Advances in Aircraft and Spacecraft Science, *Vol. 1, No. 3 (2014) 331-351*
DOI: http://dx.doi.org/10.12989/aas.2014.1.3.331

Design of a morphing actuated aileron with chiral composite internal structure

Alessandro Airoldi*, Giuseppe Quaranta, Alvise Beltramin and Giuseppe Sala

Department of Aerospace Science and Technology, Politecnico di Milano,
Via La Masa 34, 20156, MILANO, ITALY

(Received December 17, 2013, Revised February 24, 2014, Accepted March 11, 2014)

Abstract. The paper presents the development of numerical models referred to a morphing actuated aileron. The structural solution adopted consists of an internal part made of a composite chiral honeycomb that bears a flexible skin with an adequate combination of flexural stiffness and in-plane compliance. The identification of such structural frame makes possible an investigation of different actuation concepts based on diffused and discrete actuators installed in the skin or in the skin-core connection. An efficient approach is presented for the development of aeroelastic condensed models of the aileron, which are used in sensitivity studies and optimization processes. The aerodynamic performances and the energy required to actuate the morphing surface are evaluated and the definition of a general energetic performance index makes also possible a comparison with a rigid aileron. The results show that the morphing system can exploit the fluid-structure interaction in order to reduce the actuation energy and to attain considerable variations in the lift coefficient of the airfoil.

Keywords: smart structures; chiral topologies; morphing structures; aeroelastic design

1. Introduction

The aerodynamic forces acting on an aircraft depend on the external shape of the aerodynamic surfaces. Therefore, shape variation is a typical characteristic of aeronautical structures and it is used for the generation of forces required to control the aircraft, and for the optimization of the aerodynamic performances during different mission segments.

In recent years, researchers have carried out considerable efforts to conceive and develop flexible structures capable of smooth and progressive external shape changing, which are typically referred to as morphing structures. Although different definitions of morphing structures exist, the distinctive aspects of morphing system is the possibility of continuous shape variations that can be seen as an alternative to the rigid motion of moveable surfaces, such as flaps or ailerons, driven by internal mechanisms.

Actually, flexible structures for guidance, control and adaptation to flight conditions were taken into account since the beginning of human flight, as it is proved by the solution devised in the Wright's flyer to attain control around the roll axis (see Anderson 1999). However, the increasing flight speeds and the consequent higher structural loads rapidly lead to discard such solutions in

*Corresponding author, Assistant Professor, E-mail: alessandro.airoldi@polimi.it

http://www.techno-press.org/?journal=aas&subpage=7 ISSN: 2287-528X (Print), 2287-5271 (Online)

Bornengo, D., Scarpa, F. and Remillat, C. (2005), "Evaluation of hexagonal chiral structure for morphing airfoil concept", *Proceedings of the Institution of Mechanical Engineers Part G, J. Aerospace Eng.*, **219**(3), 185-192.
Campanile, L.F. and Anders, S. (2005), "Aerodynamic and aeroelastic amplification in adaptive belt-rib airfoil", *Aerosp. Sci. Tech.*, **9**(1), 55-63.
Campanile, L.F. and Sachau, D. (2000), "The belt-rib concept: A structronic approach to variable camber", *J. Intel. Mat. Syst. Str.*, **11**(3), 215-224.
Gandhi, F. and Anusonti-Inthra, P. (2008), "Skin design studies for variable camber morphing airfoils", *Smart Mater. Str.*, **17**(1), 1-8.
Ichrome Ltd. (2011), *Nexus Documentation v. 1.1.07*.
Katz, J. and Plotkin, A. (1991), *Low-Speed Aerodynamics*, Cambridge University Press, Cambridge, UK.
Lakes, R.S. (1991), "Deformation mechanisms in negative Poisson's ratio materials: Structural aspects", *J. Mater. Sci.*, **26**(9), 2287-2292.
Leng, J., Lan, X., Liu, Y. and Du, S. (2001), "Shape-memory polymers and their composites: Stimulus methods and applications", *Prog. Mater. Sci.*, **56**(7), 1077-1135.
Martin, J., Heyder-Bruckner, J.J., Remillat, C., Scarpa, F., Potter, K. and Ruzzene, M. (2008), "The hexachiral prismatic wingbox concept", *Phys. Status Solidi. B.*, **245**(3), 570-577.
Sofla, A.Y.N., Elzey, D.M. and Wadley, H.N.G. (2008), "Two-way antagonistic shape actuation based on the one-way shape memory effect", *J. Intel. Mat. Syst. Str.*, **19**(9), 1017-1027.
Sofla, A.Y.N., Meguid, N.A., Tan, K.T. and Yeo, W.K. (2010), "Shape morphing of aircraft wing: Status and challenges", *Mater. Design*, **31**(3), 1284-1292.
Spadoni, A. and Ruzzene, M. (2007), "Numerical and experimental analysis of the static compliance of chiral truss-core airfoils", *J. Mech. Mater.*, **2**(5), 965-981.
Yokozeki, T., Takeda, S., Ogasawara, T. and Ishikawa, T. (2006), "Mechanical properties of corrugated composites for candidate materials of fexible wing structures", *Compos. Part A. Appl. S.*, **37**(10), 1578-1586.

EC