Simultaneous Analysis of Strongly-Coupled Composite Energy Harvester-Circuit Systems Driven by Fluid-Structure Interaction

Andreas Zilian / Srivathsan Ravi

University of Luxembourg, Faculty of Science, Technology and Communication
6, rue Richard Coudenhove-Kalgeri
L-1359 Luxembourg, Luxembourg

A specific class of energy harvester devices is investigated, that allow conversion of ambient fluid flow energy to electrical energy via flow-induced vibrations [1] of a piezo-ceramic composite structure positioned in the flow field. Potentially harmful flow fluctuations are harnessed to provide independent power supply to small electrical devices [2]. Such concept simultaneously involves the interaction of a composite structure and a surrounding fluid, the electric charge accumulated in the piezo-ceramic material and a controlling electrical circuit. In order to predict the efficiency and operational properties of these devices and to increase their robustness and performance, a predictive model of the complex physical system allows systematic computational investigation of the involved phenomena and coupling characteristics.

A monolithic approach is proposed that provides simultaneous modelling and analysis of the harvester, which involves surface-coupled fluid-structure interaction, volume-coupled electro mechanics and a controlling energy harvesting circuit for applications in energy harvesting. A three dimensional space-time finite element approximation [3] is used for numerical solution of the weighted residual form of the governing equations of the flow-driven piezoelectric energy-harvesting device. This method enables time-domain investigation of different types of structures (plate, shells) subject to exterior/interior flow with varying cross sections, material compositions, and attached electrical circuits with respect to the electrical power output generated [4].

The space-time finite element model presented incorporates a novel method to enforce equipotentiality on the electrodes covering the piezoelectric patches, making the charge unknowns naturally appear in the formulation [5]. This enables to adapt any type of electrical circuit added to the electromechanical problem.

Keywords: energy harvesting, flow-induced vibrations, strongly-coupled analysis

References

[1] A Zilian: *Modelling of Fluid-Structure Interaction – Effects of Added Mass, Damping and Stiffness*. In H Irschik; A K Belyayev (Eds.): "Dynamics of Mechanical Systems with Variable Mass", Springer, 2014.

[2] A Zilian: *Energy Harvesting*, Science and Technology, 2015, 15.

[3] B Hübner, E Walhorn and D Dinkler: *A Monolithic Approach to Fluid-Structure Interaction Using Space-Time Finite Elements*. Computer Methods in Applied Mechanics and Engineering, 193:2087-2104, 2004.

[4] A Erturk and D J Inman: *An Experimentally Validated Bimorph Cantilever Model for Piezoelectric Energy Harvesting From Base Excitations*. Smart Materials and Structures, 18:2-18, 2009.

[5] S Ravi and A Zilian: *Numerical Modeling of Flow-Driven Piezoelectric Energy Harvesting Devices*. In A. Ibrahimbegovic (Ed.): "Computational Methods for Solids and Fluids", Computational Methods in Applied Sciences 41, Springer, 2016.