Theoretical and Experimental Investigation of a Pendulum Absorber-Harvester System

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The use of mechanical vibrations as a source of electrical energy has attracted increasing attention in recent years. This growing interest is largely driven by the European Union's energy policies, which promote the development of innovative energy-harvesting technologies. While vibrations are typically undesirable in many dynamical systems and are therefore mitigated using various control strategies, integrating an energy harvester into a vibration absorber enables simultaneous vibration reduction and energy extraction. Achieving this dual objective remains a challenging task, as it requires a careful trade-off between effective vibration suppression and maximization of the harvested power.
We propose a pendulum-based vibration absorber system attached to the primary structure (Figure 1). The absorber incorporates an electromechanical energy harvester, consisting of a magnet oscillating inside a coil. The motion of the pendulum induces vibrations of the magnet, which in turn generate an electric current in the coil. This configuration forms an integrated absorber–harvester system (AHS), enabling simultaneous vibration mitigation and energy harvesting [1, 2].

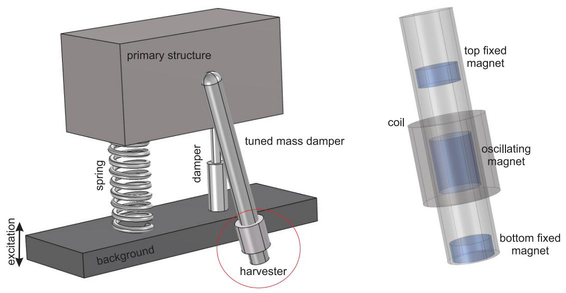

Figure 1. A multifunctional AHS system enabling simultaneous vibration suppression and energy harvesting.

Nonlinear vibration absorbers exhibit effective performance over an extended frequency bandwidth; however, precise tuning of their governing parameters is essential, as nonlinear dynamical systems may display multiple coexisting response regimes. This study investigates the potential of a vibration absorber as a means of energy harvesting. Numerical analysis is performed using a path-following continuation method, enabling systematic tracking of steady state solutions and nonlinear dynamic behavior. The analytical framework is based on the harmonic balance method, which provides closed-form approximations of periodic responses and offers deeper insight into the underlying system dynamics. Finally, the theoretical predictions are validated experimentally using a special designed laboratory test rig.

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