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# Vortex Induced Vibration of a NACA 0012 Airfoil

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## Abstract

This study presents a high-fidelity numerical analysis of the dynamics of a flexibly mounted NACA 0012 airfoil undergoing vortex-induced vibrations (VIV). The objective is to characterize the flow features and the dynamical behavior of the airfoil while improving the prediction of associated aerodynamic loads. These loads are critical to the performance, fatigue life, and structural safety of rotorcraft, eVTOLs, and wind turbines operating in unsteady flow environments. VIV is a flow-induced vibration phenomenon characterized by oscillations caused by an alternating pressure distribution due to vortex shedding from a body immersed in fluid flow. Once the vibration begins, the vortex shedding frequency deviates from that of a static configuration and may synchronize with the natural frequency of the system over a range of reduced velocities, known as the lock-in range. This synchronization or resonance can cause large-amplitude responses. In non-circular bluff bodies such as airfoils, a non-zero mean lift may lead to complex coupling between VIV and self-excited vibrations, producing significant bending and torsional loads that may cause structural failure. Despite extensive research on bluff bodies, VIV in airfoils remains comparatively less understood.

In the present study, the dynamics and flow features of a NACA 0012 airfoil at a Reynolds number (Re) of 50,000, constrained by a translational spring, are investigated using an in-house solver to perform implicit large eddy simulations (iLES) of the incompressible Navier–Stokes equations. A forced system model is adopted, in which the aerodynamic loads are assumed to depend solely on time, and not on the dynamics of the airfoil, such as its displacement and velocity. This single-degree-of-freedom framework offers a cost-effective yet sufficiently accurate representation of VIV for preliminary investigations. The forced system model is validated against published experimental results for a circular cylinder at Re = 200, showing that the maximum amplitude predicted over a range of Skop-Griffin numbers aligns well with experiments. This validated range is extended to study the VIV response of the airfoil for various reduced velocities, damping ratios, and angles of attack (3°, 6°, and 12°). Results show that, unlike circular bodies, the Strouhal number for an airfoil varies significantly with the angle of attack. Moreover, in turbulent flows, multiple lock-in regimes emerge, a behavior not observed in laminar flows. These findings provide new, high-fidelity data for future numerical and experimental studies on VIV of airfoils.