Passive Morphing of Solar Powered Flying Wing Aircraft

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1 Introduction

A morphing flying wing can maximize the energy absorption of solar panels on the wing surfaces by changing its configuration such that the panels have highest exposure to the sun. This change in the geometry of the flying wing is highly effective in energy absorption during times just before sunset and just after sunrise, and consequently the aircraft can endure longer flight. The energy efficiency and aerodynamic performance of High Altitude Long Endurance (HALE) flying wing usually accomplish each other; in addition, limitations on the weight of the aircraft and the sources of energy make the aeroelastic design very challenging. Use of solar energy is a novel method that eliminates one of the design constraints to a considerable extent by removing the limitation on the source of energy. The morphing flying wing concept could be either based on wing morphing systems or airfoil morphing systems, or a combination of both (Gamboa et al., 2009). So far in the literature, several morphing concepts and systems have been developed based on altering various geometric parameters of the wing (such as span, chord, camber, sweep, twist and even airfoil thickness distribution) to make the aircraft suitable for different missions and flight conditions (Gamboa et al., 2009; Gomez and Garcia, 2011). Former comparisons showed that NATASHA's results are in excellent agreement both for the onset of instability (Sotoudeh et al., 2010) and the behavior of the system eigenvalues below and above the flutter speed (Mardanpour et al., 2012). In this study a solar powered High Altitude, Long Endurance (HALE) flying wing aircraft is considered to morph into a "Z" configuration to allow for sustained uninterrupted flight. Energy absorption of this aircraft is maximized if the sun exposure of the solar panels distributed on the wings is maximized; see Fig. (1). For this purpose a three-wing HALE flying wing follows the sun and morphs passively (without actuators at the hinges and only making use of aerodynamic force and thrust) into a Z shaped configuration, while the bending moments about hinge lines at the beam connections are zero. To capture these phenomena, NATASHA has been augmented with new equations to analyze aeroelastic trim, stability and time marching of such aircraft. Local bending moments are zeroed out at the beam connection points while the hinges are locked and are kept at zero while the aircraft morphs. The morphing motion is brought to a stop before the hinges are again locked. The emphasis of this study is to demonstrate the systematic processes required for passive morphing of a flying wing with Z configuration.

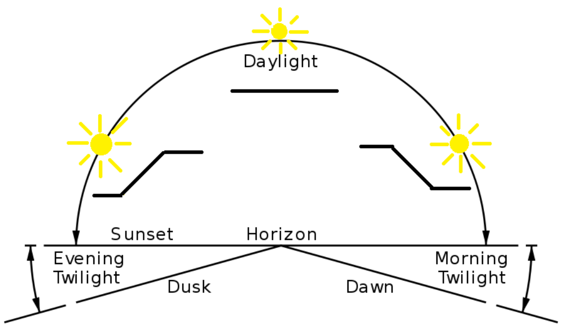

Fig. 1 Schematic view of the flying wing morphing and the sun position

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2 Theory Behind NATASHA and Morphing

NATASHA is based on a geometrically exact composite beam formulation of Hodges (2006) and finite-state induced flow aerodynamic model of Peters et al. (1995). The governing equations for structural model are geometrically exact, fully intrinsic and capable of analyzing the dynamical behavior of a general, nonuniform, twisted, curved, anisotropic beam undergoing large deformation. The partial differential equations' dependence on x_1 is approximated by spatial central differencing detailed in Patil and Hodges (2006).

In order to passively morph the flying wing (i.e. avoiding actuators) using aerodynamic forces and thrust, a new set of equations in addition to the former trim equations is required to trim the aircraft. It is noted that these forces should fold the wings in a quasi-static morphing process so as to avoid inducing vibrations. It is also required that the moment about the folding hinge stays zero at each prescribed fold angle. For this purpose, a hypothetical hinge vector (**h**) is introduced in the direction in which the hinges are designed to fold. The scalar product of the hinge vector and wing bending moment (**M**) at the hinge location needs to be maintained zero, so that there is no resistance while folding occurs.

NATASHA is capable of time marching the aeroelastic system of equations using the scheduled control of the aircraft that comes from the trim solution. When time marching the morphing process, four aircraft controls (a value for all engines and three flap settings) with prescribed location are scheduled to morph the aircraft over a suitable time period and time steps. The fold angles are the unknown variables in the state vector of the time marching, whereas in the trim solution they were prescribed.

3 Concluding Remarks

The analysis underlying NATASHA was extended to include the ability to simulate morphing of the aircraft using a new set of trim and kinematical differential equations. An example of the kind of morphing considered in this study requires the wings to fold so as to orient a solar panel to be hit more directly by the sun's rays at specific times of the day. Because of the "long endurance" feature of HALE aircraft, such morphing needs to be done with as near zero energy cost as possible, i.e., without relying on actuators at the hinges and use of aerodynamic forces and engine thrust. The three-wing solar powered HALE aircraft morphs passively into a Z shape configuration while local bending moments are zeroed out at the beam connection points while the hinges are locked and are held at zero while the aircraft morphs. The morphing motion is brought to a stop before the hinges are again locked. A systematic process for trim and time marching for passively morphing flying wing is presented. The present study does not account for stiffness and damping in the hinges. These aspects are recommended for future study.

Keywords: Passive Morphing, Solar Powered Flying Wing Aircraft, Energy Efficient Flying Wing, HALE aircraft, Nonlinear Aeroelasticity, NATASHA

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