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A COMPARISON OF MULTI-FIDELITY APPROACHES TO UNSTEADY COAXIAL ROTOR PERFORMANCE MODELING ON EXTRATERRESTRIAL UAVS

Abstract

Due to the complex flow fields induced by coaxial rotors, coaxial rotor performance modeling typically requires medium to high-fidelity modeling approaches to accurately model rotor loads. As such modeling approaches ranging from combined panel/free wake methods to blade resolved computational fluid dynamics (CFD) simulations trade off model accuracy with computational expense. In the development of unmanned aerial vehicles (UAV)s for extraterrestrial exploration such as NASA's Dragonfly lander accurate modeling of these coaxial rotor loads affects many areas of development such as battery sizing, flight dynamics, control system design and ultimately mission capabilities. In this research we present a multi-fidelity approach to predict unsteady coaxial rotor performance on the NASA Dragonfly lander for flight simulation and control. The novelty in this work is the use of multi-fidelity methods to model complex coaxial rotor loads including rotor-fuselage interactions suitable for fast model execution. The methods in this work can be decomposed into three main stages as follows. In the first stage low fidelity rotor performance data is obtained from simplistic models of the coaxial rotors attached to the lander. Two low-fidelity modeling datasets utilizing steady RANS and unsteady Euler CFD simulations will provide the basis for modeling the dominant rotor fuselage interactions for steady and quasi-steady vehicle dynamics. In the next stage, limited high-fidelity Detached Eddy Simulations (DES) of the coaxial rotors on the lander will be obtained. These simulations will include unsteady flight maneuvers to excite unsteady inflow and wake development on the rotors as well as unsteady rotor-fuselage interactions. In the third stage two approaches for merging the low and high-fidelity datasets will be evaluated. The first approach will determine an optimal basis for the combined low-fidelity datasets which will then be used in mapping the limited high-fidelity data to the desired output domain. The second approach will utilize a multiplicative/additive corrective model structure to map the low fidelity results to the high-fidelity results. This general structure will allow for the use of recurrent machine learning models for the determination of the multiplicative/additive functions in the corrective model structure. The results of this study will be a comparison of the mixed-fidelity modeling approaches to high fidelity validation data in the form of rotor loads. Additionally, estimation and comparison of power requirements for a simulated mission will be compared.