Aeromechanical Analysis Tools for Design and Simulation of VTOL UAV Systems

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Abstract

A new generation of VTOL UAVs (VTUAVs) are under development for a range of surveillance, reconnaissance, and combat missions as well as for a variety of civil roles. To optimize and field such vehicles, design tools are required that can encompass the wide range of possible configurations envisioned for these aircraft (e.g., single or coaxial rotors, ducted fans, wings/lifting surfaces). Many VTUAVs are also constrained by performance limitations inherent in operating with high tip Mach numbers and low chord Reynolds numbers (R_e). This paper will identify and address some of the key issues involved in adapting established rotorcraft modeling tools to the VTUAV environment, focusing on recent efforts to extend a comprehensive, full-airframe vehicle model to meet these challenges. These extensions encompass a hierarchy of methods, including semi-empirical scaling techniques, augmented fast potential flow models, and the use of finite volume viscous flow solvers to address airfoil, rotor, and duct aerodynamics at low to moderate R_e. The paper includes a variety of validation results for open, coaxial, and ducted rotor systems and briefly outlines further projected efforts to address additional challenges in the analysis of this class of vehicle.

Introduction

The growing interest in the design of small rotary wing vehicles and supporting aeromechanical technology has been documented in a variety of recent efforts and publications. For example, expanding operational requirements are leading to the development of a new generation of Army VTUAVs to complement and in some cases replace manned rotorcraft (e.g., Knarr 2001, Chase 2002, Ordonez 2002) in surveillance, reconnaissance, and combat missions. Several candidate vehicles designed to meet these needs emerged from industry and government development programs, including the DARPA A160, various Organic Air Vehicle (OAV) demonstrators, as well as vehicles built in support of the Dragon Warrior and DARPA Micro Air Vehicle programs; additional concept development is underway as part of the Army/DARPA UCAR (Unmanned Combat Armed Rotorcraft) programs (Figure 1). The emergence of unmanned tactical rotary wing aircraft has also been paralleled by a growing interest in the design and demonstration of small rotary wing vehicles for civil applications (e.g., Aiken et al. 2000, Young et al. 2002).

Figure 1: Representative prototype and conceptual VTUAV concepts: the Sikorsky Cypher II and a notional Boeing UCAR (top) and MicroCraft and Honeywell OAV prototypes (bottom).

Design of these vehicles involves most of the challenges of analysis of full scale rotorcraft, both in determination of rotor performance and the study of complex full-airframe interactional aerodynamics issues. While recent experience with design of the hub/pylon region and empennage of the Army's latest rotorcraft (Duque and Meadowcroft 1999, Hassan et al. 1997) indicate that considerable progress has been made in analyzing such problems, the critical challenge of providing designers with a reliable, general, efficient tool for capturing crucial full-

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