

Design of a shape-memory alloy actuated macro-scale morphing aircraft mechanism

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ABSTRACT

As more alternative, lightweight actuators have become available, the conventional fixed-wing configuration seen on modern aircraft is under investigation for efficiency on a broad scale. If an aircraft could be designed with multiple functional equilibria of drastically varying aerodynamic parameters, one craft capable of 'morphing' its shape could be used to replace two or three designed with particular intentions. One proposed shape for large-scale (geometry change on the same order of magnitude as wingspan) morphing is the Hyper-Elliptical Cambered Span (HECS) wing, designed at NASA Langley to be implemented on an unmanned aerial vehicle (UAV). Proposed mechanisms to accomplish the spanwise curvature (in the y-z plane of the craft) that allow near-continuous bending of the wing are narrowed to a tendon-based DC motor actuated system, and a shape memory alloy-based (SMA) mechanism. At Cornell, simulations and wind tunnel experiments assess the validity of the HECS wing as a potential shape for a blended-wing body craft with the potential to effectively serve the needs of two conventional UAVs, and analyze the energetics of actuation associated with a morphing maneuver accomplished with both a DC motor and SMA wire.

Keywords: Morphing, shape change, HECS, adaptive structure, Weissinger, shape memory alloy, SMA

1. INTRODUCTION

Conventional aircraft to date have been predominantly confined to fixed wing designs due to material constraints. This restriction also restricts the flexibility of a craft's available flight parameters, leading to the creation of fleets of diverse aircraft, each optimized for certain objectives such as fast dash, loiter, or maneuverability. The morphing aircraft program attempts to break out of the confines of rigid wings with the intention of creating vehicles with multiple, functional equilibria, now that the technology is available to competently address the advantages of flexible wings.

The goal of this project is to develop one such airworthy structure. Working in conjunction with the Structural Dynamics facility at NASA Langley, as well as the Flow Physics and Control Branch, a task was assigned over the summer of 2003 to put into flight an airfoil known as the Hyper-Elliptical Cambered Span (HECS) wing, a biologically-inspired aft-swept wing shape with a continuously varying span-wise curvature. The wing, supported by theoretical work of Cone (1962)¹ and Burkett (1989)², has been analyzed by Dr. Barry Lazos of the Flow Physics and Control Branch to examine its flight-worthiness. The wing, with its aft-swept tips, would 'morph' from its planar state, where it was conjectured to have aerodynamic benefits over a standard elliptical wing, to the 'furled' state, where it was conjectured to have further lift-to-drag ratio increases over either of the other wings. The variation between these states, and potentially to a number of intermediate configurations, would allow for the tuning of the aerodynamic properties in flight to suit the needs of the mission – either long-loiter capabilities while furled, or enhanced maneuverability and decreased flight signatures while planar, due to the extra induced vorticity generated by the furled wing shape.

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