Analytical and Experimental Micro Rotorcraft Design Studies

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Overview

While Micro Rotorcraft (MRCs) have tremendous potential for missions such as remote sensing, surveillance, and autonomous exploration, severe aerodynamic limitations inherent in operating at low Reynolds number have greatly constrained the ability to optimize vehicle performance. This paper demonstrates a formulation of analysis techniques that can support development of next generation MRC rotor systems, providing a suite of design tools to enable aerodynamic studies of small unmanned rotorcraft. The suite of tools being formulated builds on 2D airfoil analyses, a comprehensive rotor model, and hybrid CFD coupling techniques to provide an advanced analysis capability tailored to low Re applications. This paper outlines the assembly and application of the first, lower resolution tiers of this tool suite, as well as a series of parallel experimental and design studies that were undertaken to validate this level of modeling. Work on developing higher tiers of modeling involving more advanced methods is briefly outlined, and will be the subject of future papers.

Introduction

Though the traditional focus of rotorcraft design and development has naturally been on human-occupied vehicles, a wide range of converging trends in electronic miniaturization, advanced materials, and micro-fluid mechanics has generated a groundswell of interest in small, autonomous helicopters and tiltrotors or Micro Rotorcraft (MRCs), one component of the widening array of VTOL Uninhabited Air Vehicles (VTUAVs) studied in recent years. Adding to the long-standing interest of innovative hobbyists in the RC helicopter community has been a proliferation of potential military and civil MRC missions, including remote surveillance, imaging and intelligence gathering, retrieval and inspection functions, sensing in hazardous environments and autonomous exploration (Hundley 1992, McMichael and Francis 1997, Kroo and Kunz 2000, Aiken et al. 2000, Young et al. 2000).

Work on VTUAV concepts over the last decade has involved a wide variety of configurations, ranging from true micro vehicles to 300-lb. autonomous helicopters (e.g., Figure 1). A variety of roles are envisioned for these vehicles, with a new generation of military VTUAVs projected to complement and in some cases replace manned rotorcraft (e.g., Knarr 2001, Ordonez 2002) in surveillance, reconnaissance, and combat missions (Figure 2).

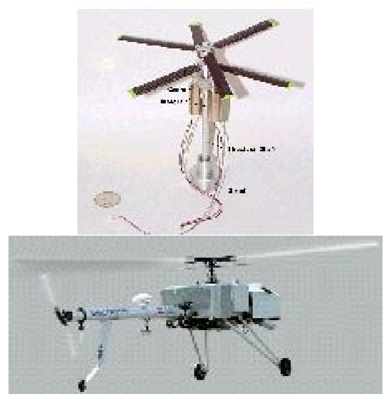

Figure 1: Prototype MRCs/VTUAVs: Univ. of Md. MICOR coaxial rotor system (Samuel 2000) (top); Schiebel Corporation Camcopter (bottom).

Enabling development of such vehicles is potentially important for many NASA missions, as well. For example, many of the same aerodynamic design issues faced by the new generation of small terrestrial rotorcraft are shared by spatially larger vehicles projected for roles in planetary exploration, e.g., the Martian Autonomous Rotorcraft for Science (MARS) concept recently discussed by Young, et al. 2000. Though the present paper is focused on terrestrial aviation applications of low Re designs, the design technology proposed here would be directly transferable to NASA

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