Dynamics of coherent structures over wind turbine blade

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Abstract

The primary objective of the thesis is to quantitatively assess the dynamic behavior of turbulent airflow around a NACA airfoil as a function of the upstream flow. The upstream flow consists of a family of coherent structures, each with its own distinct temporal and spatial scales. Additionally, this upstream flow may include a mean shear due to a largescale boundary layer. These situations are commonly encountered in wind and marine turbine farms, where the wake generated by one turbine becomes the upstream flow for the next one, and where the atmospheric boundary layer can influence the dynamics of the airfoil's airflow. Aerodynamic research on wind turbines has primarily focused on the general response of airfoils, and the flow downstream. However, airfoils are not considered yet in an upstream flow with the presence of a family of coherent structures. This study takes into account the spatial and temporal aspects, which is crucial for understanding how efficiently the kinetic energy carried by these coherent motions is captured within the wake. The novelty of the project is to provide a complementary and more detailed analysis of the airfoil-upstream flow interactions based on the analysis of the intermittency of the upstream conditions. This helps to gain insights into the dynamic response of the downstream airfoil and the distribution of kinetic energy over the airfoil. To achieve this goal, pressure distributions (coherent structures) must be phase-averaged with a conditioning based on the dynamics of the upstream flow. This type of analysis represents a novel approach and requires the development of specialized methods to be applied to such complex cases. One of the key areas of investigation within the project is the study of the total turbulent kinetic energy (TKE) when the upstream coherent structure packets interact with the downstream airfoil. Additionally, further research can be involved into turbulent kinetic energy, considering the interactions between different components of fluctuations, such as the interactions between coherent and random motion. This thesis work is integrated in the framework of DYNEOL (ANR-17-CE06-0020) project that is funded by the French National Agency of Research (ANR). The project is a collaborative research involving four French laboratories, including the CORIA laboratory.