Wind tunnel experiments on fluttering flat plates for parametric investigation of energy harvesting capability

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Recent developments on power generation consider fluid-structure interaction phenomena as energy sources, among which dynamic instabilities can provide effective solutions. According to the studies in literature, flutter-based solutions seem to be the most promising (*e.g.*, [1, 2]). The flutter mechanism entails self-sustained oscillations with rapidly increasing amplitudes after the critical threshold. This behaviour is suitable for energy harvesting purposes but reliable predictive models for the post-critical pattern are still missing and even experimental investigations are lacking due to the limited interest for conventional civil/aeronautical structures.

In this work, sectional models undergoing two-degrees-of-freedom (2-DoF) flutter are considered, namely elongated rectangular cross sections with width-to-depth ratios above 15:1. Their aeroelastic response can be controlled by varying the position of the elastic and mass centres. Furthermore, the damping in the heaving and pitching degrees of freedom can modify the phase of the aerodynamics loads, contributing to different typologies of Limit Cycle of Oscillation (LCO). Workable power generators require low onset wind speed, large operative range and high efficiency. Then, a systematic parametric approach is needed to find optimal configurations.

Linear analyses are used to design the experimental campaign and to determine the critical condition. Wind tunnel tests in smooth flow are performed in the CRIACIV wind tunnel, where a specific 2-DoF aeroelastic setup is designed to obtain linear mechanical properties also for large oscillations. The energy extraction is simulated via additional damping in the heaving DoF (*e.g*, [3]). LCOs are observed by both increasing and decreasing the flow velocity and the stability of the branches is evaluated with respect to different initial conditions [4].

A significant reduction of the critical wind speed is achieved by moving downward both the elastic and mass centres. In both cases, the slope of the amplitude-velocity pattern is higher than for the original configuration, producing beneficial effects on the efficiency. Moreover, when the heaving damping is increased, the downstream mass unbalance further reduces the instability threshold and extends the subcritical branch. The obtained results confirm the high potential of fluttering systems for energy harvesting applications and motivate further developments.

References

[1] K. Isogai, M. Yamasaki, M. Matsubara and T. Asaoka. Design study of elastically supported flapping wing power generator, in *Int. Forum on Aeroelasticity and Structural Dynamics*, Amsterdam, 2003.

[2] M. Bryant and E. Garcia. Modeling and Testing of a Novel Aeroelastic Flutter Energy Harvester, *J. Vib. Acoustics* 133 (1), 011010 (1-11), 2011.

[3] S. Roundy. On the Effectiveness of Vibration-based Energy Harvesting, *J. Intel. Mat. Syst. Str.* 16 (10), 809-823, 2005.

[4] X. Amandolese, S. Michelin and M. Choquel. Low speed flutter and limit cycle oscillations of a two-degree-of-freedom flat plate in a wind tunnel, *J. Fluid. Struct.* 43, 244-255, 2013.