Aerospace Science and Technology ••• (••••) •••–•••

Contents lists available at ScienceDirect

Aerospace Science and Technology

www.elsevier.com/locate/aescte

Morphing aircraft: The need for a new design philosophy

Rafic M. Ajaj [a,*], Christopher S. Beaverstock [b], Michael I. Friswell [b]

[a] University of Southampton, Southampton, SO17 1BJ, UK
[b] Swansea University, Singleton Park, Swansea, SA2 8PP, UK

ARTICLE INFO

Article history:
Received 17 January 2015
Received in revised form 20 November 2015
Accepted 21 November 2015
Available online xxxx

ABSTRACT

This paper proposes a novel framework for classification of morphing technology based on its functionality, operation, and the structural layout. In addition, it highlights the limitations of the conventional design approach to exploit the benefits of the technology using representative examples and results.

© 2015 Elsevier Masson SAS. All rights reserved.

UNCORRECTED PROOF

1. Introduction

Concepts that enable radical shape changes to augment the flight performance or control aircraft were developed prior to the inaugural powered and controlled flight in 1903 [1]. Weisshaar et al. [2] state that the contributions of these pre 1903, and early variable geometry concepts, had little impact on the aviation community and its continuing development. The disappearance of these mechanisms in the early 1900's coincides with the increased requirement for greater structural rigidity due to the loads experienced (because of the greater demand for speed), which precluded the use of the flexible materials available during this era. Technological advancements have allowed renewed interest in mechanisms that enable significant configuration modifications, leading to a number of projects that have developed a number of morphing systems for actuating significant geometry modifications [3]. Example aircraft that deploy systems for significant planform changes include the F-14 and Tornado. These systems are used to adapt to varying flight phase or flight condition, for improved performance (either mission efficiency, controllability or manoeuvrability) through deploying 'rigid' body mechanisms. Recently, with the development of advanced materials, and wider application, or integration, of these more compliant materials to aircraft systems [4,5], there has been a revived interest in developing flexible mechanisms and structures that are capable of enabling significant planform changes through large deformations. With the concurrent development of novel structural arrangements (such as the FishBAC [6–9], compliant spar [10], zig-zag wingbox [11], the GNAT spar [12], hybrid hinge-less trailing edge concept developed at METU [13] and variable-stiffness camber morphing airfoil [14]), actuation methods, and multi-scale modelling and analysis techniques, has made it feasible to reinvestigate deploying these systems to achieve significant modifications to the aircraft geometry, and an opportunity for the successful integration of these systems onto full-scale aircraft. Barbarino et al. [3] present a more complete overview/review of aerospace morphing concepts and technologies that have been developed.

Morphing technology generally encompasses technologies that enable significant geometry modifications, although there exist several overlapping definitions of morphing in relation to aircraft. According to Weisshaar [2], morphing is a technology, or set of technologies, that allows air-vehicles to alter their characteristics to achieve improved flight performance and control authority, or to complete tasks that are not possible without this technology. The NATO RTO Technical Team on Morphing Vehicles suggested that morphing is the real-time adaptation to enable multi-point optimised performance [15]. A more detailed definition was provided by the DARPA Morphing Aircraft Structures (MAS) program. According to Seigler [16], the MAS program defines the morphing aircraft as a multi-role platform that changes its state substantially to adapt to changing mission environments, provides superior system capability not possible without reconfiguration, and uses a design that integrates innovative combinations of advanced materials, actuators, flow controllers, and mechanisms to achieve the state change.

Much of the literature on morphing to date includes structural concepts, morphing actuators and mechanisms, and some morphing systems analysis. Underlying the systems analysis, morphing structural concepts, actuators and mechanisms have generally been analysed as retrofitted systems to an already existing aircraft system [17,18], comparing the effect of retrofitting a morphing system relative to the performance of an equivalent classic system that delivers the same functionality. These investigations are largely

* Corresponding author.
E-mail addresses: r.ajaj@southampton.ac.uk (R.M. Ajaj), c.s.beaverstock@swansea.ac.uk (C.S. Beaverstock), m.i.friswell@swansea.ac.uk (M.I. Friswell).

http://dx.doi.org/10.1016/j.ast.2015.11.039
1270-9638/© 2015 Elsevier Masson SAS. All rights reserved.