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The Adaptive Aspect Ratio morphing wing: Design concept and low fidelity skin optimization

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ABSTRACT

This work introduces a new aircraft wing span morphing concept. Known as the Adaptive Aspect Ratio wing, this concept couples a compliant skin to a mechanism based internal structure to create a morphing wing capable of significant changes in span and aspect ratio. The technologies of the concept are first introduced and discussed. The compliant skin is established to be the dominant component in the design of this concept, requiring balancing of in-plane and out-of-plane stiffnesses. An initial skin design optimization exercise is performed using analytical models, providing insight into the interplay between the various parameters of the skin design.

1. Introduction

The Adaptive Aspect Ratio (AdAR) wing is a compliant skinned morphing wing concept under development at Swansea University. The word "adar" is Welsh for "bird", and connects this concept to its inspiration; the smoothly adaptive aspect ratio and span change achievable by bird wings. As with the case of avian flight, it is useful in manmade craft to be able to change the aspect ratio of a wing to find the optimal tradeoff between induced drag and wetted area drag. While the flight speeds and Reynolds numbers of birds and aircraft are significantly different, the driving forces are the same. Operation at high lift coefficients, for example during low speed flight or maneuvering, leads to significant lift-induced drag, which is best mitigated by increasing the aspect ratio of the wing. However, in direct contrast to this, operation at low lift coefficients, for example at higher flight speeds or lower operating weights, leads to significant profile drag on the wing, which is best mitigated by reducing the wetted area of the wing, through reduction in the span for example. Currently, aircraft wings are designed with a shape which provides a compromise between these competing considerations given the particular mission profile expected of that aircraft. Generally speaking this approach works well, particularly for aircraft such as long haul commercial airliners which spend most of their flight time in one particular operating condition. For these aircraft a compromise wing design weighted heavily towards the cruise portion of the flight will provide good overall performance. However, there are many aircraft which are expected to operate over a more widely varying set of conditions. One example is aircraft that are used for surveillance type missions where it is desirable to travel between locations at a maximum possible speed and then slow down once on station to a more efficient loiter speed to increase time on station. There are many other mission profiles which also require changes in operating condition, and indeed the use of morphing may allow for entirely new mission types not currently possible. However, the dash and loiter conditions of a surveillance aircraft provide a useful range of operating conditions for the current discussion.

2. Adar wing concept overview

The AdAR concept combines four key technologies to create a span morphing concept capable of a 100% increase in the span of its morphing section; a compliant skin made from elastomeric matrix composite (EMC), a telescopic rectangular box spar, sliding ribs, and a strap drive system. While other span morphing wings have been built and tested in the past [2,3,6,7], the AdAR wing has a unique combination of technologies and properties. First and foremost, the change in length required of the skin surface is achieved in this concept through material compliance. The elastomer matrix of the EMC composite is capable of achieving the high levels of strain required with a single continuous skin surface, removing the steps and discontinuities found with rigid sliding skin designs. A mechanism based solution consisting of a telescopic sliding spar is chosen for the primary load bearing

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