Energy harvesting from flutter instability of a piezoelectric plate

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Olivier Doaré⋆ and Sébastien Michelin⋆⋆
⋆ Unité de Mécanique,ENSTA-Paristech, 91761, Palaiseau, France
⋆⋆ LadHyX, École Polytechnique, 91128, Palaiseau, France

Drawing profit from ambient geophysical flows to create electrical power received a growing attention recently in particular for small-power or low-velocity applications where the use of traditional wind-turbine technologies is made prohibitive or inefficient by either the size, the cost or remoteness of the equipment considered. For those applications, fluid-solid instabilities generating spontaneous and self-sustained periodic oscillations of a solid body are promising energy harvesting mechanisms, provided one is able to convert into usable form the solid kinetic or elastic energy. We investigate here the energy harvesting potential of a plate in an axial flow equipped with a distributed series of small piezoelectric elements, as sketched on Figure 1a. It is now well known that a plate in axial flow displays large amplitude oscillations once a critical value of the flow velocity is reached, a phenomenon commonly referred to as "flag flutter" [1]. Each of the piezoelectric pairs is connected to an energy harvesting circuit, as sketched in Figure 1b. In the this modelling, the power dissipated in the resistance represents the power effectively harvested by the system. This harvested power acts like a damping on the mechanical system and thus can affect the critical flutter velocity and the dynamics of the plate. We are then faced to a strongly coupled fluid-solid-electrical system.

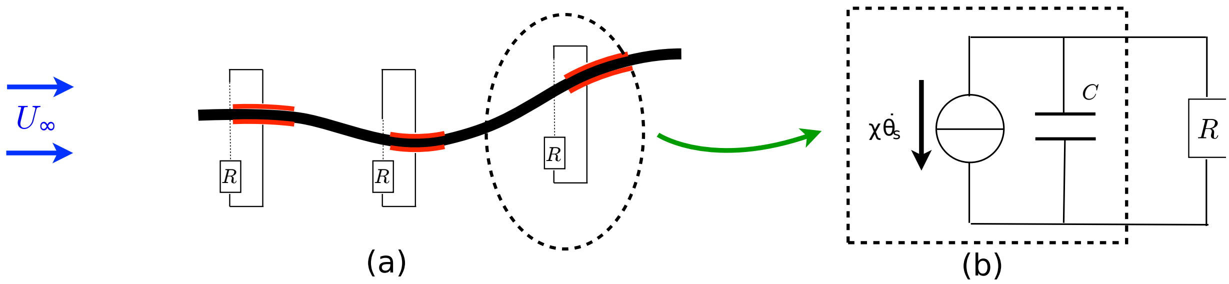

Figure 1: (a) Schematic view of a plate in an homogeneous axial flow, equipped with small length piezoelectric patches on both sides. Each piezoelectric pair is shunted with a circuit. (b) Equivalent circuit modeling of the piezoelectric patch connected to a simple resistive circuit.

In a recent work [2], considering the continuous limit where the length of the piezos is small compared to the typical wavelengths of deformation, we showed that this system is effectively able to produce electrical energy and found the conditions for maximizing the energy harvesting efficiency. We now address the consequences on the dynamics of the use of inductive electrical elements, and the effect of using non-infinitesimal length piezoelectric patches.

References

[1] Kornecki, A. and Dowell, E. H. and OBrien, J. (1976) On the aeroelastic instability of two-dimensional panels in uniform incompressible flow. *Journal of Sound and Vibration* **47**:2, 163-178.

[2] Doaré, O. and Michelin, S. (2011) Piezoelectric coupling in energy-harvesting fluttering flexible plates: linear stability analysis and conversion efficiency. *Journal of Fluids and Structures* **27**:8, 1357-1375.