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A New Method for Vibration Energy Harvesting from Shock Absorbers

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Extended Abstract

Shock absorbers, also known as dampers, are used to smooth out shocks and to damp vibrations (Czop and Slawik, 2011). They have been widely used in automobiles, motorcycles, wheeled or tracked vehicles, aircrafts, as well as some industrial machines. Hydraulic shock absorbers are capable of yielding greater damping force mainly by means of fluid friction, and are reliable to work under harsh impulses. As such, the hydraulic absorbers have the largest market share.

Hydraulic shock absorbers work by converting kinetic energy into acoustic or thermal energy, which is then released into the fluid in the absorber and the surrounding environment. They, passive or active, are energy-wasting components. If captured, the energy consumed by shock absorbers has a great potential for engineering applications. Therefore, the objectives of this study are to: a) propose an integrated energy harvesting and shock absorption design method, b) devise a prototype based on the proposed design, and c) conduct electromechanical modeling and experimental characterization and analysis of the proposed prototype and model. Our current research scope is limited to hydraulic shock absorbers due to their wide applications.

Various methods have been reported in the literature to harvest energy from the shock absorbers. These methods can be classified as direct-driven (e.g., Chen and Liao, 2012) and indirect-driven (e.g., Li and Liang, 2012). In the direct-driven methods, linear generators have generally been used to harvest the energy of the vibratory excitation directly. The advantage of the direct-driven approach is the structural simplicity. However, the downside is the limited energy harvesting capacity due to the limited travel of the linear moving coil. This gives rise to the indirect-driven methods that can increase the travel of the vibratory excitations and hence capture more energy.

However, the frequent bidirectional oscillation of the generator can cause a large impact force. This further leads to deteriorated energy harvesting performance, moving parts fatigue, and even system failure. For this reason, this study proposes to use a hydraulic rectifier with four check values to integrate the shock absorption and energy harvesting functionalities. In this case, the bidirectional oscillation of the shock and vibration is converted into unidirectional rotation to drive the generator. A prototype shock absorber with energy harvesting capability has been fabricated based on the following conceptual design scheme.

We employ a hydraulic circuit rather than the mechanical transmission and smoother responses to irregular shocks can be achieved. The core of our design is a hydraulic cylinder, which is divided into two chambers by a piston. Two rods, across the two chambers, connect with two sides of the piston respectively. The reason of using the two-rod cylinder is to guarantee identical oil flow between the two chambers. One of the rods is attached directly to one terminal of the absorber, while another one is sheltered by a cap, to which another terminal is connected. The two ports of the cylinder are connected to the two ports of a hydraulic motor via a hydraulic rectifier. The output shaft of the hydraulic motor is connected to a 3-phase electromagnetic generator, whose output electricity is used to power a load through a 3-phase electrical rectifier. The proposed conceptual design makes it possible for the rectilinear vibration between the two terminals of the absorber to be used to drive the unidirectional rotation of the hydraulic motor in a smooth manner, and generate the electricity on the load at the same time. The shock energy is absorbed as a result of: (1) energy harvesting by the load, and (2) energy dissipation through the oil flow and the motion transmission. Apparently, shock absorption and energy harvesting can be achieved simultaneously using the proposed design.

The main advantages of this design include the conversion of bidirectional linear movements into smooth unidirectional rotation and hence the elimination of the frequent impact, the integration of the hydraulic shock absorption and energy harvesting functionalities, and the reliability and durability inherent in the hydraulic shock absorber.

Electromechanical modeling and analysis have also been carried out to examine the behavior of the prototype device. The prototype performance in terms of energy harvesting efficiency, mechanical force responses to the vibratory shocks has been examined. Three sets of experiments have been carried out for electrical parameter characterization, mechanical parameter characterization, energy-harvesting efficiency and shock absorption performance analysis respectively. The parameters of the electromechanical model have been identified based on experiments. The results have shown that the shock absorber is capable of harvesting the energy and absorbing the shock concurrently. Our experiments have shown that the energy harvesting efficiency can reach 30% or higher via harmonic excitation with the load resistance being tuned properly. The experimental results have also shown that both the vibratory excitation and the electrical load are directly related to the electromechanical responses of the proposed system.

As the hydraulic nature is preserved, the proposed method and the device are more suited for real applications. The device can be further improved by reducing backlash, mechanical and electrical loss factors of the structure to increase the energy harvesting efficiency, and by a more compact design to reduce the size and weight of the device.

References

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