Investigations on stoppers effects on energy harvesting absorbers when controlling structures under base excitation

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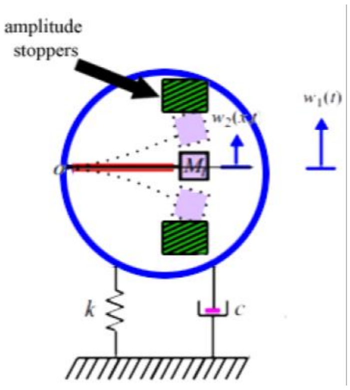
Abstract. A structure under high oscillations is very concerning to the structure's designers. One source of these high oscillations is base excitation. Since base excitation generates high oscillations at the resonance region of the structure, tuned-mass dampers are an ideal method of controlling these oscillations. In this study, a piezoelectric energy harvester is utilized as the tuned-mass-damper system. To further increase the operable range of the energy harvesting absorber, amplitude stoppers are introduced to the energy harvesting absorber. In this study, a reduced-order model of the system is derived for the coupled system. An overall performance analysis of structural control and energy harvested is conducted.

Introduction

One major concern of engineers during the design of structures is high oscillations due to environmental conditions. One common source is base excitation. Base excitation can cause the most damage when the forcing frequency matches the natural frequency of the structure. Since the high oscillations occur harmonically, tuned-mass dampers are excellent systems to eliminate these oscillations. The classical tuned-mass dampers convert the mechanical energy of the structure to unusable mechanical energy in the secondary system. In remote locations or hard or dangerous to reach locations, it is desirable to convert the mechanical energy into usable electrical energy to power small sensors. McNeil and Abdelkefi [1] have shown that a piezoelectric energy harvester with a tip mass can adequately perform both control and energy generation and has been selected as the tuned-mass damper for this system. To further increase the energy harvesting absorbers operable range of harvesting energy, the inclusion of amplitude stoppers are included to create a highly nonlinear mechanical interaction. Zhou et al. [2] discovered that the nonlinear effects of amplitude stoppers have shown to drastically increase the range of piezoelectric energy harvester, as seen in Figure 1b. Additionally, a range of stopper stiffnesses will be investigated to optimize the system, as well as to understand the induced nonlinear behaviour do to the contact-impact interaction between the absorber and the stoppers.



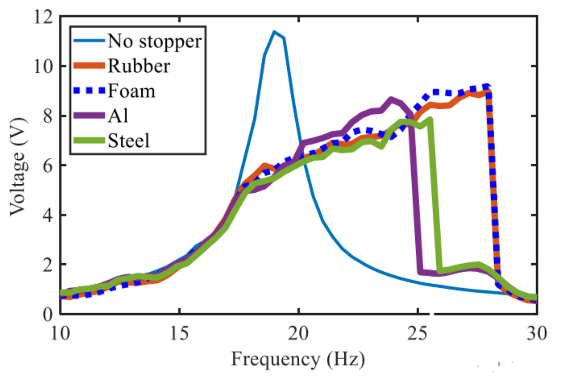


Figure 1: (a) Representation of the system with stoppers, and (b) energy harvester response with different stopper materials [2].

Results and discussion

Unlike in Zhou et al. [2] study where the stoppers were excited with the harvester, this investigation stoppers are coupled to the system's response. This coupling is a driving factor of the novel investigation to maintain adequate control of the primary structure while generating an ultra-wide band response of harvested power. A nonlinear reduced-order model is developed using a spring-mass-damper system for the primary structure, as seen in Figure 1(a), and the nonlinear equations of motion were solved by the Euler-Lagrange equations. The energy harvesting absorber is modelled using Euler-Bernoulli beam's theory and Galerkin discretization is employed to approximate the energy harvesting absorber's response. Due to the nonlinearities in the stoppers, a convergence analysis is carried out to determine the required modes in the Galerkin method. Some preliminary results show promising control of the primary system, as well as adequate power generation from the energy harvesting absorber.

References

[1] McNeil, I. and Abdelkefi, A., (2021) Nonlinear modeling and vibration mitigation of combined vortex-induced and base vibrations through energy harvesting absorbers. Communications in Nonlinear Science and Numerical Simulation, 95, p.105655.

[2] Zhou, K., Dai, H. L., Abdelkefi, A., Zhou, H. Y., & Ni, Q. (2019). Impacts of stopper type and material on the broadband characteristics and performance of energy harvesters. AIP Advances, 9(3), 035228.