Master thesis subject

New models for airfoil self-noise combining physics-informed machine learning, linearized methods and high-fidelity simulations

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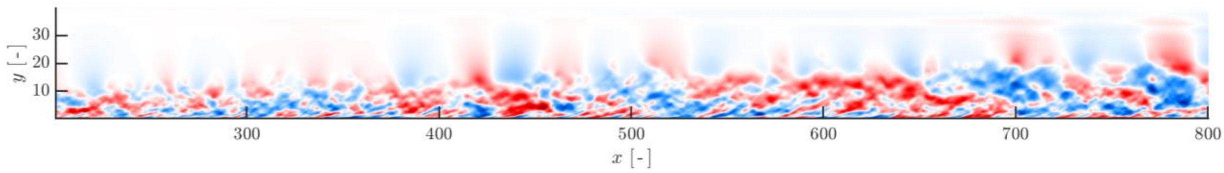
Wind farms play an essential role in combating climate change. To realize the full potential of onshore wind farms, limiting factors such as noise pollution must be reduced or even eliminated. A major contributor to noise pollution is trailing edge noise. Therefore, understanding and modeling the physical phenomena involved in trailing edge noise is critical to the development of effective noise mitigation techniques. At the Laboratory of Flow Instabilities and Dynamics, we investigate the pressure fluctuations responsible for radiated sound using reduced-order models based on linearized Navier Stokes equations. This type of modeling has the advantage of being physics-based, providing meaningful diagnostics, and also highlighting sensitive areas of the flow where control is most effective in reducing noise emissions.

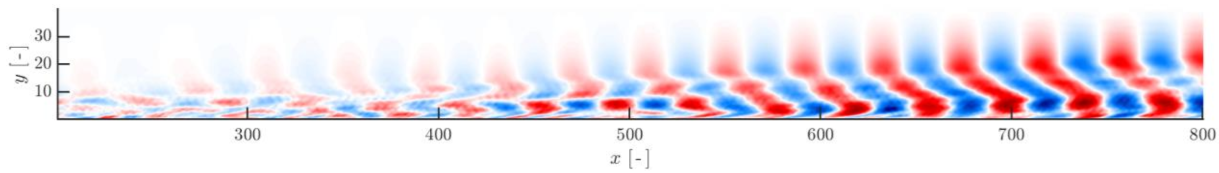
However, for the range of Reynolds numbers in which wind turbines operate, the boundary layer near the airfoil is turbulent. Hence, the linear equations are set up using the time-averaged flow as the base state, which leads to a significant complexity; the interaction between coherent fluctuations and the smaller-scale turbulent eddies must be approximated with a turbulence model. Finding a suitable turbulence model for the linearized mean flow equations is the subject of this project. To tackle this goal, highly detailed large-eddy simulations (LES) of turbulent, wall-bounded flows will first be performed. Based on the generated data set, suitable turbulent closure models will be identified in a second step using Physics Informed Neural Networks (PINNs), a recently developed tool for data assimilation, and subsequently tested in the form of an a priori analysis.

The main tasks for this project will include:

- Setting up and running the numerical simulation using Dedalus;
- Using PINN on the LES mean flow to assimilate an appropriate closure field.
- Post-processing of LES data using spectral POD and linearized in-house codes to find the coherent structures in the turbulent flow and perform a-priori analyses;

The prospecting student should already have some knowledge of linear algebra, fluid dynamics and numerical simulations for fluid dynamics. Experience with coding languages such as Python and MATLAB is recommended. In addition, knowledge of linear flow stability and/or machine learning techniques is an asset.





Top figure: Snapshot of streamwise velocity from LES of turbulent boundary layer with zero pressure gradient.

Bottom figure: Coherent structures in the same boundary layer, identified with a spectral proper orthogonal decomposition (SPOD) of the LES dataset.