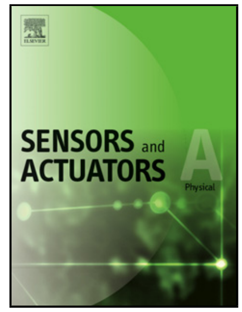

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Authors: Jiantao Zhang, Zhou Fang, Chang Shu, Jia Zhang, Quan Zhang, Chaodong Li

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A rotational piezoelectric energy harvester for efficient wind energy harvesting

Jiantao Zhang*, Zhou Fang, Chang Shu, Jia Zhang, Quan Zhang, Chaodong Li

School of Mechatronic Engineering and Automation, Shanghai University, Shanghai 200072, China

* E-mail: zhangjt@shu.edu.cn

HIGHLIGHTS:
Harvesting wind energy to power the sensor nodes has evoked great interests. But the challenge in designing such wind energy harvesters is to improve the efficiency of energy harvesting for a wide range of wind speeds. In this research, a rotational piezoelectric energy harvester for efficiently harvesting wind energy is proposed. The piezoelectric (PVDF) beam generates electricity using the impact-induced vibration. But it is found that the energy output of the harvester doesn't always increase with increasing the wind speed. An analytical model is presented and simulated using finite element method. The transient responses of the piezoelectric beam subjected to an impulse pressure are obtained. The relationship between rms output voltage and excitation frequency is analyzed. To improve the harvester performance, the methods for the adjustment of the vibration frequency of the PVDF beam are proposed. The developed wind energy harvester can generate sufficient energy and does not require the excitation frequency to be close to the resonance frequency of the harvester. Since the dimension of the turntable and the position of the piezoelectric beam may be adjusted, large vibration amplitude of the beam can be obtained. So the harvester can effectively generate electricity.

ABSTRACT: A rotational piezoelectric energy harvester for efficiently harvesting wind energy is developed. The piezoelectric (PVDF) beam generates electricity using the impact-induced vibration. An analytical model is presented and simulated using finite element method. The transient responses of the piezoelectric beam subjected to an impulse pressure are obtained. The relationship between rms output voltage and excitation frequency is analyzed. It is found the impact frequency is an important factor for the harvester performance. When the impact frequency is beyond the critical one, the output power of the harvester will decrease with increasing the wind speed. To improve the harvester performance, the methods for the adjustment of the vibration frequency of the PVDF beam are proposed. The harvester can effectively scavenge the wind energy. A maximum rms voltage of 160.2 V and a maximum output power of 2566.4 μW were obtained at the wind speed of 14 m/s in configuration 2.

Keywords: Piezoelectric, Wind energy harvesting, Impact-induced vibration, Finite element analysis

1. Introduction

The recent technological advancement in wireless sensor and microelectronic technologies have led to the development of low-cost, low-power, multifunctional sensor nodes. These devices are being powered by the batteries. However, the batteries have finite storage capacities and need to be replaced periodically. In an attempt to solve this problem, harvesting energy from the environment has been explored to supplement or even replace batteries. The use of ambient energy, such as vibration, wind, sunlight, heat, has evoked great interests [1-4]. In particular, wind energy is a good source of electricity supply for its unique characteristics, such as clean, environmentally preferable, affordable and inexhaustible. Recently, many research works have been focused on the study of converting the wind energy to electricity [5-9].

Li *et al.* demonstrated that a cross-flow stalk-leaf configuration has better power generation performance, than a parallel-flow stalk-leaf. This study showed that the self-induced vibration of the trailing edge played the main role [10]. Zhao *et al*. proposed an arc-shaped piezoelectric generator which is capable of harvesting the energy from multi-directional winds [11]. Li *et al*. evaluated three distinct operation modes of piezoelectric energy harvester. It was showed that the Mode I is the most effective one. They attributed this result to large bending and torsion involved in this operation mode [12]. Yang *et al*. proposed a rotational piezoelectric wind energy harvester. The impact-induced resonance was used to improve the output power of the harvester [13]. Xia *et al*. showed that the resonance between the circuit and the piezoelectric flag’s flapping motion leads to a significant increase in the harvested energy [14]. Priya *et al*. demonstrated a piezoelectric windmill. The 12 piezoelectric bimorph transducers are utilized to harvest electrical energy [15]. The challenge in designing such wind energy harvesters is to improve the efficiency of energy harvesting for a wide range of wind speeds.