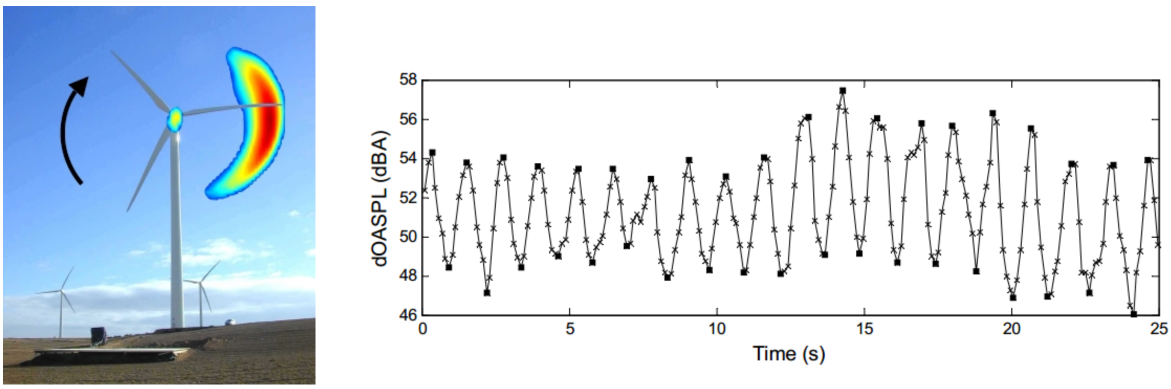
Institut des Sciences de la Mécanique et Applications Industrielles

Post-doctoral position of 12 months in Aeroacoustics: Physically-based sound synthesis of broadband and tonal components of wind turbine noise

Context

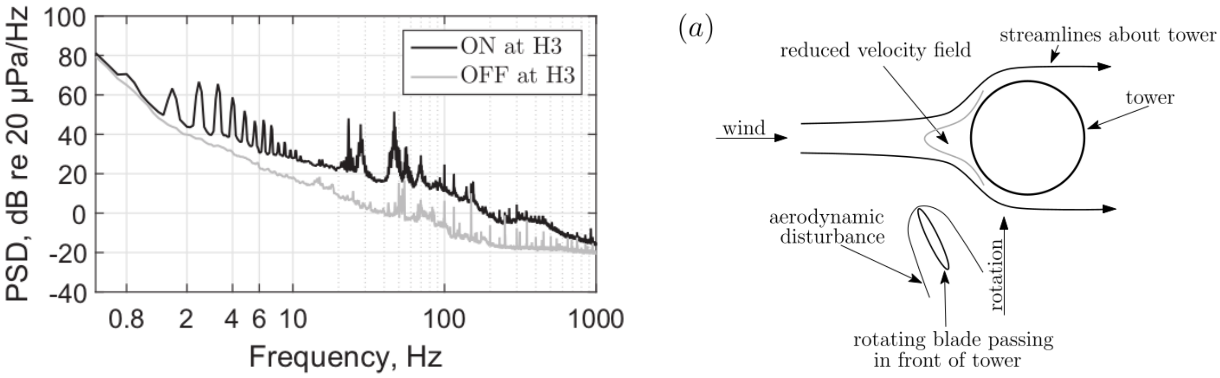
Wind energy is expanding rapidly in France, as elsewhere in the world, and the population is worried about the health impacts of noise emitted by wind turbines and some people are concerned about a significant annoyance that might be partly due to the nature of the noise emitted, which includes important low frequency components (audible or not), with a modulated temporal structure, as shown in Figure 1. One of the objective of the French project RIBEolH (Research on the impacts of wind turbine noise on humans: sound, perception, health), is to perform a psychoacoustic study under controlled conditions using signals measured and synthesized for different operating conditions of wind turbines. This approach enables the synthesis of noise based on well-identified and controllable physical parameters, which will make it possible to precisely determine the parameters that have an important role in the effects of wind turbine noise on perception and annoyance. The sound synthesis will make it possible to eliminate background noise, wind turbine noise being characterized by low signal to noise ratios, and to consider conditions that may differ from those found during acoustic measurements in the field. Contrary to existing sound synthesis tools, based on signal processing techniques (e.g. PhD thesis of Pieren [1]), the physically-based sound synthesis approach will enable us to identify the the parameters that have an important role on loudness and annoyance related to wind turbine noise.



(a) (b)

Figure 1: (a) Array measurement of wind turbine noise (Oerlemans *et al.*, 2007), and (b) amplitude modulation measured by Dick Bowdler (`www.dickbowdler.co.uk`)

The sound synthesis tool of the RIBEolH project will thus be based on the physical modeling of noise sources radiated by wind turbines and on their propagation in the atmosphere. It will take into account the fact that the source is extended and in motion in order to correctly predict the directivity pattern and amplitude modulations of wind turbine noise [2].



(a) (b)

Figure 2: (a) Wind turbine noise spectra measured at 3 km from a wind farm [4], and (b) mechanism of blade-tower interaction noise for an upwind wind turbine [5].

