Piezoelectric Actuators Mode of Vibration Influence on Energy Harvesting Applications

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Abstract

At this research, the authors have been focused on the mechanical and vibrational energy harvesting system with piezoelectric actuators. By studying the characteristics vibration modes of the piezoelectric harvester and the clamping setup configuration, a design optimization has been carried out in order to analyze its influence on energy scavenging.

Introduction

Nowadays, energy harvesting is a highly demanded technology to scavenge energy in a sustainable, and efficient way, able of feeding small electronic and IoT (Internet of Things) devices with optimizated power consumption. Esentially, energy harvesting is based on the scavenging of electrical power for instantaneous consumption or to store for subsequent use, by taking advantage of sorrouding enviromental energy sources [1, 2]. There are many possibilities of energy harvesting, however one of the sytems with the greatest power extraction capacity is the use of piezoelectric generators able of transforming mechanical and vibrational energy into electric current [2] to power electronic devices. There are various materials in the nature with piezoelectric characteristics, among them the best known are those of a ceramic nature such as the lead zirconate titanate (PZT) [3] due to their voltage and frequency operational ranges. Thanks to the piezoelectric effect, these smart materials can harvest electrical power when are subjected to mechanical deformation. In this framework, the research area in which the authors are focus, covers from the smart material understanding to the electronics management and storage strategies including the piezoelectric harvester simulation, the electronics management circuits or the storage unit, among others, for the full piezoelectric energy harvesting system understanding and optimization based on the concept of scavering maximization and low power consumption to achieve a full optimized piezoelectric energy harvesting system.

Motivation and goals

In the framework of the Industry 4.0 and the Smart Industry, there is a great demand to provide sustainable and efficient self-powering solutions for small IoT sensing and communication electronic devices [4, 5]. However, the design of electrical power systems based on energy harvesting, entails the need to develop highly efficient solutions in energy extraction [6, 7]. For this reason, the authors have focused on the study of mechanical vibrations, demonstrating that the optimization of energy extraction must start from the optimization of the mechanical deformation of the harvester [8].

Results

The piezoelectric harvester manufactured perform the tests is a specimen composed of two PZT sheets of PIC 255 material in a bimorph configuration with a brass interlayer. The electrical configuration selected is the series, due to their higher power scavenging potential. To analyze the influence on the vibration modes due to the clamping system in the amount of energy harvesting, two clampings setups have been designed to modify the centre of gravity in the system. The first one, C_1, has been designed to achieve a distribution of vibrations coming from excitation source centred on the *OZ* axis. The second one, C_2, has been designed to modified the center of gravity following the literature examples [9], where the centre of gravity is off-centre of the OZ axis of the vibration source, as shown at Fig.1.

A Smart Material excitation shaker has been used to generate the vibrational excitation of the bimorphe piezoelectric harvester. The frequencies range used was from 10 Hz to 50 Hz, and the RMS voltage output has been measured in open circuit configuration, where the results are shown at Fig. 2.

The results obtained show minimal differences at lower frequencies, from 10 Hz to 17 Hz, in the $V_{output, RMS}$ behaviour between both configurations, C_1 and C_2, as wel as, at high tested frequencies, from 32 Hz to 50 Hz. Nevertheless, the behavior changes drastically at the maximum resonatition frecuencies, between 17 Hz and 32 Hz, where the maximum energy is harvested. An increasing of the $V_{output, RMS}$ is observed in the C_1 configuration achiving an increased of the 25% than C_2, indicating the great influence of clamping system in the vibrational and load distribution and its vibration modes of the bimorphe piezoelectric harvester and, consequently, in the energy hartevested from the system.

Conclusions

In energy harvesting application designs, it is especially important to pay attention to the performance of the full system to take advantage of all the available energy and to maximize their efficiency on energy scavenging. This work demostated the great influence of the clampling system of the experimetnat setup to achieve the maximum energy collection from the surrounding enevironement in vibracional aplications. Allowing the system to increase up to the 25% of usable voltage when the clamping system is centred with the vibrational source in the OZ axis.

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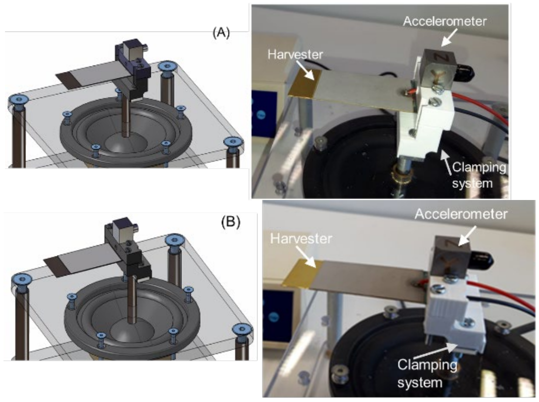

Fig. 1. Clamping system of tbimorph piezoelectric harvester: (A) C_1, distribution of vibrations coming from excitation suorce centred on the OZ axis (scheme and real setup) and (B) C_2, centre of gravity off-centre of the OZ axis of the vibration source.

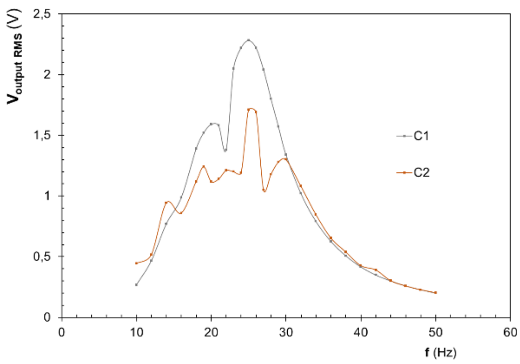

Fig. 1. $V_{output, RMS}$ vs frequency for C_1 and C_2 configurations.