An adaptive nonlinear hybrid vibration absorber

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Abstract. Linear hybrid dampers combining passive and active control are promising devices for vibration mitigation. In this work, we extend this concept to nonlinear vibration absorbers. A nonlinear hybrid vibration absorber is proposed, which combine sensor, actuator, control law and nonlinear dynamics to improve the adaptability and responsiveness of the absorber.

Introduction

Several ways have been explored to improve the classical linear tuned mass damper (TMD). The Nonlinear Energy Sink (NES) is a well known passive absorber device based on the use of an essential nonlinearity to get an irreversible energy transfert, also called Targeted Energy Transfert (TET) [1]. On the other hand, hybrid vibration absorbers [2] combine passive and active control and makes use of sensors, actuators. Besides the increase in performance, it also provides a 'fail-safe' feature since the passive absorber still operates if the active part is shut down. In this paper, the two approaches are combined to create a nonlinear hybrid absorber. The active control is used to make the absorber adaptive by modifying its damping and its nonlinearity when operating conditions are changing.

We consider an academic 2-dof system governed by the adimentionalized following equation :

$$\begin{cases} \ddot{x}_1 + \epsilon\lambda_1\dot{x}_1 + x_1 + \epsilon\lambda_2(\dot{x}_1 - \dot{x}_2) + \epsilon k_2(x_1 - x_2) + \epsilon k_{nl2}(x_1 - x_2)^3 = \epsilon F\sin(\omega t) + \epsilon F_a(x(t), \dot{x}(t)) \\ \ddot{x}_2 + \lambda_2(\dot{x}_2 - \dot{x}_1) + k_2(x_2 - x_1) + k_{nl2}(x_2 - x_1)^3 = -F_a(x(t), \dot{x}(t)) \end{cases} \tag{1}$$

where x_1, x_2 are the mass displacements, F the amplitude of the harmonic external force; $\lambda_1,\ \lambda_2,\ k_2,\ and\ k_{nl2}$ are damping's coefficients, linear and nonlinear coefficients respectively. $\epsilon \ll 1$ the mass ratio. Finally, the nonlinear feedback $F_a(x(t), \dot{x}(t))$ can take different forms : polynomial, non-polynomial. To better understand the energy flows involved in the slow dynamics, the analysis of the system is performed with respect to the Slow Invariant Manifold (SIM) [4].

Results and discussion

In Fig. 1, two numerical results for different active forces are compared : NES with modified singular points (a), NES with polynomial active part (b) and temporal response comparaison for a NES with polynomial active part (c). Active control is used to overcome the design flaws of a nonlinear vibration absorber. For example, the nonlinearity of the absorber can be tuned in order to modify the singular points and/or the unstable zone of the SIM, which in turn will change the activation threshold and the appearance of strongly modulated responses, or even create additionnal ones. The robustness of the methodology will be assessed by means of a parametric study [3]. Finally, an experimental validation will complement the proposed numerical model and serve as a proof of concept.

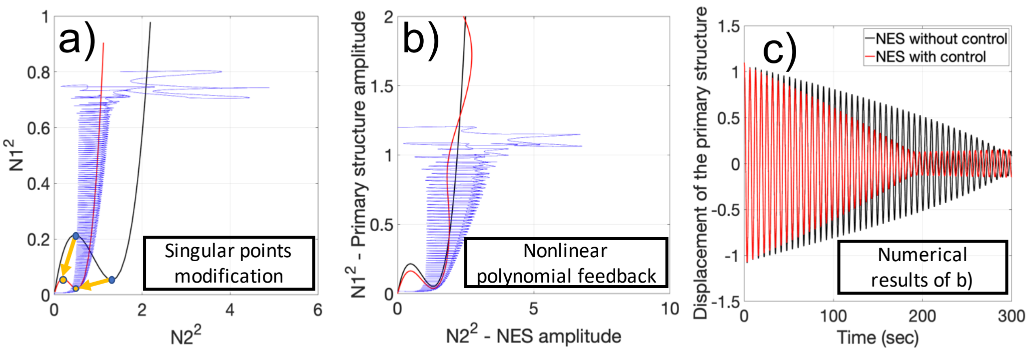

Figure 1: a) & b) SIM : black (no control), red (with control) and transient results in blue. c) Transient comparaison of b)

References

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