Adaptive structural systems and compliant skin technology of morphing aircraft structures

Justin Manzo[*a], Ephrahim Garcia[a], Adam Wickenheiser[a], Garnett C. Horner[b]
[a]Sibley School of Mechanical and Aerospace Engineering, Cornell University Laboratory for Intelligent Machine Systems, 226 Upson Hall, Ithaca, NY, USA 14853
[b]Structural Dynamics Branch, NASA Langley, Mail Stop 230, Hampton, VA, USA 23681

ABSTRACT

Morphing aircraft design – the design of aircraft capable of macroscale shape change for drastic in-flight performance variation – is an extremely broad and underdefined field. Two primary means of developing new concepts in morphing exist at Cornell University: design of broad test platforms with generalized motions that can provide future insight into targeted ideas, and specifically adapted aircraft and shape change mechanisms attempting to accomplish a particular task, or hybridize two existing aircraft platforms. Working with both schools of thought, Cornell research has developed a number of useful concepts that are currently under independent analysis and experimentation, including three devices capable of drastically modifying wing structure on a testbed aircraft. Additional concerns that have arisen include the desire to implement ornithological concepts such as perching and wingtip control, as well as the necessity for a compliant aerodynamic skin for producing flight-worthy structural mechanisms.

Keywords: Morphing, shape change, HECS, compliant skin, adaptive structure, oblique joint

1. INTRODUCTION

For over a century, airframes have been rigid structures. Not since the Wright brothers flew a flexible wing craft to investigate the role of wing shape on flight have aircraft structures looked beyond the rigid spars, ribs, batons, stringers, etc. that are used today. A rigid fixed frame utilizing smaller subframes to generate forces and moments to control the rotations of the aircraft has been the model for flight controls of virtually all aircraft.

The rigidity of an airframe not only confines its shape, but also its mission parameters. For the most part, aircraft are single mission vehicles that are designed with specific objectives in mind, such as high maneuverability, long loiter, or extreme speeds. Multiple mission vehicles tend to be compromises of the different missions, and generally yield adverse performance over all the missions. Inevitably, some aircraft have utilized "morphing" by moving subsections of rigid frames to create virtual aerodynamics shapes. Wing sweep, slats, and flaps are all examples of this.

The goal of the morphing initiative is to develop airworthy structures with multiple, functional equilibrium points. There are two ways to attack the broad subject of morphing aircraft, both of which are under investigation at the Cornell Laboratory for Intelligence Machine Systems (LIMS). The first is to investigate the potential of morphing concepts to fulfill multiple mission parameters with testbed aircraft capable of providing a broad amount of data on flight characteristics. Wings can alter their primary configurations – sweep, dihedral, and wing incidence – on a macroscopic scale in order to determine what aerodynamic tradeoffs are made within this additional three degree-of-freedom framework. This can then be used to choose from an experimentally and analytically determined set of results which missions can be synthesized into one aircraft. This school of thought is being employed in the design of the modified Stewart platform and oblique joint mechanisms in the LIMS lab.

The other design scheme is to choose multiple missions to synthesize, or to choose an additional mission objective with which to augment an existing type of craft, and determine the shape change that must be developed to attain this new hybrid. Long-loiter aircraft such as the Global Hawk or Predator intelligence, surveillance, and reconnaissance (ISR) craft, could be forged into a new platform that also has the capacity for high speeds and maneuverability. Work towards such a targeted goal is being done on the hyper-elliptic cambered span (HECS) wing aircraft, being developed jointly

* Jem54@cornell.edu; phone 1 607 255-5457; fax 1 607 255-1222

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