Use of Nonlinear Energy Sinks in suppressing stall-induced aeroelastic instabilities

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Abstract. Dynamic stall behavior as input aerodynamics to an aeroelastic system can give rise to high amplitude self-sustained limit cycle oscillations (LCOs) in the response dynamics called stall flutter. The onset of stall flutter can induce considerable fatigue damage over time and can lead to structural failure. In order to attempt to suppress these high amplitude oscillations, this study proposes the addition of a nonlinear energy sink (NES) to a pitch-plunge airfoil. A bifurcation analysis is performed while varying flow speed, as well as the NES parameters such as nonlinear stiffness, mass ratio, and NES offset distance. To compare the effectiveness of the NES in in-field scenarios, both deterministic and stochastic wind loads are considered.

Introduction

Suppressing nonlinear aeroelastic instabilities is of vital importance to the safety and performance of structures - especially when it involves violent torsional oscillations as in the case of stall flutter. To that end, various methods of control have been proposed, one being the NES, which suppresses vibrations by the means of targeted energy transfer between the primary system and the attached secondary system (NES). While considerable attempts have been made to use NES towards suppressing *classical* aeroelastic instabilities [1, 2, 3], minimal attempts have been made towards stall-induced aeroelastic instabilities. One can attribute this to the inherent complexities involved in resolving the discontinuity-induced bifurcations that a stall flutter problem involves [4]. Investigating the possibility of suppressing stall-induced instabilities is therefore highly needed and the present study is devoted towards this end of concern. We do the same by adopting a numerical model akin to our earlier study [4] and attaching an NES. To augment the findings towards realistic scenarios, this study fosters both a deterministic and stochastic approach, wherein the on-coming axial flows can fall into the above two categories.

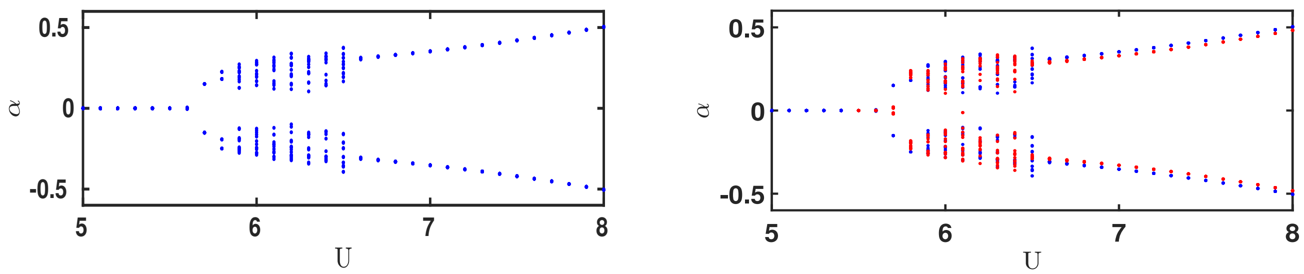

Figure 1: (left image) Base-line deterministic bifurcation without NES and (right image) NES added bifurcation plot.

Results and Discussion

The base-line deterministic bifurcation in the stall-induced aeroelastic system is presented in Fig. (1 (left image)) and is akin to that in our earlier work [4]. The system showed a fixed point response till $U = 5.6$, after which it transitioned to aperiodic oscillations via an LCO regime, and then to high amplitude stall flutter LCOs. Upon adding an NES, we even note a shift in the primary bifurcation point - possibly due to the added damping term. While there is a reduction in LCO amplitude, we observe that the amplitude reduction is rather minimal (refer Fig. 1 (right image)). To remedy this, studies are on-going to explore the role of the NES parameters, and location of NES, towards suppressing a deterministic stall flutter. Subsequently, we shift our focus towards the effectiveness of the considered NES in suppressing stall flutter under stochastic input wind. Specifically, the role of noise intensity and time scales of the input wind over the NES performance is presented.

References

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