

PROCEEDINGS

Sensitivity of Airfoil Flow and Performance to the Material Parameters of Flexible Trailing-Edge Flaps

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ABSTRACT

The bio-inspired application of flexible structures, traced to the foundational waving-plate theory which highlighted the propulsive advantages of flexible motion [1], has evolved into a promising strategy for aerodynamic flow control. Recent studies on Flexible Trailing-edge Flaps (FTFs) have substantiated their benefits, such as mitigating flow separation and reducing aeroacoustic noise by eliminating surface discontinuities [2]. Building upon this, the present numerical study investigates the fluid-structure interaction (FSI) between a rigid airfoil and an FTF, with the key issues being focused on the sensitivity of airfoil flow and performance to variations in the flap's flexural rigidity and dimensionless length. A coupled FSI solver based on the Immersed Boundary Method coupled with the Lattice Boltzmann Method (IB-LBM) is employed to examine the dynamic response of FTFs attached to a NACA0012 airfoil with an angle of attack of 10° at varied flap bending stiffness and length. A critical stiffness threshold is identified, below which the flap undergoes significant passive deformation. This adaptive reconfiguration effectively streamlines the aft section, altering the separation shear layer, leading to substantial drag reduction. Conversely, higher stiffness values result in minimal deformation and negligible performance gains. Furthermore, the analysis reveals a sensitive frequency coupling mechanism: the vortex-shedding frequency from the airfoil is shown to lock into the natural structural frequency of the flap within a specific stiffness range, nonlinearly influencing the lift fluctuations and the overall drag coefficient. The study concludes that the aerodynamic performance enhancement is not guaranteed but is highly sensitive to the selected material parameters, defining an optimal design window for effective passive flow control.

KEYWORDS

Airfoil; wake dynamics; flexible flap; immersed boundary method

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