DESIGN OF LEAF SPRING STRUCTURE TO IMPROVE POWER AND STRUCTURAL INTEGRITY OF A VIBRATION ENERGY HARVESTER

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ABSTRACT

A successful energy harvester design needs to meet power requirement as well as structural integrity (including durability and cost effectiveness). Even though plenty of researches have been reported on improving the power requirement, very little effort has been made to address the integrity issue since energy harvesting research up to now. To this end, this paper presents design optimization study to enhance integrity while satisfying power generation performance an electromagnetic vibration energy harvester. The harvester to be discussed in this paper is for a maintenance-free power supply for a wireless sensor module which monitors rail bogie axles and bearings. The energy harvester is designed to collect vibration energy on the axles during railroad operations. There are two leaf springs assembled on the both side of the harvester which facilitate the vibration along the direction of the shaft in the middle of device. Our research team realized a durability issue on the leaf spring when the harvester experiences high vibrating impulse loading during railroad operations. That is, the current leaf spring design is problematic because of high stress concentration and the corresponding fatigue failure before expected performance life of the device.

In this paper the optimization study has been conducted to redesign the shape of the leaf spring and reduce the stress concentration while satisfying the power requirement reflected by vibration amplitude (flexibility) within the frequency range of interest as well as manufacturability. For the accelerated design process, we firstly identified several initial models from literatures– circular plates composed of four equal angularly divisions. Each division has a same concentric zig zag track in a spring and their orientation and arrangement provides a reflective symmetry pattern. These models have been chosen to minimize any unnecessary parasitic motion off the harvester axis. The spring with three turns, among others, has been selected as an initial model because of acceptable stress magnitude and flexibility as well as easier manufacturability. In the shape optimization study, geometry of the spring was programed parametrically in ANSYS APDL considering physical and manufacturing limits. Based on the new design, four parameters were defined as design variables considering manufacturability. SQP algorithm was used to find optimum value of variables using a MATLAB code linked to the ANSYS software. Level of stress was calculated using PSD analysis and amplitude of vibration was evaluated with harmonic analysis. A separate electromagnetic analysis has been done to figure out the required vibrational amplitude. The results of this research showed that the new spring model could reduce the magnitude of stress concentration in the structure of the leaf spring while satisfying required vibration amplitude and natural frequency of the device for energy harvesting. As future work, amount of power generated by the device will be estimated and experimental verification will be performed.