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Modeling and Simulation of Thin-Walled Piezoelectric Energy Harvesters Immersed in Flow Using Monolithic Fluid-Structure Interaction

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A monolithic numerical scheme for fluid-structure interaction with special interest in thin-walled piezoelectric energy harvesters [1] driven by fluid is proposed. Employing a beam/shell model for the thin-walled structure in this particular application creates an unconventional FSI problem in which a $(n-1)$-dimensional structure is embedded in a n-dimensional fluid flow. This choice induces a strongly discontinuous pressure field along the moving fluid-solid interface [2]. We overcome this challenge within a continuous finite element framework by a splitting-fluid-domain approach.

The governing equations of the multiphysics problem are solved in a simultaneous fashion in order to reliably capture the main dynamic characteristics of the strongly-coupled system that involves a large deformation piezoelectric composite structure, an integrated electric circuit and an incompressible viscous fluid. The monolithic solution scheme is based on the weighted residuals method, with the boundary-fitted finite element method used for the discretization in space, and the generalized-α method for discretization in time.

The proposed framework is evaluated against reference data of two popular FSI benchmark problems. Two additional numerical examples of flow-driven thin-walled piezoelectric energy harvesters demonstrate the feasibility of the framework to predict controlled cyclic response and limit-cycle oscillations and thus the power output in typical operational states of this class of energy harvesting devices.

REFERENCES

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