Longitudinal dynamics of a perching aircraft concept

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ABSTRACT

This paper introduces a morphing aircraft concept whose purpose is to demonstrate a new bio-inspired flight capability: perching. Perching is a maneuver that utilizes primarily aerodynamics – as opposed to thrust generation – to achieve a vertical or short landing. The flight vehicle that will accomplish this is described herein with particular emphasis on its addition levels of actuation beyond the traditional aircraft control surfaces. A computer model of the aircraft is developed in order to predict the changes in applied aerodynamic loads as it morphs and transitions through different flight regimes. The analysis of this model is outlined, including a lifting-line-based analytical technique and a trim and stability analysis. These analytical methods – compared to panel or computational fluid dynamics (CFD) methods – are considered desirable for the analysis of a large number of vehicle configurations and flight conditions. The longitudinal dynamics of this aircraft are studied, and several interesting results are presented. Of special interest are the changes in vehicle dynamics as the aircraft morphs from a cruise configuration to initiate the perching maneuver. Changes in trim conditions and stability are examined as functions of vehicle geometry. The time response to changes in vehicle configuration is also presented.

Keywords: morphing, aircraft, bio-inspired, perching, lifting-line, modeling, simulation

1. INTRODUCTION

One of the major goals of the development of morphing aircraft structures is to enable new missions and new capabilities for aircraft. The most obvious sources of inspiration for these new capabilities are Nature's fliers. The gross extents to which birds morph their bodies allow them to perform maneuvers irreproducible by current manmade aircraft. One such infeasible maneuver is perching. Perching can be described as a high angle-of-attack approach, with the purpose of using the air flow for braking, followed by a planted landing. While vertical landings have been accomplished by rotary and VSTOL aircraft, it is desired to perch using aerodynamics alone, with little input from thrust-generating devices. This will alleviate the need for the heavy, inefficient thrust generators required to land vertically, which are not compatible with long endurance aircraft systems. Thus, perching will be especially useful for small, efficient reconnaissance aircraft, for example.

This paper presents a concept for a perching aircraft and an analysis of its longitudinal dynamics. This concept is based on the Aerial Regional-Scale Environmental Survey (ARES) Mars scout craft[1], an aircraft designed to unfold from a Viking derivative aeroshell and fly for approximately 70 minutes over a Martian landscape, collecting scientific data. The idea to try to perch a similar airframe grew from the challenge to save the ARES scout from a high-speed crash landing at the end of its mission. Thus stems the desire to perch this aircraft with as few additional actuators as possible and without changing the overall design of the airframe. The original ARES craft features a blended-wing body with folding tail boom, tail surface, and wings, shown in Figure 1. In order to add perching capabilities, actuators are incorporated into the tail degrees of freedom, and variable incidence is added to the folding wing sections. These additional degrees of actuation in the perching flight vehicle, dubbed the ARES-C, are shown in Figure 2.

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