Flow Control via Bio-Inspired Leading-Edge Tubercles for Enhanced Airfoil Performance

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This study investigates the effect of whale fin inspired leading-edge tubercles on airfoil performance for improved fuel efficiency and maneuverability in aircraft. These small protrusions on humpback whale fins have been shown by literature to increase lift and delay the onset of stall. Mimicking these evolutionary adaptations has the potential to address the global demand for improved aircraft design. The goal of this project is to optimize the physical parameters of tubercles, specifically the amplitude and wavelength of the leading edge curve. The NACA0012 airfoil is used as a baseline for its common use in airfoil studies. Computational fluid dynamics (CFD) simulations were used to create a regression model and find the maximum increase in lift to drag ratio, and wind tunnel testing was done to back up these results in a real-world environment. Simulations yielded a significant increase in lift to drag ratio at lower amplitudes and wavelengths, with a maximum of 23.5% at 3% amplitude and 10% wavelength as a percentage of chord length. They also provided visual streamlines to qualitatively observe improvements in flow characteristics, such as delayed flow separation. Wind tunnel experimentation suggested an improvement very close to the simulation's corresponding value. These results suffered from major sources of error such as non-normal flow and inaccurate force measurements, but still supports the efficacy of tubercles in increasing lift in airfoils. This research builds upon existing literature in advancing airfoil design for more sustainable and efficient aircrafts.

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