Galloping Piezoelectric Energy Harvester for Low Wind Speed

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Abstract. Aiming at the natural environment with low wind velocity, galloping piezoelectric energy harvester (GPEH) is comprehensively optimized in three aspects. Firstly, based on the fluid-solid coupling theory, the square cylinder in the GPEH is modified to improve the conversion of fluid energy into mechanical energy efficiency and reduce the critical velocity of the system. Secondly, piezoelectric cantilever beam with variable cross-section is established, and the analytical solution is obtained by piecewise Galerkin method, and the beam geometry is optimized by particle swarm optimization method. Thirdly, considering the various connections between the resistors, capacitors and inductors, the circuit of the energy harvester is optimized. The finite element simulation is established to verify the correctness of the theoretical solution. Therefore, the optimized energy harvester can obtain the largest power density and therefore can reduce the cost of piezoelectric wind energy harvester.

Introduction

Energy harvester is usually the process of converting light, heat, solar energy and vibration energy into electrical energy. The research on energy harvester has always been one of the hot topics in the academic field, and a large number of researchers have made extensive research in this field [1]. During the past few years, many studies have focus on converting ambient and aeroelastic vibrations to usable form of electrical energy by using energy harvesting. Recently, the concept of harvesting energy from galloping of prismatic structures has been proposed in many studies. And piezoelectric materials are also widely used in the design and development of energy harvester [2]. Therefore, galloping energy harvester has become a hot research content. Galloping energy harvester mainly consists of three parts: a prismatic, a piezoelectric cantilever beam and a circuit system for collecting electric energy. Hence, the optimization of energy harvester is also be carried out from these three parts.

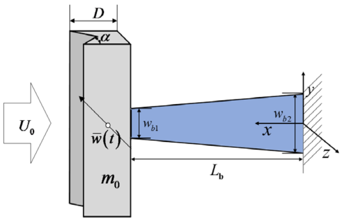

Figure 1: Figure 1: Schematic of the galloping piezoelectric energy harvester with a V-shaped groove.

Results and discussion

Our goal is to improve the efficiency of galloping piezoelectric energy harvester in low wind speed environment. The results are divided into three parts. Part one, the V-shaped groove on the windward side of the prismatic cylinder is designed to improve the efficiency of converting wind energy into kinetic energy. Ten groups of galloping piezoelectric energy harvesters were designed and tested in a wind tunnel by gradually changing the angle of two symmetrical sharp angles of the V-groove. The more accurate mathematical model was made by using the sparse identification method to calculate the empirical parameters of fluid based on the experimental data and the theoretical model. And the V-groove with a sharp angle of 45° was selected as the optimal shape. Part two, the mathematical model of the energy harvester is calculated by the piecewise Galerkin method. The advantages of this method are short calculation time and high precision, which makes it possible to use big data analysis method for optimization. The finite element simulation is established to verify the correctness of the theoretical solution. Part three, under different resistance, the piezoelectric coupling coefficient, critical velocity, energy conversion efficiency and other parameters of the energy harvester is calculated. The optimal energy harvester is selected by comparing these parameters. The critical velocity of the system was calculated by analyzing the local Hopf bifurcation of the model. The minimum critical velocity was 4.35 m/s smaller than the maximum critical velocity at 10.69 m/s. These results make the energy harvester more suitable to harvest wind energy efficiently in a low wind speed environment.

References

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