850. Design and numerical analysis of a novel coaxial rotorcraft UAV

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Abstract. This paper reports the design of a novel coaxial rotorcraft UAV with canard wing, main wing and tail rotor, which is capable of converting status between contra-rotating case model and fixed wing model. Computational fluid dynamics approach involving momentum source method is adopted to study its aerodynamic characteristics in various states. A validation case is introduced in this paper to verify the reliability and precision of this method. The result proves that the designed coaxial rotorcraft UAV is able to hover, take off and land vertically as well as change between the contra-rotating case model and the fixed wing model. Accordingly, it is able to accomplish various operating statuses and demonstrate good aerodynamic characteristics during the whole fight envelope.

Keywords: coaxial rotorcraft, UAV, momentum source, low Reynolds flow, aerodynamic.

Nomenclature

C_T	=	Thrust Coefficient
C_L	=	Lift coefficient
C_D	=	Drag coefficient
L_D	=	Lift-to-drag ratio

Introduction

Unmanned Aerial Vehicles (UAVs), in particular unmanned helicopters, are drawing more and more attention from researchers all over the world as a result of their capabilities of hovering and Vertical Taking-Off and Landing (VTOL), which meets military demands for effective information-gathering capability in combat situations [1]. Recent work by Yihua Cao has focused on the flight history and development of rotorcrafts [2].

One popular configuration of helicopters is coaxial rotor configuration, which comparing to a single rotor in the conventional design, produces the net thrust and then makes the rotorcraft compact and thus safer during military missions. The traditional rotorcrafts have to balance the angular momentum, usually by the tail rotor, which on the other hand adds the weight and also makes the size larger. Furthermore, a single rotorcraft is inherently directionally less stable and thus less safe to fly at low speeds. The tail rotor sometimes enters the vortex-ring state during sideward flight [3]. While in a coaxial-rotor configuration, the angular momentum is automatically conserved with the counter-rotating coaxial rotors. Useful lift and thrust in the coaxial system are then generated. A coaxial rotorcraft can also be designed with a smaller footprint without the need for separating rotors. However, besides above advantages, the two rotors and their wakes interact with each other, bringing a more complicated flow-field than is found in a single rotor system [4]. Very limited experimental and computational work has been performed on coaxial rotor aerodynamics. Seiko Micro Flying Robot [5] and the Micor [6] are examples of coaxial UAVs, which were developed at the University of Maryland. Also in [6], the performance of coaxial rotor at torque equilibrium was explored. Recent study by Liu performed at different rotor axial spacing to study their mutual interferences on the static performance [7]. For computational studies, there have been various approaches. Slipstream theory was at first introduced to solve the aerodynamics of coaxial rotors, and was further