On the shock performance of a tri-stable vibration isolator

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Abstract. This work investigates the response of a tri-stable vibration isolation system under impulsive excitations. A tri-stable isolation system allows to obtain a high static stiffness and low-amplitude response for weak excitations and, at the same time, a very low dynamic stiffness for moderate and strong excitations. The tri-stable behavior is obtained adding, in parallel with an elastic spring, a mechanism that shows an initial gap and then a negative linear plus a positive cubic stiffness. The existence in the potential profile of two side wells is exploited in order to trap the vibrating mass in the wells and to suppress accelerations and displacements.

Introduction

The response of strongly nonlinear vibration isolation systems under impulsive excitations is not widely explored [1, 2]. In this work a tri-stable isolation system subject to three different types of pulse loads representing the near fault seismic excitation is studied. The restoring force of the isolation system is composed of two contributions. The first is the response of a classic Elastomeric Isolation System (EIS) while the second term the response of a Negative stiffness-Shape memory alloy (NS-SMA) damper [3]. The negative stiffness mechanism is represented by a negative linear (k_n) and a positive cubic (k_3) elastic stiffness contributions. For displacements below the gap, the stiffness of SMA wires balances the negative stiffness, thus the overall response coincides with the elastomeric one. For displacements greater than the gap displacement, corresponding to the SMA wires phase transformation, the negative stiffness strongly reduces the total stiffness and restoring force. If the negative stiffness is greater than the elastic stiffness of elastomeric isolators, the overall stiffness after the gap displacement becomes negative and two lateral equilibrium positions arise. The attraction of these equilibria is directly connected to the negative stiffness magnitude. The main objective of this work is to investigate the benefits and limits of this type of tri-stable configuration under pulse loads.

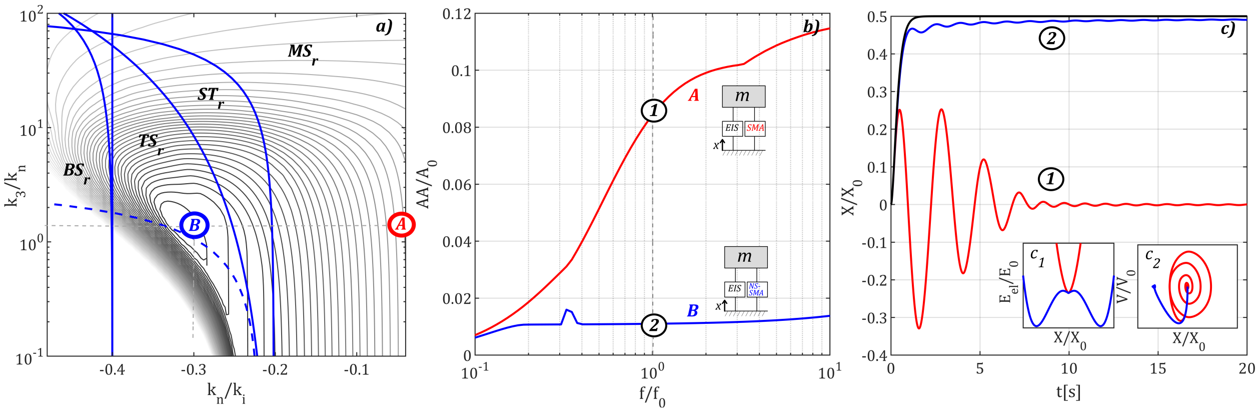

Figure 1: a) Performances map in terms of RMS of Absolute Accelerations Curves (AACs) on the parameter space. b) AACs for the mono-stable configuration A (red line) and the optimized tri-stable-configuration B (blu line). c) Displacements time history, c1) potential profiles and c2) phase plane orbits for the mono-stable configuration A (red line) and the optimized tri-stable-configuration B (blu line) under a pulse load with $x_{max}/x_0 = 0.5$ and $f/f_0 = 1$.

Results and discussion

Absolute displacements, absolute accelerations and relative displacements curves (ADCs,AACs,RDCs) for a SDOF mass are numerically obtained changing the overall nonlinear stiffness of the mechanism, both the linear negative and the cubic positive stiffness coefficients, ranging from a mono-stable to a tri-stable configuration. Performance maps are obtained in the parameter space of the negative stiffness mechanism (k_n, k_3) by recording the peak and the area subtended by each curve. In the same plane the bounding curves between the following regions were analytically obtained: monostable region (MSr), snap-through region (STr), tri-stable region (TSr) and bi-stable region (BSr). Comparing the performance and stability maps, it is shown how pairs of optimum design parameters always lay in the tri-stable region, thus proving the capability of the well-trapping phenomenon to strongly reduce the response of the isolated mass.

References

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