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A study on adaptive vibration control and energy conversion of highly flexible multifunctional wings

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

In this paper, a highly flexible multifunctional wing with embedded piezoelectric materials and thin-film battery cells for adaptive vibration control and energy harvesting is studied. It provides a description of the electro-aeroelastic equations of multifunctional wings with piezoelectric devices functioning as both actuators for active vibration control and energy harvesters. The energy harvesters also act as dampers for passive vibration control. An LQR controller is implemented for the feedback control of the piezoelectric actuators. The optimal selection of the pre-placed piezoelectric device configuration for efficient flutter suppression is explored by minimizing the state and control costs while maximizing the harvesting output. The priority of the multifunctional wing design is put on a capability of vibration alleviation than energy harvesting. In addition, an active control algorithm for gust alleviation adaptively switching piezoelectric device functions is developed. A multifunctional wing that takes advantage of both active actuation and energy harvesting is then numerically studied by exploring the state, control, and harvesting costs in different numerical simulations under gust disturbances and aeroelastic instabilities. Finally, an energy storage design using thin-film lithium-ion batteries is considered to accumulate the harvested energy from piezoelectric devices. The performance of the multifunctional wing with such energy storage device is also explored.

Keywords: Piezoelectric material, multifunctional wing, active control, energy harvesting, energy storage

* Corresponding author. Tel.: +001-205-348-6728, Fax: +001-205-348-7240.
E-mail addresses: suw@eng.ua.edu (Weihua Su).