Quasi-zero stiffness vibration isolator under vertical seismic loads

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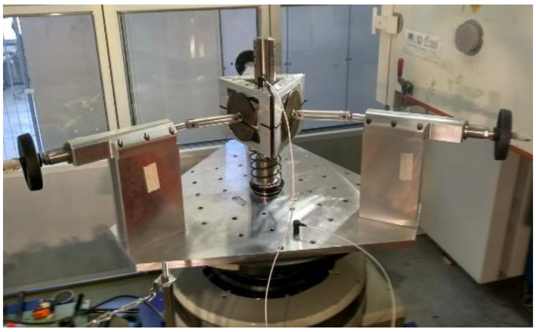
Abstract. An experimental study on the vibration of a payload isolated through a quasi-zero stiffness (QZS) isolator subject to vertical ground motion is presented. QZS isolators exploit kinematic nonlinearities to enhance the vibration attenuation of a linear mass-spring system. In this paper, stepped-sine tests have been performed to identify the system parameters and determine the isolator transmissibility. The parameter identification has been carried out by fitting a phenomenological model to the experimental data. The QZS isolator transmissibility exhibits a natural frequency reduction, and the system effectively suppresses the ground harmonic vibration about the fundamental frequency of the mass-spring isolator. A non-negligible presence of dry friction has been observed, leading to the stick-slip phenomenon, and affecting the suspension activation at low frequencies. Then, the suspension response under different realistic earthquake signals is presented and critically discussed.

Introduction and Results overview

Every year, more than one million seismic events and a large number of fatalities challenge the human population [1]. The development of new building technologies, and early warning and prevention systems can make the difference in countering the disastrous effects of an earthquake. In this framework, exploiting the inherent nonlinearities inside the system could represent a way to develop a new class of high-performance devices for preventing buildings from disastrous damages during seismic events.
The proposed mechanism consists of a tripod made by a translating mass m resting on a vertical spring of stiffness kv, three oscillating rods of length l connected to the mass and to three horizontal springs of stiffness kh, and a base plate [2]. The oscillating mass is constrained by three linear sliders to translate over a vertical guide, and loose tolerances have been considered to reduce the over constrain, see Figure 1(a).
Considering the Christchurch earthquake as the shaker base input, the experimental results shown that QZS mechanism improves the vibration suppression guaranteed by the respective linear mass-spring system and successfully isolates the payload from the ground motion, providing acceleration peak reduction of 85.95 % and 80.87 % in terms of RMS, see Figure 1(b).

(a)



(b)

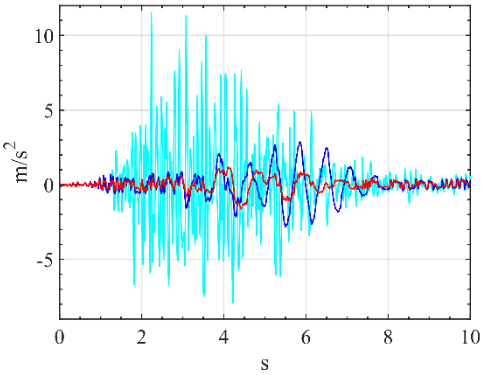


Figure 1: (a) Quasi-zero stiffness isolator and, (b) system response to Christchurch eartquakes. (— ground acceleration, — linear suspension, and — QZS isolator)

References

[1] Doocy, S., Daniels, A., Packer, C., Dick, A., and Kirsch, T. D., (2013), The Human Impact of Earthquakes: A Historical Review of Events 1980-2009 and Systematic Literature Review., PLoS Curr., **5**.

[2] Iarriccio, G., Molaie, M., Zippo, A., Pellicano, F. Experiments on a Quasi-zero Stiffness Suspension for Passive Vibration Control (2022) Mechanisms and Machine Science, 122 MMS, pp. 306-312. DOI: 10.1007/978-3-031-10776-4_36