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Diankun Pan, Yanqi Li, Fuhong Dai

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28The influence of lay-up design on the performance of bi-stable piezoelectric energy harvester

Diankun Pan, Yanqi Li, Fuhong Dai*,

Center for Composite Materials and Structures, Harbin Institute of Technology, Harbin 150001, China

Abstract

Bi-stable composite laminates with piezoelectric transducers have been shown to capture energy over a wide frequency range and deliver significantly greater energy than resonant devices. In this work, the influence of lay-up design on the performance of bi-stable piezoelectric energy harvester (BPEH) based on bi-stable hybrid symmetric laminate (BHSL) is analyzed and verified. The initial voltage induced by stable configuration and longitudinal curvature of BPEH with different lay-up and hybrid width were calculated and analyzed by a static finite element analysis. The lay-up can vary initial voltage and longitudinal in opposite directions, and hybrid width can adjust these two variables in the same direction. The strain variations of piezoelectric transducer between two stable configurations were also analyzed. The initial voltage of BPEH depends on strain variations in the two directions. And then the finite element results are verified by experiment. Three types of BPEH were manufactured and actuated by two methods to measure their output powers. These BPEHs presented different dynamic responses, and the output powers under different vibration modes were measured. The highest output power of BPEH in this work is 42.2 mW and the highest power density is 78.1 mW/cm^3.

Keywords: bi-stable, energy harvesting, laminate, piezoelectric, finite element analysis

1. Introduction

Energy harvesting from wasted or unused power has been a topic of discussion in recent years. Unused power exists in various forms such as industrial machines, human activity, vehicles, structures and environment sources [1]. The unused power can be converted to electrical energy by using electromagnetic, piezoelectric and electrostatic mechanisms. Compared with other alternatives, the piezoelectric transduction has some advantages such as high power density, a much simpler design and much smaller size [2].

Generally, a piezoelectric energy harvester is a cantilevered beam with one or two piezoelectric layers. The cantilever-type piezoelectric harvesters are usually designed to work in the on-resonance mode. The maximum output power of such a device occurs when the fundamental frequency of the device is near the dominant frequency of ambient vibration insuring a resonance response maximizing the strain into piezoelectric layers. Therefore, an important issue for resonant vibration energy harvesters is that the best performance of the device is limited to a very narrow bandwidth. However, there are many situations where the excitation is unknown or random, and in such situations the on-resonance harvesters are unbeneficial.

The harvester with a broadband or adaptive response is a way to improve the adaptability of piezoelectric energy harvesting technology. Castagnetti et al. [3] realized broadband energy harvesting by fractal-inspired multi-frequency structures. Ferrari et al. [4] employed an

Corresponding author. Tel: +86 0451 86418172
Email address: daifh@hit.edu.cn (F. Dai)