Simulation of Aeroelastic Instabilities to Evaluate the Power Output of Flutter-based Electromagnetic Energy Harvesters

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Summary

The unstable vibration of flexible T-shaped cantilever systems due to the aeroelastic instability phenomena like flutter can be used as an effective input source for small-scale energy harvesting. The extracted environmental energy of a vibrating system can be converted into electrical power using an electromagnetic transducer. The paper presents a two-dimensional fully coupled CFD solverfor simulatingthe flutter induced vibration ofa T-shaped prototypeharvester to model the power output numerically. A flow solver based on Vortex Particle Method and a structural solver using Finite Element formulationsare coupledefficiently to model the unstable vibration of the cantilever harvester.Theoretically, a structural systembecomes unstable and exhibits flutter phenomena when the negative aerodynamic damping exceeds the total system damping. However, for electromagnetic harvester, the total system damping is the sum of the mechanical damping and the additional electrical damping from electromagnetic transducer. The CFD simulations are performed to find the critical onset flutter wind speed and the results are compared with wind tunnel test results for model validation. The critical electrical load resistances for onset of flutter are also identified for different wind speeds and compared withthe wind tunnel results. Finally, the voltage and power output of the harvester under different wind speeds and electrical load resistances are modeled, compared and modifications on the harvester system are done to increase power output.

Keywords: Energy harvesting, Flutter vibration, Vibration energy, Vortex Particle Methods, Sensor, Structural health monitoring.

1. Introduction

Energy harvesting has been an active research area in recent years as the demands for renewable energy sources for wireless sensor network and self-powered microsystems have emerged remarkably. A variety of mechanisms or materials have been explored to exploit the mechanical vibration of a system for power generation such as the power generation from mechanical strain using piezoelectric transducers [1-3], or theinductance power using electromagnetic transducer [4,5,8].Wind induced vibrationare found to be an effective alternative source of vibration, for example, the vortex induced vibration (VIV) [2], or the aeroelastic instability phenomena like galloping [3, 4] and flutter[6-8] are often been used for energy harvesting.

Flutter is a potentially destructive phenomena and likely to happen in long span cable supported bridges. However, the flutter induced vibrations of T-shaped cantilever beam and plate were used to mechanically strain piezoelectric patches to generate power [7, 8].Moreover, extensive studieswere done in [8] on the ability and performance of T-shaped flexible cantilever system for flutter-based electromagnetic energy harvesting.The susceptibility of the T-shaped flexible cantileversystem to 1-

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