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Title

A VERSATILE DYNAMIC ROTOR AND PROPELLER MODEL FOR eVTOL SIMULATION APPLICATIONS

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Abstract

This study presents a versatile, dynamic rotor and propeller model for various all-electric and hybrid-electric vertical takeoff and landing aircraft (eVTOL) simulation applications. It inherits various features of mathematical rotor models in one generic model. It can be used as a propeller model, articulated rotor model, ducted fan model, coaxial rotor model, etc. The model is based on Blade Element Theory. Rotor inflow is estimated utilizing the uniform dynamic inflow model or Pitt-Peters dynamic inflow model. They are interchangeable based on the application's fidelity and complexity. It allows to position and orient multiple rotors and propellers in any desired configuration in simulation for the analysis. The goal is to reflect different eVTOL configurations, having the potential of carrying various types of thrust sources using one model. Since it is an all-parametric and computationally robust tool, it is to be used in performance calculations, stability analyses, sensitivity analyses, optimization, and trade studies (even isolated rotor simulations) during the conceptual design phase. The model outputs are compared using wind tunnel test data of isolated rotors found in literature and isolated rotor models in the Flightlab software. Simulation results of an example complex multirotor eVTOL are shown.

Introduction

Technological developments realize eVTOL with unconventional concepts. They are considered a promising solution to environmental issues caused by carbon emissions and efficiency issues in terms of time and money due to loaded traffic in densely populated cities. In addition, they are interpreted as a replacement for conventional VTOL aircraft. Therefore, rising investments in the Advanced Air Mobility industry accelerated the research and developments to overcome the challenges to integrate eVTOLs in public. Consequently, since 2010 when the first electric tiltrotor aircraft design, AgustaWestland Project Zero, was introduced, hundreds of eVTOL concepts have already been announced, and tens of companies have flown their prototype eVTOL aircraft to date. However, challenges to improving the designs still exist to meet the requirements of the market. Designing a safe, reliable, cost-efficient eVTOL is one of the critical challenges in the industry. Therefore, trade studies between all possible concepts are necessary for the best operation of the mission. Considering the necessity of these trade studies, the engineering models' requirement to predict the aircraft's performance arises to conduct them. Since, in the beginning, the primary determinant component that changes the concept is the rotor for eVTOL aircraft, a mathematical rotor model for each configuration is needed in the conceptual design phase.

This study proposes a versatile, dynamic rotor model to reduce the workload of creating different mathematical models reflecting different rotor configurations. It aims to combine the dynamics of varying rotor configurations with essential aerodynamic phenomena in one mathematical model having desirable fidelity. It is an all-parametric and computationally robust tool used for isolated rotor simulations, performance calculations, stability analyses, sensitivity analyses, and optimization.