Inlet Flow Separation Control via Novel Lip-Spoilers for Ducted Fan based VTOL Uninhabited Aerial Vehicles

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Ducted fan propulsion systems provide attractive solutions for manned and unmanned aerial vehicles, with potential applications in general aviation and military missions. They provide higher power-to-thrust ratios over their free-rotor counterpart. However, ducted fans currently implemented in VTOL type aerial vehicles have an inherent duct lip separation and inlet flow distortion problem in edgewise flight. This problem is severe when the flight direction of the VTOL vehicle and the rotor axis of rotation are normal to each other. Separation at the leading edge duct lip disallows flow from effectively entering the fan rotor causing unwanted inlet flow distortion problems. Discussed here will be optimized design solutions to controlling and/or eliminating this separation at the leading edge duct lip. Designed were three types of lip-spoilers: parametric, detached duct lip, and double duct. The parametric lip-spoilers consisted of inner-face and outer-face duct lip-spoilers. Inner-face duct lip-spoilers predominantly contributed to increased control over the negative nose-up pitching moment while the outer face and detached duct lip-spoilers predominantly controlled the increase in the mass flow rate through the fan rotor. The double-ducted fan (DDF) was successful in eliminating duct lip separation through its added second duct. The main purpose of this study is to design and test various duct lip-spoilers that improves the ducted fan aerodynamic performance in edgewise flight. Conceptual design, analysis and flow visualization for a number of novel lip-spoilers are discussed in detail.

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Table 1: Configurations with respective visuals

Partial lip for a DDF design

Fig. 7: Contours of velocity magnitude (m/s) of Configuration 1

Fig. 8: Zoomed view of leading edge. Configuration 1 of velocity-magnitude with streamlines.