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From resonant to unstable dynamics control via nonlinear energy sinks

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Abstract

Passive vibration control has been the theme of numerous scientific works along decades for reducing vibrational amplitudes or user's discomfort when aerospatial structures are concerned. Tuned Vibration Absorbers are a good alternative for this purpose by synchronizing its natural frequency to the specific target vibration frequency of the primary dynamical system. When one desires to reduce multiple frequencies, multimodal vibration absorbers are used. Nonetheless, their efficiency is sensitive to variations of the main system's frequency.

To face this sensitivity issue, essential nonlinear elastic forces have been considered for the tuned vibration absorber which are denominated as Nonlinear Energy Sink (NES). Indeed, these nonlinear attachments can lead to an irreversible energy transfer from the primary system toward the NES which are known as target energy transfer. An important feature of this kind of device is that there is no preferable frequency of oscillations because of their intrinsic nonlinear nature. Therefore, the NES is able to capture the energy from a large broadband resonant condition.

Most of the works so far have dealt with a nonlinear attachment represented by a cubic stiffness. The feasibility on how to obtain a purely cubic stiffness has been presented in [1]. Beyond this, others type of nonlinear functions has been evaluated analytically and some has been explored experimentally; among these, magnetic-strung mechanisms [2] and a vibro-impact NES with non-smooth nonlinear functions [3]. Figure 1 illustrates different NES developed and explored experimentally.

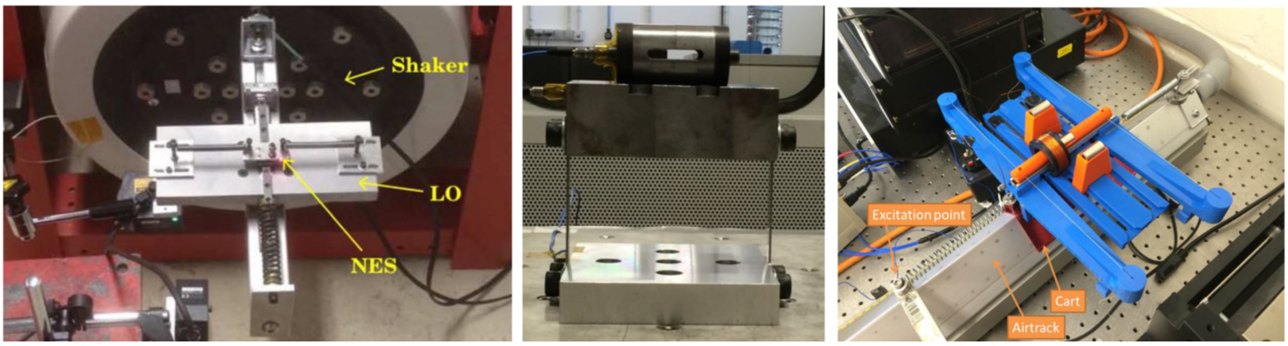

Fig.1 – Examples of cubic NES, Vibro-Impact NES and Magnet-strung NES designed for resonant conditions

Therefore, depending on the NES characteristics, the primary structure under a forcing excitation can respond with a steady-state amplitude or even reach a strong modulated response regime (SMR). These different regimes depend on the amplitude level of the response. Moreover, undesired nonlinear phenomena can appear such as jumps or isolated responses. The response regime is not robust to the excitation characteristics.

Even if the comprehension about the use of NES for vibration amplitude control at resonant conditions is well understood, important development for applying them for controlling instabilities are necessary. Different from a resonant condition, an instability is characterized by the veering of two natural frequencies that submits the structure to high amplitude and divergent oscillations. Since the structure is no more able to dissipate the input energy, high amplitude is reached which leads to its total destruction. Among others, the dynamical instabilities on aerospatial structures addressed are aeroelastic flutter, helicopter ground resonances or shimmy landing gear instabilities.

Concerning NES application for instabilities control, the previous design rules developed for resonant structures are not valid anymore. NESs have been studied when applied to passive control of these instabilities. In [4], a NES was used to control the limit cycles of a Van der Pol oscillator, to suppress aeroelastic instabilities [5] and divergent oscillations of the ground resonance of helicopters [6]. Figure 2 highlight some of the referred works.

The main objective of this paper is to highlight the differences on the design of NES for controlling resonant and unstable phenomena. Moreover, the main perspectives for a successfully achievement of NES design will be pointed out.

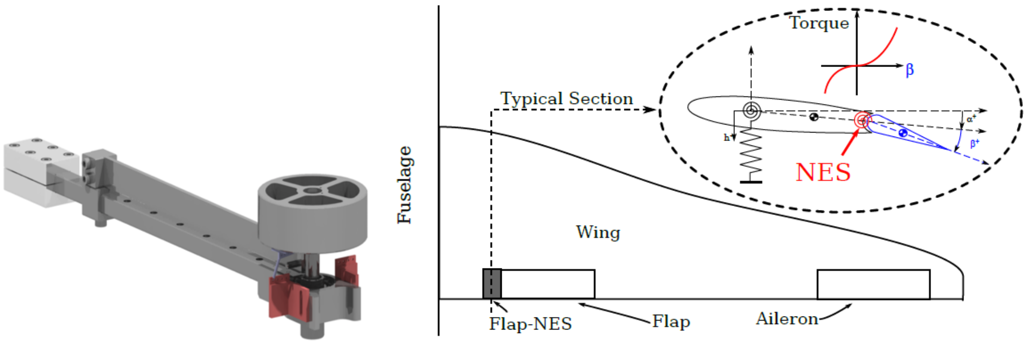

Fig.2 – Embedded NES on aeronautical structure for Instability control

References

[1] E. Gourc, G. Michon, S. Seguy, and Alain Berlioz. Experimental investigation and design optimization of targeted energy transfer under periodic forcing. Journal of Vibration and Acoustics, 136(2):021021, 2014.

[2] G. Pennisi, B.P. Mann, N. Naclerio, C. Stephan, G. Michon, Design and experimental study of a Nonlinear Energy Sink coupled to an electromagnetic energy harvester, Journal of Sound and Vibration, Volume 437, 2018, Pages 340-357.

[3] G. Pennisi, C. Stephan, E. Gourc, and G. Michon. Experimental investigation and analytical description of a vibro-impact nes coupled to a single-degree-of-freedom linear oscillator harmonically forced. Nonlinear Dynamics, pages 1–16, 2017.

[4] O. Gendelman, T. Bar, Bifurcations of self-excitation regimes in a van der pol oscillator with a nonlinear energy sink, Physica D, Volume 239(3), pages 220–229, 2010.

[5] Amar. Nonlinear passive control of an aeroelastic airfoil, simulations and experimentations. PhD Thesis. 2017, Toulouse University.

[6] J. F. Pafume Coelho, Contrôle Passif Nonlinéaire du Phénomène de Résonance Sol des Hélicoptères, PhD Thesis, 2017, Toulouse University.