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Dynamic Wind Tunnel Testing of Perching Maneuvers

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ABSTRACT

This paper presents the results of dynamic wind tunnel experimentation on a novel morphing aircraft design whose purpose is to perform a bio-inspired perching maneuver. This maneuver features in-flight vehicle reconfiguration that enables stable flight and maneuvering at the extreme angles of attack required for effective aerobraking. The distinctiveness of this wind tunnel model is that both the conventional control surfaces and morphing degrees of freedom can be controlled real-time during experimentation, so that time-varying aerodynamic data may be taken during shape reconfiguration. The experiments are used to analyze transient aerodynamic effects on the morphing degrees of freedom as well as on the traditional control surfaces, comparing them against pre-existing quasi-static data. Effects of the separated boundary layer on the lifting surfaces are studied in order to characterize the stochastic nature of the aerodynamic loads for controller development. Also discussed is the viability of dynamic stall as an additional source of lift at low speed. It is shown that, through morphing, the vehicle can maintain a higher degree of stability and controllability throughout a larger flight regime.

Keywords: morphing, aircraft, perching, aerodynamics

1. INTRODUCTION

Recently, morphing aircraft have been a popular topic in the smart structures and materials community. Current fixed wing aircraft are either designed for efficient flight at a very small subset of operational parameters, such as flight speed or altitude, or for acceptable performance at a wide range of operational parameters, as with military aircraft. The ability of morphing aircraft to change shape to fit has numerous benefits, including the ability to perform efficiently at a variety of flight regimes and the addition of new vehicle capabilities. The abilities of perching aircraft in particular allow extremely short landing distances, an attractive feature for urban scenarios, for example. This is accomplished through the use of flight at high angles of attack to greatly increase drag while using morphing capabilities to maintain full controllability. This differs from other forms of short landing, such as that used by the Harrier Jet or helicopters, in that the thrust-to-weight ratio is on the order of 1/10, allowing the aircraft to be used for long range or endurance applications.

This paper focuses on wind tunnel experiments whose purpose is to characterize the abilities of perching aircraft and how they compare to pre-existing analytic and computational models and to the abilities of fixed-wing aircraft. The specific design used is based off the ARES Mars scout aircraft [1], depicted in Fig. 1. This design has been modified to include three additional morphing degrees of freedom: variable wing incidence, variable tail boom angle, and variable tail incidence, as shown in Fig. 2. The principal reasoning behind these additional degrees of freedom is to create regions of attached and separated flow over the aircraft through various flight regimes. High-drag, separated