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Editorial

An Overview of the Topics of the Special Issue "The New Techniques for Piezoelectric Energy Harvesting: Design, Optimization, Applications, and Analysis"

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1. Introduction

Comprising a total of seven articles divided into five research articles, one review article, and one editorial article, this Special Issue is dedicated to new techniques for piezoelectric energy harvesting and its design, optimization, applications, and analysis. In their editorial article, Altabey and Kouritem [1] introduce an overview on piezoelectric energy harvesting including its design, optimization, applications, and analysis. Their article discusses the applications of piezoelectric energy harvesting in self-powered sensors for the development and sustainability of structural health monitoring (SHM) through providing energy for devices, such as sensor networks, which improves the sustainability of these devices and widens the opportunities for the use of the IoT and the possible wireless operation of sensors in sensor networks. Moreover, they discussed the opportunity for the enhancement of the modeling and simulation of piezoelectric energy harvesting through utilizing artificial intelligence (AI) techniques in its design, optimization, applications, and analysis. In addition, they present a typical integrating structural control and health monitoring system including energy harvesting.

In their review article, Naqvi et al. [2] discuss the utilization of piezoelectric materials in different techniques to harness energy from fluid flows. Moreover, they investigated different vibration-based energy harvesting mechanisms for the enhancement of piezoelectric energy harvesters' efficiency and identified opportunities and challenges. Furthermore, due to the significant number of uses of resources such as wind and water in energy harvesting and such uses being widely implemented, they introduced an overview on advances in harnessing electrical energy via piezoelectric materials, and they showed that all of the studies were carried out using fluid flow and electrochemistry. They concluded that self-powering devices can resolve the problem of sensors' sustainability and that piezoelectric materials are gaining interest day by day because of the assistance these materials provide in energy generation.

The study of Kouritem et al. [3] investigated a novel design to solve the drawbacks of traditional energy harvesting whereby the maximum electric power is generated at the fundamental resonance frequency from the piezoelectric direct effect, and the new energy harvesting device uses the automatic resonance tuning (ART) technique to improve the mechanism of energy harvesting in power generation. The authors presented the geometrical components of a new harvester of a cantilever beam and sliding mass with varying locations, as shown in Figure 1, and the energy harvester's natural frequency can be automatically adjusted via the ART mechanism.

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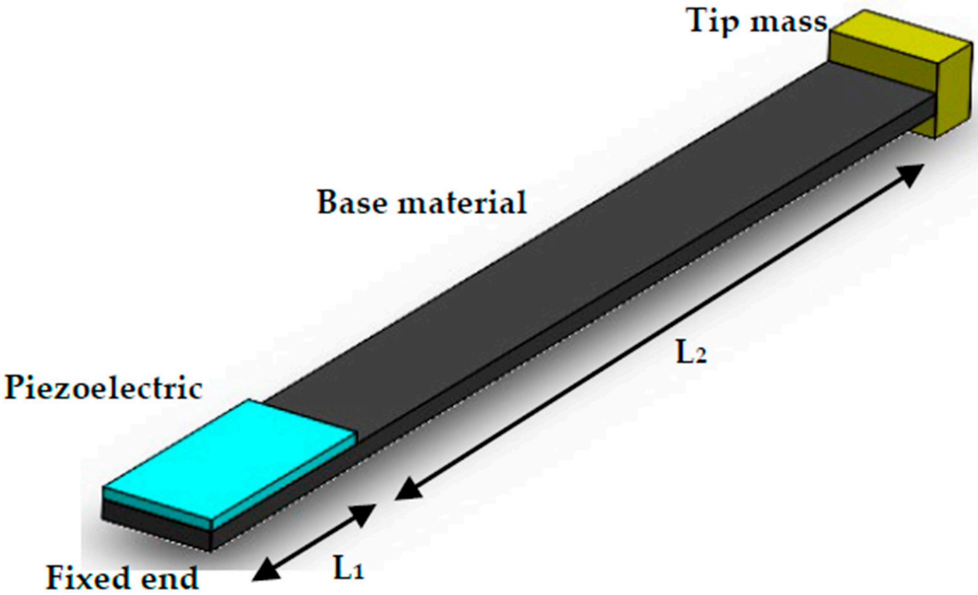

Figure 1. The diagram of the piezoelectric harvester with the tip mass, L_1 represents the composite segment of the beam with the active layer of PZT and the beam substructure, L_2 represents a single layer of the substructure of the beam [3].

