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Experimental and Theoretical Investigations on Piezoelectric-Based Energy Harvesting from Bridge Vibrations under Travelling Vehicles

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Abstract

This paper aims to investigate the amount of energy which can be harvested by a cantilever beam type piezoelectric energy harvester from a bridge vibration. The sources of vibration are vehicles traversing the bridge. Two types of masses are considered as models for traversing vehicles: concentrated and distributed masses. The mass of the harvester is assumed negligible compared to that of the bridge. First, the problem of moving mass travelling with a constant speed over a beam is considered. The formulations for both concentrated and distributed masses are presented. The obtained results are then compared to the data available in the literature, in order to validate the model of a beam with a moving mass. Next, a mathematical model for the harvester is proposed, which is composed of an Euler–Bernoulli beam as a substrate, a tip mass, and a single piezoelectric patch whose electrodes are connected to a changeable resistance. To validate the model, the harvester is fabricated and tested on a shaker. The electroelastic frequency response functions of the system are measured by low-amplitude chirp excitation tests. The optimal resistive load at the resonance frequency, obtained from theory and experiments, are compared. Finally, the acceleration time histories for the beam at mid-span, where the harvester is located, are calculated for two mass types and used as base excitation signals to the harvester. These signals are replayed on an electromagnetic shaker to simulate the bridge vibrations on the fabricated harvester and the experimental results are compared with theoretical ones. Good agreement is observed.

Keywords

Energy harvesting, structural health monitoring, piezoelectric, bridges

Introduction

Bridges play an undeniable role in ground transportation systems. Monitoring the health of civil infrastructures, such as bridges is a way, often used in order to prevent hazards from their degradation. Structural Health Monitoring (SHM) systems, which keep civil infrastructures safer and more durable, have become widely popular in the last decade [1, 2]. Furthermore, Wireless Sensor Networks (WSNs), which are able to make SHM systems more efficient, have attracted significant attention recently. These networks not only solve a number of issues with traditional wired sensor grids, such as lack of flexibility, necessity of repairing damaged cables, and changing configurations, but also they are quite affordable, can be easily implemented, need easier maintenance, increase the density of located sensors, and have a good ability to be applied to bridge infrastructures [3].

Power consumption is one of the main challenging dilemmas which WSNs encounter with. According to the simplest definition reported in the literature, the lifetime of a sensor network is the time span from the instant the network starts operating to the failure of first sensor node [4]. Meanwhile, lifetime of a sensor node has a strong dependence on the nodes' battery lifetime. Historically, small alkaline batteries had long been utilized as power supply in wireless sensor nodes owing to their high energy density and long