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Variable-span wing development for improved flight performance

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Abstract

This paper describes the development and testing of a variable-span wing (VSW) concept. An aerodynamic shape optimisation code, which uses a viscous two-dimensional panel method formulation coupled with a non-linear vortex lattice algorithm and a sequential quadratic programming optimisation routine, is used to solve a drag minimisation problem to determine the optimal values of wing span for various speeds of the vehicle's flight envelope while subject to geometric constraints. Structural design is performed using the finite element method for static analysis where the particular interface between wing parts is conveniently modelled. A full-scale prototype is built for ground testing the wing/actuator system. The wing is built in composite materials and an electro-mechanical actuation mechanism is developed using an aluminium rack and pinion system driven by two servomotors. Bench tests, performed to evaluate wing under load, showed that the system is capable of performing the required extension/retraction cycles and is suitable to be installed on a UAV airframe fully instrumented for evaluating the VSW concept prototype in flight. The data collected from the performed flights showed full functionality of the VSW and its aerodynamic improvements over a conventional fixed wing for the higher speed end of the flight envelope.

Keywords

Morphing aircraft, telescopic wing, variable-span wing, UAV, optimisation, composite structure, flight testing

Introduction

In recent years the development of morphing wing technologies has received a great deal of interest from the scientific community. These technologies potentially enable an increase in aircraft efficiency by changing the wing shape thus allowing the aircraft to fly near its optimal performance point at different flight conditions. Joshi et al. (2004) clearly demonstrated the advantages of these technologies where the flight envelope of a fixed geometry aircraft can be expanded so that new multi-role missions could be performed.

The design of adaptive mechanisms and structures, along with the development of smart materials that may allow bio-mimetic configurations of aircraft is highly desired in the near future. The new concepts and technologies developed up to now are a constant attempt to enhance the overall flight performance of aircraft, enabling new aircraft design approaches to be pursued and opening grounds for improved multi-mission flexibility.

These technologies can be divided into three different categories according to the type of geometric transformation implemented: out-of-plane transformations, aerofoil adjustments and planform changes. Out-of-plane transformations include twist, dihedral and spanwise bending. Regarding aerofoil adjustments, camber and thickness are the main geometric transformations. Finally, planform changes include variations of the wing's chord, sweep and span. The very first concept of a morphing wing was developed by Makhonine on the MAK-10 aircraft. This vehicle had a telescoping mechanism where the outer panels of the wing slid inside the wing's centre panels.

Several different concepts have been designed and tested in this field: from the pneumatic telescopic spars by Samuel and Pines (2007) and the inflatable wings by Cadogan et al. (2003) and Jacob et al. (2005), to the telescopic wing servo/pulley-actuated by Vale et al. (2011) and the zigzag (scissors-like) wing concept by Ajaj et al. (2013), among many others. Henry et al. (2005) also explored the effects on unmanned air vehicle (UAV) stability caused by asymmetric span variations.

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