacturers are considering a ground-based measurement with a microphone mounted on a perfectly reflecting plate. The idea would be to have a measurement independent of the surrounding ground in order to mimic a free field measurement or at least to reconstruct from the signal measured on the ground the signal at 1.2 m for a standardized site. Recent works [1,2] have focused on determining the geometry of the plate to obtain a frequency response of the plate as close as possible to that of a perfectly reflective ground.

Although the response of the plate is independent of the nature of the surrounding soil for medium and high frequencies and for moderate angles of incidence, the effect of the soil remains preponderant at low frequencies and for grazing angles. It is therefore necessary to characterize the ground and to take it into account when reconstructing the signal at the reference microphone.

Comparisons between the spectrum measured at 1.2 m and reconstructed from the ground measurement and an analytical model have shown the feasibility of the method. Nevertheless, a slight frequency shift of the interference predicted by the model can have a significant impact for low frequency tonal sources. The observed discrepancy seems to be due to the analytical model used to consider the ground reflection. This is based on the Weyl-van der Pol formula, which was developed for a fixed source in a homogeneous atmosphere at rest and which is a long-range approximation for grazing incidence and relatively reflective soils. The use of this formula for sources in motion appears therefore limited. Moreover, it is not possible to account for extended-reacting grounds. Finally, the meteorological effects (wind, temperature gradient, turbulence) are not modeled at all.

State of the art:

Radiation from moving sources has been widely studied, especially for applications in transportation noise (e.g. [3]). The consideration of the ground effect is however more recent. We can cite the analytical solutions developed in the 1970s by Norum and Liu [4] and Oie and Takeuchi [5] to determine the Green's function for a source moving at constant height and speed over a locally reacting ground. The ground wave, which is an important contribution at low frequencies, is nevertheless neglected. An analytical solution developed by Attenborough et al [6] corrects this shortcoming; however, the authors consider a frequency independent ground impedance. More recently, Dragna and Blanc-Benon [7] have shown the importance to account for the variation with frequency of the impedance, especially for sources moving at Mach numbers higher than 0.3. Moreover, it was shown that the analytical solution could be written in the form of a Weyl-van der Pol type formula, where the impedance is evaluated at the Doppler frequency related to the image source. This study has been continued [8,9] by considering a non-local reacting ground.

The use of numerical simulation for the prediction of the radiation of moving sources s remains limited for the moment for application purpose, in particular because of the computation time which remains important for a 3D geometry and for medium-high frequency sources. Temporal approaches seem relevant for such problems. First calculations by solving the linearized Euler equations by finite difference methods [10] have shown the interest of the approach and have also been used to validate analytical solutions [7,8].

For engineering applications, most models assume quasi-stationary sources; the pressure field is thus calculated at each instant from the analytical solution for a fixed source by considering the position of the source-receiver pair at the time of emission. This assumption proves to be sufficiently accurate for road noise (Mach number close to 0.1) but remains limited for higher speeds [6] (high speed trains or airplanes near airports where the Mach number is higher than 0.3). A semi-analytical model is proposed in Attenborough et al [6] for any source trajectory. This model considers the Doppler effect on the received frequency as well as the effective admittance seen by the reflected wave and the convective amplification. A similar model was recently used by Arntzen and Simons [11] for the sound synthesis of aircraft noise near airports but has not been validated with comparisons to direct approaches.

Work program

In order to improve the reconstruction of the signal at the reference microphone from the signal measured on the ground, a semi-analytical model will be developed to predict the acoustic radiation of a harmonic source moving along any trajectory. This model will be based on the one proposed by Attenborough et al [6].

1. Particular attention will be paid to the modeling of the ground effect. The aim will be to extend the current model which only considers a locally reacting ground to a ground with an extended reaction, which can have a notable effect for grazing angles. Care will be taken to select a relevant impedance model from the literature.
2. Furthermore, the effect of turbulence on the decorrelation between direct and reflected waves will be considered. We will first perform a state of the art on the proposed models in the literature before implementing/developing a model of the effect of turbulence.
3. Test cases will be defined in order to validate the developed model and comparisons with a numerical solution of the Euler equations linearized by finite difference methods will be performed.

4. Different simulations will then be carried out with the developed tool in order to identify the physical parameter(s) that are essential to characterize in order to have an accurate reconstruction of the signal at 1.2 m from the ground signal.

References

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