As shown in Figure 1, the authors explained how the new harvester works by moving the mobile (sliding) mass on the harvester cantilever beam to modify the natural frequency of the ART energy harvester. They presented an analytical model of the new harvester model and compared it with the investigated FEM COMSOL model and available experimental results in the literature. They found the results to be highly identical. They concluded that the proposed broadband design provides a high-power density of 0.05 mW mm^{-3}, which provides new piezoelectric dimensions and load resistance to maximize the output voltage and output power.

Haniszewski and Cieśla [4] applied a harvesting device of motion energy (M-EHS) from a crane-hoisting mechanism for use in self-power measurement devices. The authors focused on M-EHS experiments and their features in the context of energy-harvesting efficiency in the crane case. They compared the efficiency of the selected construction energy and harvester parameters for specific hoisting speeds and the length of the motion conversion system arm. They plotted the results of piezoelectric elements on an RMS diagram for output voltage and found the impact of individual solutions of the proposed motion energy-harvesting device on the efficiency of energy harvesting. They concluded that the proposed design for energy harvesting can make adjustments according to the given conditions by tuning up the M-EHS to the working conditions of the excitation frequency.

The research of Alvis et al. [5] investigated magnetic restraints effects using the Euler–Lagrange principle on a piezoelectric energy harvesting absorber and, at the same time, controlled the harnessing of energy and a primary structure, as shown in Figure 2. An accurate forcing representation of the magnetic force was researched and developed. They found that the proposed configurations of the magnet cannot improve the system significantly before pull-in occurs.

