Nonlinear flutter suppression of composite panels with nonlinear energy sinks

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Abstract. Composite laminated plates are widely used in supersonic vehicles due to its high stiffness combined with low weight. However, undesired aeroelastic phenomena, such as panel flutter, results in the risk of fatigue failure. Thus, this paper investigates a passive control technique to suppress such aeroelastic vibration. The goal is to establish a numerical study on the use of nonlinear energy sinks (NES) for suppressing flutter of composite laminated plates under supersonic flow regimes, assess the NES's effectiveness, and perform a parametric study of how different NES parameters affect the nonlinear dynamic response of angle-ply laminates.

Introduction

Aerospace structures subjected to supersonic flow can undergo aeroelastic instability, such as panel flutter. These vibrations imposed to aerospace skin make it susceptible to fatigue failure. Thus, several techniques have been proposed to passively or actively control this undesired phenomenon. Passive methods do not need additional energy and sensors to function, being more stable and simple to design. In this context, the NES has been receiving growing attention due to its simplicity and ability to extract energy from the system [1]. NES is an oscillator attached to a structure and may continuously capture and dissipate the energy input by external loads. Zhang Y. et al [2] analyzed a 4-layered cross-ply composite plate with a nonlinear energy sink. They concluded that this technique can effectively suppress the plate's excessive vibration in a short time. However, they investigated only pre-flutter conditions, missing the key aims of NES technique: suppressing flutter and reducing limit cycle oscillations (LCOs) amplitudes. Pacheco et al. [3] analyzed the pre- and post-flutter conditions of isotropic plates and provided an energy pumping quantification. He showed that even a non-optimized NES can suppress flutter for a range of dynamic pressures, and considerably reduce the maximum LCOs amplitudes at higher dynamic pressures of isotropic plates. In this context, the present work aims to establish a numerical study on the use of NES for suppressing flutter of composite laminated plates under supersonic flow regimes. The main goal is to assess the NES's effectiveness for angle-ply laminates, which is not available in the current literature. The panel is modeled as a geometrically nonlinear Mindlin plate and the NES as a small mass attached to the panel by a linear damper and a purely-cubic spring. The aerodynamic loads are obtained through the first-order piston theory. The iterative Newmark method solves the second order nonlinear equation system that results from the aeroelastic model discretized with the Finite Element Method.

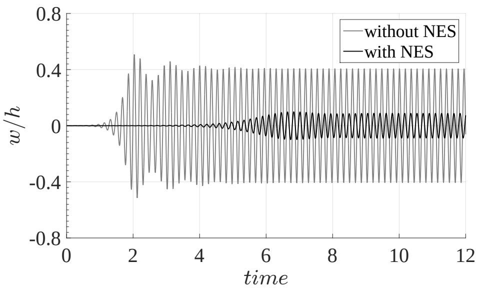

Figure 1: Time response at $\lambda = 390$ for $\theta = 10°$.

Results and discussion

The panel is modeled as a simply-supported plate with an attached NES at the $\frac{3}{4}$ position. The lamination scheme analyzed was 10-layered symmetric laminate $[+\theta, -\theta, +\theta, -\theta, +\theta]_s$. Three values of θ were analyzed: $10°$, $30°$, and $60°$ to investigate how the NES parameters may change to promote effective energy pumping. Pre-flutter and post-flutter regimes are surveyed, and a parametric study concerning the stiffness and damping constants is carried out to assess the system sensitivity to the NES effect. The parametric study found that the NES can either suppress flutter, reduce the amplitude of the LCOs as in Figure 1, and even cause chaotic motion. Thus, through performing variations in the NES parameters, huge differences in the panel nonlinear dynamics were found for certain values of the damping and stiffness constants.

References

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