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Self-Powered Dynamic Systems

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Abstract

This paper concerns energy harvesting associated with dynamic systems in the context of Self-Powered Dynamic Systems. Due to the rapidly increasing energy demand in the 21st century, it is crucial to examine the energy potential and technological issues of various forms of energy. The paper carries out a study on several energy harvesting systems in various schemes as self-powered dynamic systems. In this paper, a self-powered dynamic system is defined as a dynamic system powered by its own excessive kinetic energy, renewable energy or a combination of both. State-of-the-art technologies are explored in the paper including self-powered sensors, regenerative force actuators, energy harvesting from human motion, and harvesting ambient energy through structures (those not specifically built for renewable energy applications) that are exposed to external excitations. Various scenarios of energy harvesting are presented with applications associated with aerospace, automotive, rail, electrical components and structures. In particular, a solar powered airship (based on the concept of Multibody Advanced Airship for Transport), energy harvesting from vehicle suspension, and structural vibration control by regenerative actuators are discussed. A bio-inspired design is addressed for the case of wind energy. It is shown that the bio-inspired system can improve the power density.

For the above applications three energy conversion schemes are employed which convert kinetic energy to electrical energy. Electromagnetic, electrostatic and piezoelectric systems are utilized to convert kinetic energy to useful electrical energy. For instance, the wasted energy in the suspension systems of road and tail vehicle systems, where vibration of the vehicle is converted to wasted heat energy, can be harvested to useful energy using a regenerative actuation system. This system can also be used in the explorer vehicles in space such as the mars exploration rover type systems. The same idea of regenerative actuation is valid for structural vibration control such as vibration control of an air or space vehicle. In such case the regenerative actuator can act as a generator and harvest the energy from the vibration and convert it to electrical energy. Then this electrical energy can be fed back to the system to control the same vibration. This can be used to avoid catastrophic failure of the structure. Obviously because of the limited efficiency of a regenerative system the amount of

harvested and usable energy is less than the input kinetic energy. However it can be proven that this energy is sufficient to avoid any failure of the structure when excited by vibrations. A piezoelectric system can be used similarly for structural vibration control which can act as a generator and actuator. Such systems can particularly be applied as embedded actuation system in aerospace structural systems (e.g. wings). The above actuators can be exploited as self-powered actuators as they do not need external source of power and instead they consume unwanted kinetic energy of their own system as the input power source. A vibration sensor can harvest vibration being measured by the sensor and convert it to electrical energy through an electrostatic system. Such system can be used as a self-powered sensor. This is particularly beneficial for vibration monitoring of remote structures where either there is no external power source available for the sensor or if the sensor is powered by a battery then this battery can not be placed due to the accessibility problems to the system.

Piezoelectric based system can be built as cantilever structures which can flutter when exposed to wind excitations and therefore generate electrical energy. If a few cantilevers are placed in a certain distances relative to each other inspired by fish schooling, they can generate the maximum power compare with the case when they are placed in any other distances relative to each other. Such bio-inspired system has been discussed in this paper.

In this paper the general theory of energy harvesting from kinetic energy has been presented and then it is expanded for various self-powered systems mentioned above.