Inverted resonance capture cascade from low to high modal frequency

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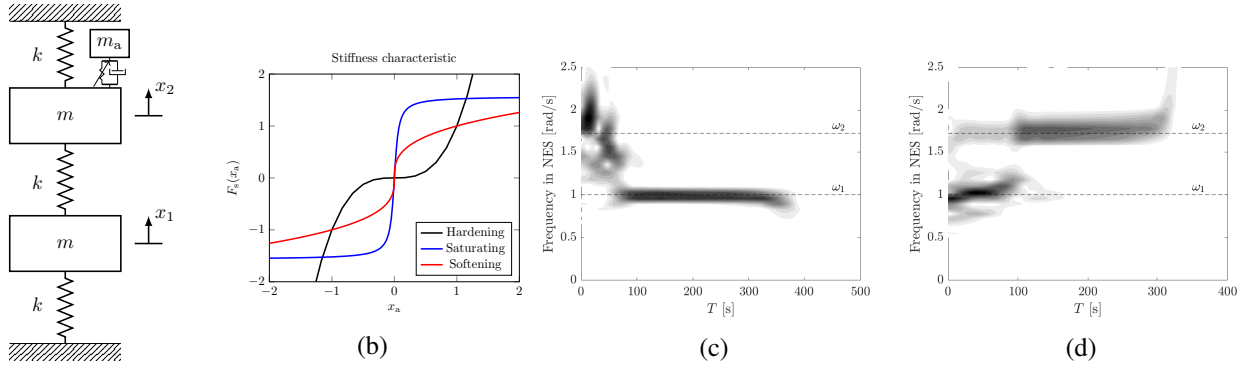
Abstract. In shock-loaded multi-degree-of-freedom (MDOF) mechanical host systems featuring a nonlinear energy sink (NES), resonance capture cascade (RCC) occurs. This is the sequential transfer and dissipation of modal vibrations from high to low modal frequency from the host system to the NES. The sequence of frequency transfer, from high to low frequency, is caused by the hardening polynomial restoring force that is typically considered in the nonlinear vibration absorber. In this abstract, it is shown that for softening restoring force, the opposite sequence occurs, i.e. from low to high frequency. By applying a multi-dimensional harmonic balancing for all modal vibrations concurrently, slow invariant manifolds are obtained where modal interactions determine the order of modal vibration transfer.

Introduction

Nonlinear vibration absorbers or nonlinear energy sinks (NESs) with a nonlinear restoring force have a variable natural frequency that depends on its amplitude. This property can be exploited to obtain a more broadband absorber under harmonic loading as opposed to linear tuned-mass-dampers (TMD), or to induce resonance capture cascade (RCC) under transient loading to dissipate several frequencies. An MDOF host system, e. g. the 2DOF system in Figure 1a, under shock-loading will vibrate according to its vibration modes. When an NES with a hardening stiffness is attached, the vibrations of the host system transfer and dissipate sequentially from high to low frequency. This phenomenon was first shown in [1], and other the studies existing in literature adopt the hardening stiffness [2, 3]. So far, RCC with other stiffness characteristics such as softening or saturating, see Figure 1b, have not been investigated.



(a) (b) (c) (d)

Figure 1: A 2DOF host system with NES on the top mass (a), several nonlinear stiffnesses (b), wavelet transform of NES with hardening stiffness (c) and softening stiffness (d). The RCC and inverted RCC is clearly visible from the wavelet transforms, where the NES sequentially dissipates the modal frequencies ω_1 and ω_2.

Results and discussion

The 2DOF host system in Figure 1a, with an attached NES, is considered. A classical hardening NES with restoring force x_a^3, and a softening one with a softening and saturating restoring force $\arctan(20x_a)$ are investigated.. In the two cases, wavelet transforms of the NES displacement in free vibrations exhibit opposite behaviors, Figure 1c and Figure 1d for the hardening and softening restoring force, respectively. For a hardening NES, the NES vibrates first with the highest modal frequency (ω_2), and than with the lowest one (ω_1). This corresponds to a typical RCC. The opposite happens for a softening NES, where a so-called inverted RCC takes place. Namely, the NES first interact with the first lower mode, and then higher one.

References

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