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Flow Around a Plunging Airfoil: A Study Using the New Immersed Boundary Method Algorithm in foam-extend 4.1

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Synopsis

This study reports a numerical analysis of unsteady flow over a plunging elliptical airfoil utilizing Immersed Boundary Surface Method (IBS) implemented FOAM-Extend 4.1 framework. The aim of this work is to validate force coefficient results using the recent discrete-forcing IB algorithm from a published study which used the continuous-forcing IB algorithm. The motivation comes from the necessity of precise flow modeling around oscillating airfoils in engineering applications like flapping-wing aerodynamics and bioinspired propulsion. Compared to its previous version, the more recent IB implementation is intended to enforce boundary conditions more precisely like the body-fitted method, particularly when there are moving boundaries. Simulations are performed at a Reynolds number $Re = 500$ with a constant reduced frequency $\kappa = 6.283$, while two distinct values of κh (0.31 and 1.0) are considered to explore different oscillation amplitudes. The airfoil is subjected to a vertical plunging motion defined by a sinusoidal profile. The study focuses on evaluating the lift and thrust coefficients obtained from the new IB implementation and comparing it with the literature. The result shows a strong agreement in force predictions, validating the accuracy and robustness of the IBS formulation. This study serves as a benchmark for upcoming enhancements and three-dimensional extensions and demonstrates the capacity of FOAM-Extend's more recent IB algorithm to simulate changing boundary flows.