Piezoelectric energy harvesting for airships and investigation of bio-inspired energy harvesters

Farbod Khoshnoud[1], Amir Shahba[1], Omair Riaz[1], Rahul Shah[1], Ray Shimura[1], Yong K. Chen[1] and Giorgio Gaviraghi[2]
[1]School of Engineering and Technology, College Lane Campus, University of Hertfordshire, Hatfield, AL10 9AB, UK
[2]Exponential design lab-Europa, Via Troubetzkoy 130, Verbania, Italy

Abstract

In this paper various schemes of energy harvesting using piezoelectric based devices are addressed. The particular applications for these energy harvesters are on power supply for various electronic components of airship systems. An efficient source of energy for airships can be considered as solar. The large surface area of airships provides an ideal space for installing solar panels. The solar energy can generate sufficient power for almost all airship applications such as avionics, control systems and propulsion systems in an airship. For instance, Multibody Advanced Airship for Transport (MAAT) is fully powered by solar without the use of any fuel energy. In addition to the solar power, small electronic components can be built in the function of self-powered systems. A self-powered wireless sensor is an example of such systems which does not run on any external power source. By implementing the self-powered systems the use of batteries or external power source for such systems can be eliminated. This also reduces the maintenance required for the sensor as a battery replacement will be required, due to limitations of the batteries finite life. A self-powered sensor or actuator can be built based on a piezoelectric based system. When external load is applied to such self-powered device it generates electricity due to the piezoelectric effect. In this paper the two main sources of external excitation to piezoelectric are considered. The first external excitation is the kinetic energy of vibration due to unwanted vertical or lateral oscillations of the airship. These oscillations can excite a piezoelectric based device and consequently supply electrical energy for various applications. The second type is based on human powered systems. The kinetic energy of passengers and crews body motions can be converted to electricity through a piezoelectric based device. For instance, when passengers walk on a piezoelectric strip installed on a walk way, the kinetic energy of the motion can be harnessed with the piezoelectric material. Another example is a set of facilities built particularly to convert human activities to electrical energy. This is similar to gym facilities when people's exercise in the gym can generate electricity. On an airship, because of the large space area available, a set of facilities can be installed analogous to a small gym where people can exercise and also contribute to the power demand of the airships systems. As airship flights are normally longer than aircraft journeys, due to the lower speed, then these activities can also provide a very desirable environment for passengers.

In this paper the vibration based and human powered piezoelectric energy harvesters are presented. Theoretical formulations are obtained and simulation is performed and experimental work is carried out on piezoelectric energy harvesting.

Another source of kinetic energy that can be harvested using piezoelectric based devices is the fluid induced vibration to the body of the airship. Piezoelectric material can be embedded in the body of the airship. This is particularly beneficial for hybrid airships with wings. In a generator wing, piezoelectric can be embedded in the wing structure and generate electricity from wing vibrations. This electricity can be exploited to control the same vibration for stabilising the motion of the wing if flutter occurs. In this case the piezoelectric acts as a self-powered actuator which uses the same vibration as a power source to control exceeding oscillations of the wing. In self-powered systems, if the generated power is not enough to provide sufficient power supply for the device, the power can be accumulated in a rechargeable battery or a capacitor and be used later when the power is required. Utilizing a piezoelectric cantilever based device, mounted on the outer surface (like a flag, not embedded in the structure) of an airship, harvesting might not sound feasible for aeroelastic piezoelectric energy. This is because the generated power from the wind should compensated only for the drag force induced by the same piezoelectric cantilevers. However by looking at biological systems a plausible solution may be found. Study of mechanics of fish has shown that "even a dead trout can swim upstream by extracting energy from the wake of an upstream and generating thrust-producing body deflections (Beal et al., 2006), while an earlier study showed whale flukes are capable of absorbing energy from surface waves and creating thrust whether the whale is alive or dead (Bose and Lien, 1990)". Therefore biomimetics can assist us to design unconventional engineering systems and for this reason the biologically inspired piezoelectric energy harvesters are investigated here. Even if the bio-inspired wind energy harvesting for airships can not be considered as an acceptable approach, it is certainly beneficial for land based systems that are associated with airships such as for power supply for control towers. It is also likely to harness the kinetic energy of turbulences and vortices generated by the passing flow over the airship body without inducing extra drag. This paper investigates wind energy harvesting using piezoelectric energy harvesters inspired by fish schooling and bird formation flight. Fish can swim in groups and use less muscle energy as with the concept of formation flight. This is a study on aquatic animal and birds' locomotion in designing of efficient wind energy harvesters. Theoretical study of piezoelectric energy harvesters has been addressed when kinetic energy of piezoelectric system, due to vibration, is converted to electricity. The wind excitations cause a piezoelectric cantilever system to flutter which will consequently be converted to electricity. Experimental and theoretical investigation of this optimised system is carried out by placing 5 piezoelectric cantilevers, of the same size and mechanical/electrical characteristics, in the wind tunnel and placing them in a certain distance relative to each other inspired by how fish swim in groups and formation flight.