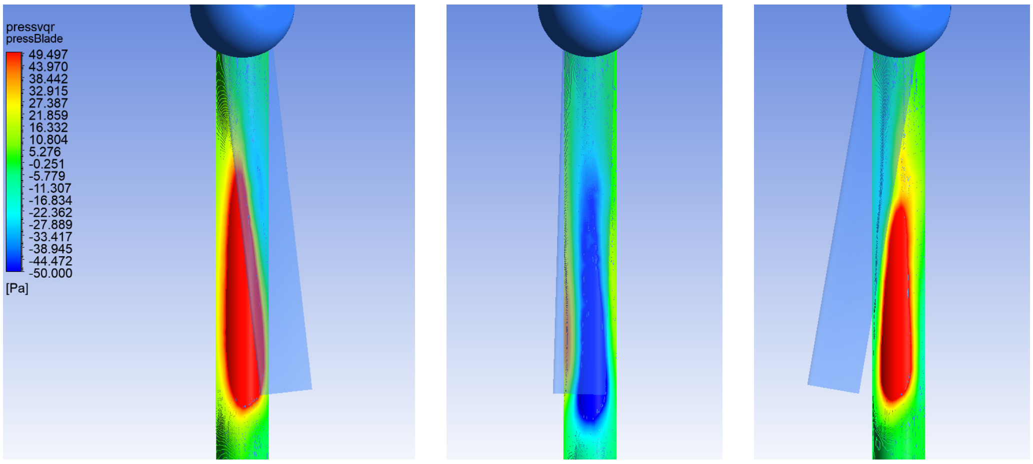


Figure 3: Pressure field on the tower surface of a model wind turbine for different blade positions (internship of Elegbédé).

The tool will be divided into three main modules:

1. broadband aerodynamic noise;
2. tonal components of aerodynamic or mechanical noise;
3. background noise associated to wind on the microphone and on vegetation.

The first module corresponds to the dominant aeroacoustic sources in the audible frequency range for large-scale wind turbines, and will be based on the recent synthesis model of Mascarenhas *et al.* [3] based on Amiet's theory. In the RIBEolH project, we will focus mostly on turbulence interaction noise, as this noise source is generally louder than trailing edge noise below 300-400 Hz. The second module synthesizes the tonal components of wind turbine noise, that are visible in Figure 2(a). The tonal components of aerodynamic noise are present at the harmonics of the blade passing frequency (typically around 0.8 Hz), and are mainly attributed to the tower-blade interaction noise, whose mechanism is schematically shown in Figure 2(b). The unsteady loading on the blades and on the tower can either be calculated using simplified aerodynamic models such as the Blade Element Momentum model, or with more refined simulations such as the ones based on the sliding mesh method (see preliminary results of the internship of Elegbédé in Figure 3). The third module, corresponding to background noise, will focus on the wind-induced noise on the microphone [6]. This noise will be included in the sound synthesis used in the perceptual validation performed in the Mechanics and Acoustics Laboratory (LMA) in Marseille in order to match the *in situ* recordings, but will not be included in the psychoacoustic tests as only wind turbine noise components will be studied.

Objectives

The objectives of this post-doctoral position are:

- to develop aeroacoustic models for broadband and tonal sources that are suitable in a sound synthesis context;
- to compare the model predictions to *in situ* measurements at different distances from the wind turbines and for various meteorological conditions, both in the time domain (amplitude modulation) and in the frequency domain (third octave band spectra) in order to test the performance of the sound synthesis tool;
- to transfer the tool to the project partners in charge of the perceptual validation of the sound synthesis.

Practical information

- **Profile**: the candidate must hold a PhD degree in Fluid Mechanics or Acoustics, with a significant experience in the field of aeroacoustics, and a good expertise in signal processing.
- **Supervision**: Benjamin Cotté from IMSIA at ENSTA Paris (`https://perso.ensta-paris.fr/~cotte/`).
- **Duration and location**: funding for 12 months. The work will take place at ENSTA Paris (`https://www.ensta-paris.fr/`) in Palaiseau (20 km south of Paris).
- **Salary**: minimum gross salary of 2600 euros per months depending on the applicant's experience.
- **To apply**: send a detailed CV with a list of publications, a short cover letter and a list of references to benjamin.cotte@ensta-paris.fr.
- **Deadline and Start Date**: There is currently no deadline. Applications are accepted until a suitable candidate is found. However, the contract is expected to begin no later than October 2021.

References

[1] R. Pieren, Auralization of Environmental Acoustical Sceneries: Synthesis of Road Traffic, Railway and Wind Turbine Noise, PhD thesis Delft University of Technology, 2018.

[2] B. Cotté, "Extended source models for wind turbine noise propagation," *Journal of the Acoustical Society of America*, vol. 145, pp. 1363-1371, 2019.

[3] D. Mascarenhas, B. Cotté, O. Doaré, "Physics-based auralization of wind turbine noise," *9th International Conference on Wind Turbine Noise*, 18-21 May 2021.

[4] B. Zajamsek, K. L. Hansen, C. J. Doolan, and C. H. Hansen, "Characterisation of wind farm infrasound and low-frequency noise," *Journal of Sound and Vibration*, vol. 370, pp. 176-190, 2016.

[5] B. Zajamsek, Y. Yauwenas, C. J. Doolan, K. L. Hansen, V. Timchenko, J. Reizes, and C. H. Hansen, "Experimental and numerical investigation of blade–tower interaction noise," *Journal of Sound and Vibration*, vol. 443, pp. 362–375, 2019.

[6] G.P. van den Berg, "Wind-induced noise in a screend microphone," *Journal of the Acoustical Society of America*, vol. 119, pp. 824-833, 2006.