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Structural and aerodynamic analyses of a hybrid trailing edge control surface of a fully morphing wing

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Abstract

In this article, the design and analysis of a hybrid trailing edge control surface of an unmanned aerial vehicle are presented. The structural design was performed to increase and decrease the camber of the control surface to match selected airfoil profiles. The design was first analyzed with the help of finite element method to assess the morphing capability. The morphed control surface was then analyzed aerodynamically and comparisons with the original target profiles were made. According to the aerodynamic analyses, it was concluded that the control surface can successfully morph into target profiles with very minor changes in the target aerodynamic values while still ensuring the structural integrity and the safety of the control surface.

Keywords

morphing, shape change, control surface, finite element method, structural and aerodynamic analyses

Introduction

In the design of a camber variable wing, there are three methods, namely, the conventional hinged mechanism, the smart material–made actuators, and the compliant mechanism (Shili et al., 2008). Although easy integration, effect on a limited zone of the wing, and the simple actuation system are some of the main advantages of the conventional control surfaces, there are also several drawbacks that cannot be ignored. Airflow separation and drag increase can significantly decrease the aerodynamic efficiency due to the existing discontinuities produced by the conventional control surfaces (Barbarino et al., 2010). Unlike the conventional counterparts, the unconventional control surfaces with the smart material–made actuators and the compliant mechanisms can provide smooth shape changes along the wing surface, which decrease the adverse effects of the conventional ones.

A variable camber trailing edge control surface whose aim is to serve as a flap was proposed by Barbarino et al. (2010). In the concept, the reference geometry of the ribs of the control surface was based on a wing of a transport aircraft and formed from shape memory alloy (SMA) truss-like structure. In some of the members of the structure, variable geometry trusses (VGTs) which are defined as a structural truss system having a number of length-adjustable actuated members were used (Furuya et al., 1985). The high cost and the heavy weight problems due to conventional actuated truss members are eliminated with this approach.

One of the adaptive trailing edge control surface development programs with smart structures and materials is the Smart Wing Program, which was funded by Defense Advanced Research Program Agency (DARPA). The trailing edge control surface developed under this program composed of an elastomeric (silicone) outer skin, a flexible honeycomb, and a fiberglass laminate as a center leaf of the honeycomb part. While the honeycomb part increases the resistance to vertical loads, the silicone skin, which undergoes large deformations, provides a smooth shape change and reduces the actuation forces in this concept. Additionally, the chord-wise shape of the control surface is stabilized by the laminate part (Bartley-Cho et al., 2004). The eccentuator is another morphing device for the trailing edge

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