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E-VTOL Concept Design with a New Underwing 'FanFoil' Ducted Fan Concept to Improve Aerodynamic Efficiency

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Abstract
This paper proposes a novel transitioning eVTOL aircraft concept utilizing distributed underwing ducted fans with a specially designed undercambered airfoil presented as the 'Maldonado-Hicks' airfoil. It is hypothesized that this concept where the airfoil is blended into the fan on the aft portion of the airfoil, referred to as the 'FanFoil' concept, is aerodynamically superior to mounting the fans over the wing. This is due to the ability to recess and partially hide the fans underneath the wing, such that the fans are not entirely visible in forward flight when looking at the wing from the front. It is expected that this 'FanFoil' technique reduces the form drag of the wing with distributed fans. In this initial study, computational fluid dynamic (CFD) simulations are performed on the Maldonado-Hicks airfoil which represent a two-dimensional section of the eVTOL wing at the cruise conditions; Mach 0.22 (260 km/h) and Reynolds number of 6.5×10^6. The lift and drag coefficients are computed in order to get an understanding of the cruise angle of attack and design lift coefficient that maximizes aerodynamic efficiency as quantified by the lift-to-drag ratio, L/D. Open vehicle sketch pad (VSP) is also used to perform a low-fidelity CFD analysis for the clean eVTOL configuration. The base drag coefficient, C_{D_0} is estimated as ≈ 0.018. Finally, a rigorous analytical model mission analysis is completed for a hypothetical maximum-range mission for a 5-passenger eVTOL concept. Based on power and energy consumption calculations, it is estimated that this aircraft concept attains a maximum range of 290 km with a 300 kW-h lithium polymer battery.

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