Aeroelastic behaviour of UAV wings due to morphing

Levent Ünlüsoy and Yavuz Yaman
Department of Aerospace Engineering, Middle East Technical University, Ankara, Turkey

Abstract

Purpose – The purpose of this paper is to analyse the effects of morphing on the aeroelastic behaviour of unmanned aerial vehicle (UAV) wings to make an emphasis on the required aeroelastic tailoring starting from the conceptual design of the morphing mechanisms.

Design/methodology/approach – In this study, flutter and divergence characteristics of a fully morphing wing design were discussed to show the dilapidating effect of morphing on the related parameters. The morphing wings were intended to achieve a high efficiency at different flight phases; thus, various morphing concepts were integrated into a UAV wing structure. Although it is considered beneficial to have the morphing capabilities to avoid the failure due to a possible wear out in flutter and divergence parameters; it is necessary to include the aeroelastic analyses at the early design phases. This study utilizes a combination of a reduced order structural model and Theodorsen unsteady aerodynamic model as primary analyses tools for flutter and divergence. The analyses were conducted by using an in-house developed pk-algorithm coupled with a commercial finite element analysis (FEA) tool. This approach yielded a fast solution capacity because of the state-space form used.

Findings – Analyses conducted showed that transition between take-off, climb, cruise and loiter phases yield a change in the flutter and divergence speeds as high as 138 and 305 per cent, respectively.

Practical implications – The research showed that an extensive aeroelastic investigation was required for morphing wing designs to achieve a failure safe design.

Originality/value – The research intends to highlight the possible deteriorating effects on structural design of morphing UAV wings by focusing on the aeroelastic characteristics. In addition to that, fundamental morphing concepts are compared in terms of the order of magnitude of their deteriorating effects.

Keywords Flutter prediction, Morphing wings, Pk-method, State-space solution, Thodorsen aerodynamics, Typical section model

Paper type Research paper

Introduction

Over the past decade, morphing technologies were evolved to a large extent by the introduction of new manufacturing techniques and highly flexible materials together with the application of advanced analyses tools. However, all the morphing concepts came along with their own structural problems, which had to be clarified and treated accordingly to avoid the possible catastrophe in flight. While searching for the solution of these structural problems, most of the researches simply disregard the importance of flutter and divergence phenomena. In the case of this study, a fully morphing wing structure was investigated in terms of its aeroelastic behaviour at different planform shapes for various phases of flight to draw attention to the necessity of aeroelastic tailoring in morphing wing designs.

The conceptual design of the fully morphing wing structure has the ability to change its planform area, span, chord length, airfoil shape and sweep angle at the same time. Having a morphing ability at this extend with the same amount of structural material originates major structural problems. The design of the fully morphing wings was performed according to escalate the power consumption efficiency. The selected phases of flight for the aircraft were take-off, climb, cruise and loitering. A basic description of the geometric properties of the fully morphing wing are given in Table I (Unlusoy, 2014).

The details of the morphing mechanism are beyond the scope of this study. Nonetheless, it would be appropriate to give a basic description of the conceptual design. The authors were inspired from three research work available in literature, and they have appended some newly developed concepts to those. The first one is the telescopic span and rib expansion concept at University of Beira Interior (Gamboa *et al.*, 2009). The second morphing concept was from a previous research project on development of an active camber changing trailing edge mechanism, in which the authors contributed at Middle East Technical University (Sahin *et al.*, 2010). The third concept was the sweep change morphing concept which has readily been applied on US military aircrafts such as F-14 and F-111. Implementation of these concepts separately were successfully accomplished; however; all together they should be used carefully. Within the scope of this study, instead of giving all the technical and geometrical details, the developed concepts are given schematically. The sweep change was implemented by a paddling spar concept shown in Figure 1. The chord extension was guided with an inchworm

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