A study of several vortex-induced vibration techniques for piezoelectric wind energy harvesting

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ABSTRACT

This paper discusses a preliminary study on harnessing energy from piezoelectric transducers by using bluff body and vortex-induced vibration phenomena. Structures like bridges and buildings tend to deform and crack due to chaotic fluid-structure interactions. The rapid variation of pressure and velocity can be tapped and used to power structural health monitoring systems. The proposed device is a miniature, scalable wind harvesting device. The configuration consists of a bluff body with a flexible piezoelectric cantilever attached to the trailing edge. Tests are run for different characteristic dimensions or shapes for the bluff body and optimized for maximum power over a wide range of flow velocities. The main motive here is to seek a higher synchronized region of frequencies for the oscillation amplitudes. The multi-physics software package COMSOL is used to vary the design parameters to optimize the configuration and to identify the significant parameters in the design. The simulation results obtained show a wider lock-in bandwidth and higher average power for the cylindrical bluff body compared to the other two bluff body shapes investigated, the greatest average power being 0.35mW at a Reynolds number of 900, beam length of 0.04m, and bluff body diameter of 0.02m.

Keywords: power harvesting, piezoelectric, flutter, vortex-induced vibration

1. INTRODUCTION

Powering densely populated wireless sensor nodes is a major challenge due to the high cost of wiring or replacing batteries. To minimize these expenses, vibration energy from their ambient, i.e. rapid variation of pressure and velocity of fluid flow, can be tapped and used for powering these devices[1]. Out of the three basic vibration-to-electric energy conversion mechanisms, namely electromagnetic, electrostatic and piezoelectric transductions, the latter has gained importance in the past decade for its high energy density, as is evidenced by the numerous research articles published.

Vortex-induced vibrations (VIV), bluff body vibrations, aeroelastic fluttering[2] and wake galloping phenomena[3] have been extensively investigated by researchers for small-scale piezoelectric wind harvesting[1]. For example the driving oscillating forces that mechanically strain the piezoelectric cantilevers can be generated in a flowing medium (air or water) by either an obstacle in the flow such as a bluff body or a so called "von Karman's vortex street"[4]. Two different designs were investigated by Pobering et al[4,5]. The first harvester consists of nine, three-dimensionally arranged bimorph piezoelectric cantilevers. Each single cantilever consists of two layers of piezoelectric material (PZT) with three surface electrodes on top, on bottom and between the layers. Power values of up to 0.1 mW and output voltages of 0.8 V have been achieved with a non-optimized geometry. The second model was optimized using the results obtained with the previous model. A total of 18 piezoelectric cantilevers have been arranged in two rows upon each other. The energy harvester was able to supply 2 mW of power at a wind velocity of 8 m/s from the second mode[5]. Akaydin et al have investigated a VIV-based energy harvester with short-length piezoelectric beams kept at the wake of the cylinder with water as the flowing medium[6]. The maximum power output, i.e. the maximum strain in the material, was measured when the tip of the beam is about two diameters downstream of the cylinder.

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