Development and Testing of a Morphing Airfoil for Increased Wing Efficiency Under High-Deflection Flight Conditions

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Conventional trailing-edge control surfaces introduce local surface discontinuities and abrupt camber changes, causing premature flow separation and pressure drag. This project aimed to design and verify a continuous camber morphing wing capable of dynamic spanwise camber adjustment to approximate elliptical lift distribution and minimize pressure and induced drag. The wing incorporates a hybrid FDM-based design: NACA 2412-profile PLA internal ribs and leading edge shells, paired with PETG trailing edge profiles and flexible 3-mil PET film. Autonomous optimization was achieved with a closed-loop control system, which uses pressure sensors located at 1/3 chord on the upper and lower surfaces at three spanwise positions. Calculated pressure differences based on sensor readings reveal localized aerodynamic data, which then allows for independent actuation of the trailing edge at 5 locations. FEA verification ensured the trailing edge profiles and PET surface deform elastically under stress during morphing. Xfoil simulations verified the aerodynamic efficiency of the morphing profile, and CFD simulations tested the pressure-adaptive design against a baseline morphing wing with constant camber. Results show that the adaptive spanwise morphing system yielded an 8 percent increase in L/D at 100k Re by reducing wingtip vortex formation. This study demonstrated that localized sensor-driven morphing represents a viable efficiency-enhancing solution in a variety of applications, including UAVs and sustainable aircraft.

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