Impacts of multi-segmented discontinuous functions on the dynamics of piezoaeroelastic energy harvesters

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Abstract. The effects of freeplay and multi-segmented nonlinearities in the pitch degree of freedom on the behavior of a two-degree of freedom piezoaeroelastic energy harvesting system is investigated. Comparisons between quasi-steady and unsteady aerodynamic representations are investigated and discussed including stall effects. The unsteady representation based on the Duhamel formulation is used to model the aerodynamic loads. The nonlinear piezoaeroelastic response is carried out in the presence of freeplay and multi-segmented nonlinearities before and after the onset of flutter. Such nonlinearities can be introduced to aeroelastic energy harvesters for performance enhancement through the possible existence of sudden jumps and chaotic responses due to the grazing bifurcation.

Introduction

Piezoelectric energy harvesters can be used to harvest energy over a wide range of frequencies and their ease of application for macro-scale vibratory-based systems having low oscillating frequencies. The applications range from remote sensor feeding and structural monitoring to vibration control, especially in aeroelastic systems [1]. In this work, a small-scale inspired wing-based system is considered in order to convert flow-induced vibrations to electrical energy through piezoelectric transduction mechanism. The aeroelastic energy harvesters under investigation are characterized on a two degree of freedom aeroelastic system with discontinuous nonlinear torsional spring in the pitch degree of freedom and as consequence, with discontinuity-induced bifurcations present and hence the possibility of having grazing bifurcations. A particular focus is paid on the effects of the type of discontinuity on the type of instability (supercritical or subcritical) and the onset speed of flutter as well as the levels of the harvested power. Figure 1 (a) shows the schematic of the freeplay mechanism of a linear 2-DOF typical section [2].

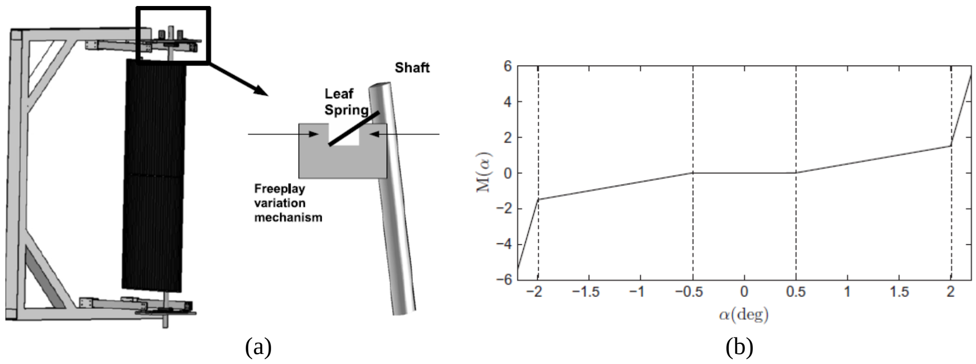

Figure 1: (a) Pitch freeplay mechanism [2] and (b) multi-segmented representation in the pitch DOF.

Results and Discussion

A comparison is first made between the quasi-steady approximation and unsteady formulations to predict the linear flutter speed based on a difference of aerodynamic loading. The linear flutter speed occurs at approximately 10.91 m/s for the unsteady formulation and 14.36 m/s for the quasi-steady approximation. The quasi-steady approximation does not account for the wake effects while the unsteady formulation represents the aerodynamic loads as a time-dependent function approximated using the Sears and Pade approximations [3]. After the comparison of these two approximations, an investigation of the freeplay and multi-segmented nonlinearities in the pitch DOF on the nonlinear responses of the system will be investigated. Moreover, the nonlinear interaction between the structural and aerodynamic nonlinearities will be studied, incorporating the piezoelectric coupling presented by Sousa et. al [4]. A nonlinear characterization on the present bifurcations will be performed by using modern methods of nonlinear dynamics.

References

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