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Coupled analysis for flow-driven energy harvester

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The piezoelectric effect transforms electrical energy into mechanical energy and vice versa. Piezoelectric materials can thus be used to harvest energy from mechanical vibration. Flow-driven energy harvesters, which harvest energy from flow-induced vibration, have attracted attention. This type of harvester has been widely investigated in the aerospace community.

There is demand for unmanned aerial vehicles (UAVs) capable of high-altitude and long-endurance flight for applications such as environmental survey and telecommunication service. Because the HALE flight requires very efficient aerodynamics, high-aspect-ratio wings (HARW) with low weight have been widely investigated to realize high lift-drag ratio. Since the HARW may undergo large deformation, geometrical nonlinearity appears. Nonlinear flow may also happen due to the large deformation. As a result, the HARW is often exposed to limit cycle oscillation (LCO), which is a self-sustained oscillation with a limited amplitude that remains constant in time caused by nonlinearities in structural dynamics and aerodynamics. Although destructive vibration must be suppressed, if a certain magnitude of vibration is allowed under the assumption that it will not damage the wing or degrade aircraft performance, the vibration can serve as a source of energy. An experimental study on UAVs with piezoelectric energy harvesting was reported [1].

Flow-driven energy harvesting is a complex problem with coupling among the host structures, piezoelectric materials, surrounding fluid, and electric circuits. For numerical evaluation of the harvester, coupled analysis is needed. Although there have been some numerical studies on flow-driven piezoelectric energy harvesters [2], many of them introduce simplifications and detailed numerical simulations have been rarely conducted.

In our previous work, we have been developing FEM-based fluid-structure-piezoelectricity coupled analysis [3]. In the present study, we integrate an electric circuit into the coupled analysis to consider piezoelectric energy harvesters and to calculate generated energy by the harvesters. We show a two-dimensional numerical simulation on active control of LCO with piezoelectric energy harvesting.

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