Simultaneous passive suppression and energy harvesting from galloping using a bi-stable piezoelectric nonlinear vibration absorber

Guilherme Rosa Franzini*, Vitor Schwenck Franco Maciel*, Guilherme Jorge Vernizzi* and Daniele Zulli **

*Offshore Mechanics Laboratory (LMO), Escola Politécnica, University of São Paulo, Brazil

**University of L'Aquila, Italy

Abstract. This contributions focuses on numerical studies on the simultaneous passive suppression and energy harvesting from the galloping of a square prism. The suppressor/energy harvester is a bi-stable piezoelectric nonlinear vibration absorver (BS-PNVA). Numerical studies revealed that the investigated device can be employed for the simultaneous passive suppression and energy harvesting.

Introduction

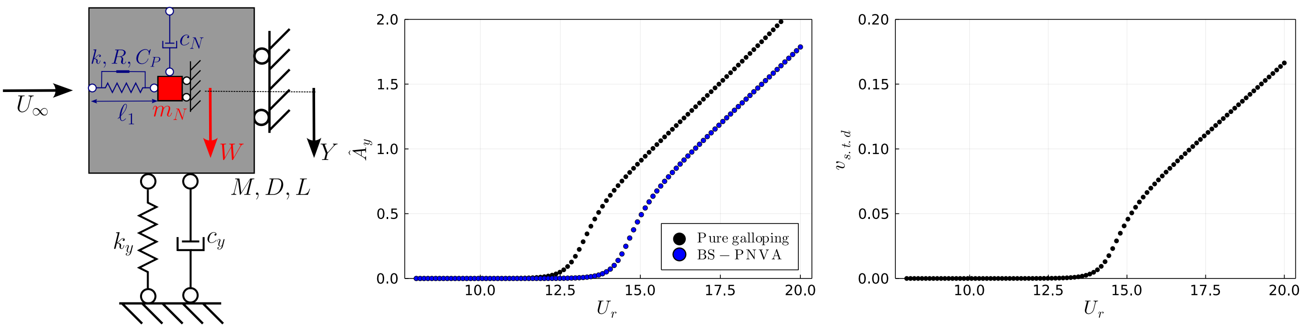
Two topics that have received attention in the last decades are the passive suppression of vibrations using nonlinear vibration absorbers (or, equivalently, nonlinear energy sinks) and the energy harvesting from structural oscillations. As the working mechanism of the nonlinear vibration absorbers involves dynamic responses of the device, some recent works take advantage of this localized motion for energy harvesting purpose. As an example, reference [1] experimentally studied the response of the system composed of a platform to which the suppressor/energy harvester is mounted.

Considering the suppression of the galloping phenomenon (a particular flow-induced vibration problem), the experimental results shown in [2] reveal that a class of nonlinear vibration absorbers effectively mitigates the vibrations of the main structure. The focus of this contribution is to present numerical studies that indicate that BS-PNVA can simultaneously mitigate the galloping response and harvest vibratory energy. At least to the best of the authors knowledge, similar studies are not found in the literature.

Mathematical model and results

The investigated system is composed of a square prism subjected to a uniform free-stream velocity profile. A BS-PNVA, composed of a small mass m_N linked to the main structure by means of a pre-compressed piezoelectric spring and a dashpot of constant c_N, works as the device for simultaneous suppression and energy harvesting; see Fig. 1(a). No impact between the main structure and the BS-PNVA occurs. The nonlinear equations of motion of the solid-fluid-electric oscillator are obtained in the dimensionless form, but not presented here for the sake of brevity of this abstract. The fluid forces are computed by means of the quasi-steady approach; see [3].

Figure 1(b) shows the oscillation amplitude of the prism a a function of the reduced velocity. As can be seen in this plot, the studied BS-PNVA is able to both postpone the critical reduced velocity associated with the Hopf bifurcation and decrease the post-critical responses. The variation of the standard deviation of the electric tension obtained at the energy harvesting circuit $v_{s.t.d}$ with the reduced velocity U_r is presented in Fig. 1(c). From the analysis of Figs. 1(b) and 1(c) one can see that the BS-PNVA is useful for the simultaneous passive suppression and energy harvesting from galloping. In the full paper, different parameters of the BS-PNVA will be considered in the numerical simulations.



(a) Investigated problem. (b) $\hat{A}(U_r)$. (c) $v_{s.t.d}(U_r)$.

Figure 1: Sketch of the investigated problem and examples of results.

References

[1] Kremer D., Liu K. (2014) A nonlinear energy sink with an energy harvester: Transient responses. *J. Sound Vib* **333**:4859-4880.

[2] Selwanis M.M, Franzini G.R., Béguin C., Gosselin F.P. (2021) Wind tunnel demonstration of galloping mitigation with a purely nonlinear energy sink. *J. Fluids Struct* **100**:103169.

[3] Blevins R.D. (2021) Flow-induced vibration. Krieger Publications.