Accepted Manuscript

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Natsuki Tsushima, Weihua Su

PII: S1270-9638(16)30644-7
DOI: http://dx.doi.org/10.1016/j.ast.2017.02.013
Reference: AESCTE 3922

To appear in: *Aerospace Science and Technology*

Received date: 18 September 2016
Revised date: 22 December 2016
Accepted date: 16 February 2017

Please cite this article in press as: N. Tsushima, W. Su, Flutter suppression for highly flexible wings using passive and active piezoelectric effects, *Aerosp. Sci. Technol.* (2017), http://dx.doi.org/10.1016/j.ast.2017.02.013

Flutter suppression for highly flexible wings using passive and active piezoelectric effects

Natsuki Tsushima[a] and Weihua Su[a, *]

[a] *Department of Aerospace Engineering and Mechanics, University of Alabama Box 870280, Tuscaloosa, AL 35487-0280, USA*

Abstract

This paper addresses both active and passive flutter suppressions for highly flexible wings using piezoelectric transduction. An active aeroelastic formulation are used in the studies, featuring a geometrically nonlinear beam formulation coupled with 2-D unsteady aerodynamic equations. The piezoelectric effect is involved in the dynamic nonlinear beam equations, allowing for the aeroelastic studies on multifunctional wings for both piezoelectric energy harvesting and active actuation. In this study, the active piezoelectric actuation is applied as the primary approach for the flutter suppression, with the energy harvesting, as a secondary passive approach, concurrently working to provide an additional damping effect on the wing vibration. The multifunctional system may also convert wing vibration energy to electric energy as an additional function. Moreover, a Linear Quadratic Gaussian controller is developed for the active control of wing limit-cycle oscillations due to the flutter instability. In the numerical studies, both the active and passive flutter suppression approaches are enabled for a highly flexible wing. The impact of the piezoelectric actuator and energy harvester placement on the wing flutter characteristic is explored. This paper presents a comprehensive approach to effectively suppress the aeroelastic instability of highly flexible piezoelectric wings, while allowing to harvest the residual vibration energy. The active multifunctional wing technology that is explored in the paper has the potential to improve the aircraft performance from both aeroelastic stability and energy consumption aspects.

[*] Corresponding author. Tel.: +001-205-348-6728, Fax: +001-205-348-7240.

E-mail addresses: suw@eng.ua.edu (Weihua Su).