Energy Harvesting in a Fluid Flow Using Piezoelectric Materials

M. Curatolo[1], M. La Rosa[1], P. Prestininzi[1]

[1]Roma Tre University, Rome, Italy

Abstract

Energy harvesting from a fluid flow using piezoelectric materials is a relatively recent topic that has been investigated experimentally and numerically [1, 2]. Its possible application in natural water currents represents an interesting strategy to easily harvest renewable energy from the environment [3].
The problem encompasses several phenomena belonging to different physical fields: solid mechanics, fluid mechanics, electrostatics and an appropriate electrical circuit capable to harvest the electrical energy developed by the deformation of a piezoelectric material induced by the fluid flow. The interaction between such disparate aspects makes the problem complex and highly non-linear. In our case, simulating energy harvesting in a fluid flow requires multi-physics, and deeply uses advanced features of COMSOL Multiphysics®. Particularly, there is a strong coupling between different physics because the solid exhibits large deformations that are enough to influence the fluid flow where it is immersed, thus requiring a fully coupled fluid-structure interaction (FSI).
We focus on a 2D problem of fluid solid interaction where a non-homogeneous bilayer beam, clamped at one end on a fixed circular constraint, is immersed in a fluid flow in a channel, see Fig. 1. The beam is composed of two layers; one is made of piezoelectric material (PZT 5-A) while the other is made of structural steel. Using two layers is necessary to increase the harvested power as the piezoelectric beam achieves larger deformations. The deformation of the piezoelectric layer generates an electrical potential that can be harvested on an electrical resistance load connected to the device. In this way, an electrical current flows through the electrical resistance load that can be supplied through the device. Moreover, the free end of the beam is composed of half cylinder in order to increase vibrations of the body that can be observed at different instants together with the fluid pressure pf and vorticity ω3 as showed in Fig. 2. We are able to measure the deformations of the body, for example the tip displacement, and the electric harvested power on the external electri- cal resistance load (see Fig. 3). The advantage of numerical simulations easily allows parametric studies for different sizes of the half cylinder and for different inlet velocities to optimize the energy harvesting device. As in [4, 5], we need both moving mesh to solve the FSI for short time intervals, and re-meshing for very large deformations of the solid.

References

[1] J.J. Allen, A.H. Techet, R.M. Kelso and A.J. Smits. Energy Harvesting Eel. Journal of fluids and structures, (2001).

[2] H.D. Akaydin,N.Elvin and Y.Andreopoulos. Energy Harvesting from Highly Unsteady Fluid Flows using Piezoelectric Materials, Journal of Intelligent Material Systems and Structures,
(2010).
[3] N. Elvin and A. Erturk. Advances in energy harvesting methods. Springer Science & Business Media, (2013).
[4] M.Curatolo, L.Teresi. The Virtual Aquarium:Simulations of Fish Swimming. Proc.European COMSOL Conference, (2015).
[5] M. Curatolo, L. Teresi. Modeling and Simulation of Fish Swimming with Active Muscles. Journal of Theoretical Biology, (2016).