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THEORETICAL AND EXPERIMENTAL ANALYSIS OF FREQUENCY UP-CONVERSION ENERGY HARVESTERS UNDER HUMAN-GENERATED VIBRATIONS

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ABSTRACT

Piezoelectric energy harvesters are devices capable of converting the kinetic energy present in vibration-based motion into electrical energy using piezoelectric transducers. This kind of device has its maximum efficiency when the exciting frequency matches its natural frequency. In the past years, some authors have explored the use of human motion as a vibration source, and harvesting energy in this situation is not trivial because the low-frequency characteristics of the motion are not compatible with small, light-weight transducers, which have relatively high natural frequencies. To overcome this problem, a method known as frequency up-conversion is used; it consists of a nonlinear vibration-based, magnetically excited harvester that exhibits frequency-independent performance, allowing the device to be efficient in a wide band of frequencies. In this work, the power output of a piezoelectric energy harvesting with frequency up-conversion submitted to walking and running vibrations is analyzed. Data are collected using an accelerometer located on the front pocket of each subject and then used in simulations. The model used consists of a cantilever beam with a permanent magnetic tip at the free end; this tip interacts with a magnetized structure that adds a nonlinear interaction to the model. A pure resistance matching the device's impedance at its fundamental frequency is used to account for the output power. To verify the advantages of using the frequency up-conversion method for vibration-based energy harvesters regarding the power output and frequency band, a comparison with the linear cantilever model is analyzed. Also, in order to confirm the simulation results, a prototype of the device is built and submitted to vibration tests using a horizontally oriented motor-driven cart that recreates the motions recorded by the accelerometer; it is tested with and without the magnetic force in order to experimentally determine the nonlinearity's effects on the power harvesting performance.

INTRODUCTION

In the last decade, many countries have devoted resources for the use of renewable and clean sources of energy. To meet this demand, harvesting energy from the environment has been extensively investigated by researchers since energy is available in many different forms, such as thermal gradients, wind flow, solar light, electromagnetic interactions, radio frequency and mechanical vibrations [1]. Due to its abundance in natural and artificial environments, mechanical vibration as a driving force for energy harvesters has received significant attention; ambient vibrations can be found in every kind of machine, vehicles, the ground and bio-motions, and can easily be converted into electrical energy by the use of piezoelectric transducers using the direct piezoelectric effect.

Vibration-based energy harvesters usually consists of a cantilevered beam, with one or two layers of piezoelectric material attached to this structure, with a tip mass; this works as a linear resonator and has its maximum efficiency when the exciting frequency matches its natural frequency [2], decreasing drastically when those frequencies are very different. Using these devices for converting the energy within bio-motion requires very low natural frequencies for the harvester since the dominant frequencies for ambient vibrations