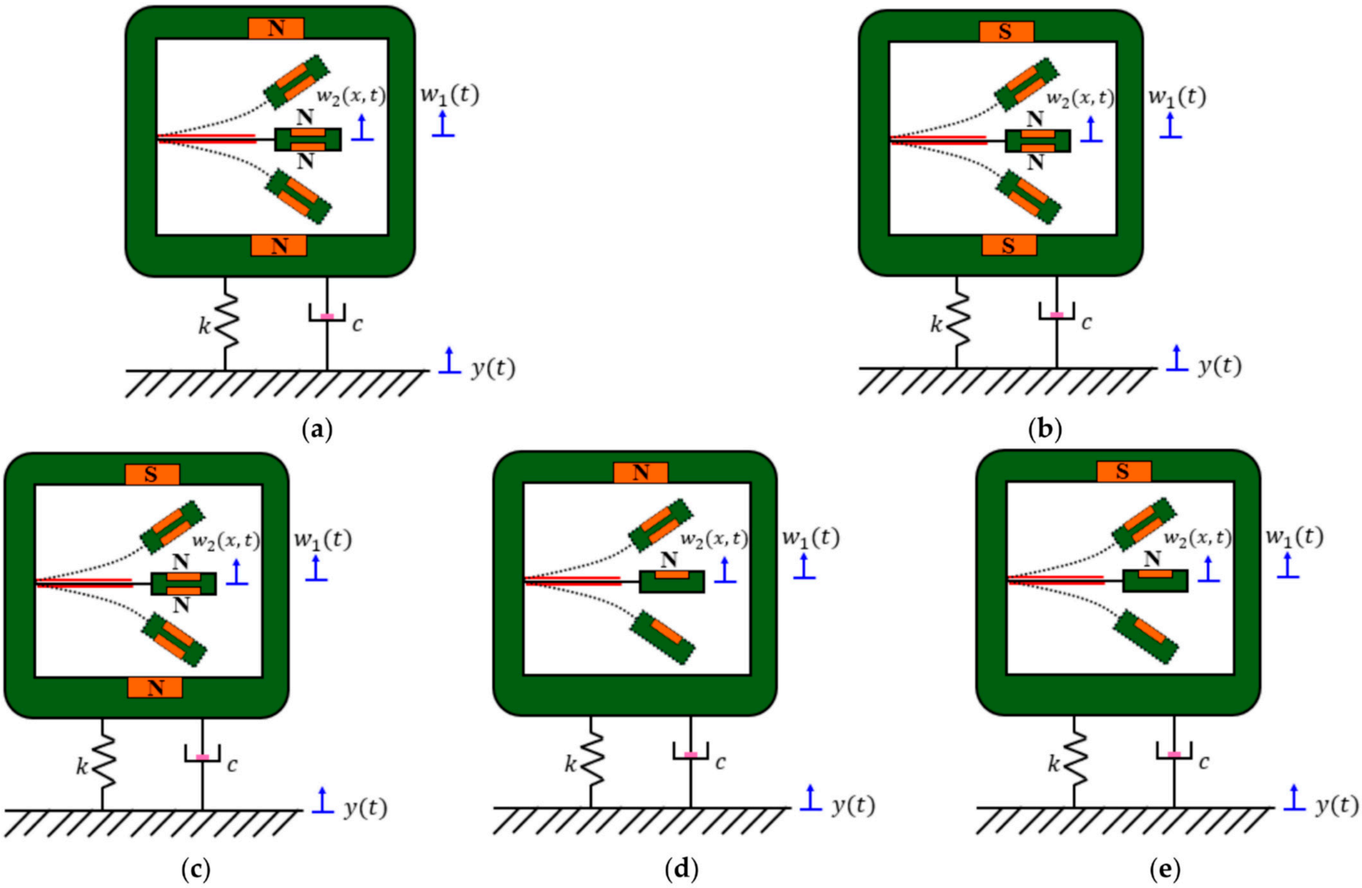

Figure 2. A representation of the coupled system under investigation with two magnet constraints with (**a**) repulsive and (**b**) attractive configurations that generate neutral static positions. The configurations that generate a change in static position are (**c**) two magnet constraints with opposite polarities and single magnet constraints of (**d**) repulsive and (**e**) attractive configurations [5].

The article of Jeong et al. [6] provides a systematic assessment of the mechanical, structural, electrical, and microstructural characteristics and properties of spin-coated poly(vinylidene fluo-ride-trifluoroethylene) P(VDF-TrFE) layers and films attained at different distances and at various rotational speeds. The authors found that the dielectric constant, remnant polarization, and crystallinity of the films increased with the increasing distance, which enhanced the piezoelectric power at the largest distance. However, they observed the same behavior when increasing the rotational speed initially, and then, it decreased when continuously increasing the Young's modulus.

The final article included in this Special Issue by Serrano et al. [7] provides a dependable reduced-order model of a multipurpose gyroscope. The authors used a semi-analytical method for harvested voltage and an electrical power model. They proposed a harvesting gyroscope model for practical optimization of the performance of its energy harvesting capacities by considering a spatially varying electric field across the electrode surface length in order to allow for examination of energy harvesting under various resistance loads, as shown in the schematic of the gyroscope sensor with energy harvesting capabilities in Figure 3. They found that the new configuration of a spatially varying model provides a model that is more versatile when modeling the piezoelectric multifunctional energy harvester's performance. It was accurate for electrical load resistances from 10^3 Ω to 10^8 Ω. At an optimal load resistance of nearly 65 KHz, the maximum output power was 1.3 mV, 1.5 mV for the open-circuit model, and 2.1 mV for the closed-circuit model. At a high-load resistance, the open-circuit model's maximum output power was 1.9 mV, and the closed-circuit model's maximum output power was 3 mV.

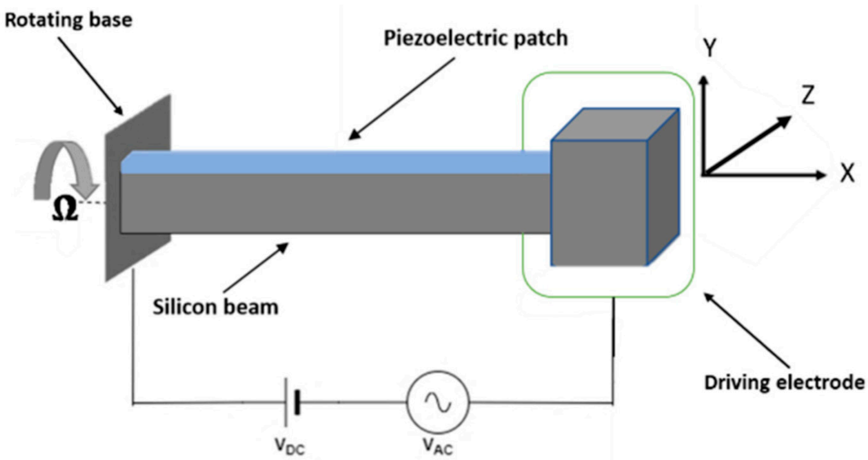

Figure 3. Schematic of the gyroscope sensor with energy harvesting capabilities [7].

2. Conclusions

The papers included in this Special Issue demonstrate the advances made in research on new techniques for piezoelectric energy harvesting and its design, optimization, applications, and analysis using experimental and numerical methods. As guest editors, we trust that the submitted research works included in this Special Issue will cover a wide range of scientific applications and methodologies and will contribute to advancing our understanding of piezoelectric energy harvesting's optimization, design, applications, and analysis and will aid the future design and optimization of advanced piezoelectric energy harvesting.

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