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A miniature generator using piezoelectric bender with elastic base

W. Li [a], T.S. Liu [a,*], C.C. Hsiao [b]

[a] Department of Mechanical Engineering, National Chiao Tung University, Hsinchu 30010, Taiwan
[b] Mechanical and Systems Research Laboratories, Industrial Technology Research Institute, Hsinchu 31040, Taiwan

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ABSTRACT

Nowadays green energy devices such as vibration generators attempt to harvest energy from environment. A lot of studies dealing with vibration generators put emphasis on mechanism designs or power generation methods, but few on lowering the resonant frequency of power generation systems. This study proposes that elastic bases attached to vibration generators can lower natural frequencies, so as to make natural frequencies closer to ambient vibration frequency. Therefore, this study investigates miniature electric generators consisting of piezoelectric benders and elastic bases. To install the elastic base, this work uses a spring with prescribed stiffness and a board with given mass between the piezoelectric bender and a vibration source to make the resonant frequency of piezoelectric benders close to the frequency of ambient vibration. Analytical derivation is carried out to obtain optimal mass and stiffness. Accordingly, more electric power can be generated from piezoelectric generators using an elastic base with appropriate mass and stiffness. According to experimental results, using an elastic base increases 376 times generated power compared with no elastic base. In the presence of the elastic base, the power increases 132% when a point mass is added.

1. Introduction

For the sake of ubiquitous computing, micro-sensors are proposed to be embedded in isolated environment like human body or concrete walls. However, how to provide electric power into these sensors remains to be solved. One of solutions is green power harvesting. In recent years, without pollution and short-life problems of traditional batteries, several kinds of energy-harvesting designs have been proposed for green energy sources. These designs include acoustic energy collection, thermal energy collection, electromagnetic and electrostatic power transducers, vibration of piezoelectric materials, etc.

Williams and Yates [1] pointed out that mechanical energy can be used to generate electric power by a mass-spring-damper system. Vibration energy can be transformed into electric power by using transduction mechanisms such as piezoelectric, electromagnetic, and electrostatic devices. And if the mechanical system oscillates at a resonant frequency, the maximum power occurs. Therefore, in this study for performance of the miniature generator, it is beneficial to design a device with resonant frequency as close as possible to frequencies that human activities result in. However, resonant frequencies of miniature electromagnetic or electrostatic generators are too high to utilize. Hence, we focus on the piezoelectric generator in this paper. The electric power is generated by the strain change of piezoelectric benders. The strain change is caused by deformation of the piezoelectric bender in vibration. Starner [2] presented that computers can be powered by human motion such as swinging arms. Shenck and Paradiso [3] proposed that when the piezoelectric material embedded in human shoes is compressed, electric power is generated. Roundy et al. [4] powered a wireless sensor by using a low-frequency vibration source. Roundy et al. [5] pointed out that a trapezoidal-shaped piezoelectric bender can generate the maximum energy in the same volume. Xu et al. [6] presented that magnitudes of generated power are quite different by different loading methods. Kang et al. [7] presented that the power magnitude is proportional to the length while inversely proportional to thickness of the piezoelectric bender. The length is more effective than thickness. In the above studies, however, the vibration mechanisms in the above studies are all fixed to a rigid base, and the natural frequency of the vibration mechanism is relatively higher than the frequency of vibrations caused by natural environment or human-being. Marinkovic and Koser [8] proposed a harvesting platform using nonlinear stretch of fixed-fixed beams for a range of frequencies from 160 to 400 Hz, and aiming at 60 Hz. Cornwell et al. [9] proposed an auxiliary mechanism to make the resonant frequency closer to the frequency of the ambient vibration. Lipscomb et al. [10] presented that the resistance of piezoelectric ceramic varies with humidity and temperature. Sherrit et al. [11] presented that piezoelectric coefficients increase as temperature rises. Sharos et al. [12] proposed that eccentric attached masses and asymmetric

* Corresponding author.
E-mail address: tsliu@mail.nctu.edu.tw (T.S. Liu).

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