An electromagnetic vibro-impact nonlinear energy sink for effective energy harvesting and vibration reduction of vortex induced vibrations

Haiqin Li*, Mengxin He *, and Qian Ding*

**Department of Mechanics, Tianjin University, Tianjin 300350, China*

Abstract. An electromagnetic vibro-impact nonlinear energy sink (EM-VINES) is proposed as a new type of vibration absorber and energy harvester in the application of vortex induced vibration (VIV). The considered system consists of a cylinder-like bluff body subject to an oncoming flow, coupled to a magnet attachment moving in coil of gap enclosure. It is found that EM-VINES can achieve fast targeted energy transfer over the whole lock-in region, thus providing a much more efficient way to absorb and harvest the VIVs than the classical linear and nonlinear ones.

Introduction

Vortex-induced vibration (VIV) is a special fluid-structure coupling phenomenon, that can be widely observed in various engineering fields when a flexible bluff body is subjected to an oncoming flow. Under a certain range of flow velocities, the structure exhibits near-resonant motions, termed as lock-in regime [1]. Suppression of VIVs by active and passive methods represents a significant topic in this field. Among passive methods, the use of a Nonlinear Energy Sink (NES) has gained much attention in recent years [1-3]. Thanks to the irreversible targeted energy transfer (TET) mechanism, an NES can resonate with different modes of vibration of the primary system to localize energy efficiently. On the other hand, prospects of VIV-based energy harvesting techniques could be found in[4,5].

Model description and analysis

In this contribution, we introduce an electromagnetic vibro-impact nonlinear energy sink in the vortex-induced vibrations, for both purposes of vibration suppression and energy harvesting. Such an EM-VINES was first proposed by the present author in [6] by employing a magnet moving inside the clearance of a coil-fixed primary structure. Preliminary numerical and analytical demonstrations of an EM-VINES coupled to a linear oscillator for effective vibration suppression and energy harvesting have been performed in [6,7]. The aim now is thus to introduce EM-VINES to the practical application of VIVs, see in Fig.1(a). The system consists of a cylinder host structure that undergoes an air flow with velocity U in the y direction, be able to activate VIVs in the x direction. A permanent magnet is attached in the coil-fixed clearance 2Δ. Fig.1(b) gives an example of the non-dimensional response amplitude of the cylinder with or without EM-VINES, a good reduction within the lock-in region could be observed. In Fig.1(c), the normalized electric power is reported, confirming the effectiveness of EM-VINES for energy harvesting.

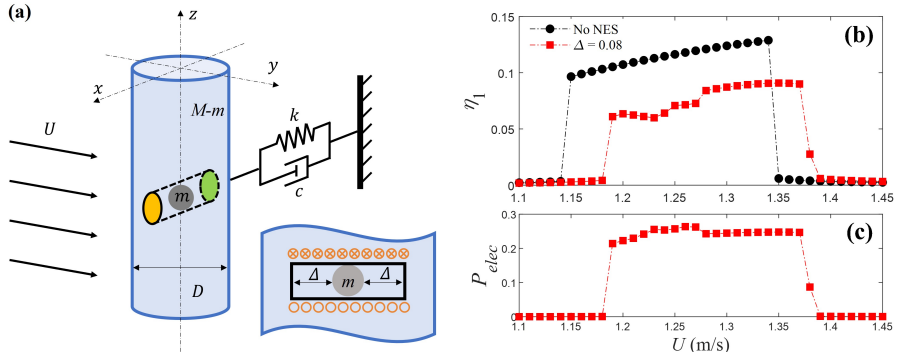

Figure 1: (a) Schematic of the cylinder structure coupled to an EM-VINES, (b) non-dimensional vibration amplitude η_1 of the host cylinder without (black) or with (with) an EM-VINES, (c) electric power P_{elec} harvested by the EM-VINES.

References

[1] A. Blanchard, L.A. Bergman, A.F. Vakakis, et al. (2019). Vortex-induced vibration of a linearly sprung cylinder with an internal rotational nonlinear energy sink in turbulent flow. *Nonlinear Dynamics*. **99(1)**: 593-609.

[2] H.Ding, L. Chen (2020). Designs, analysis, and applications of nonlinear energy sinks. *Nonlinear Dynamics*. **100(4)**: 3061-3107.

[3] A.T. Chirathalattu, B. Santhosh, C.Bose, et al. (2023). Passive suppression of vortex-induced vibrations using a nonlinear energy sink—Numerical and analytical perspective. *Mechanical Systems and Signal Processing*. **182**: 109556

[4] R.Naseer, H.Dai, A. Abdelkefi, et al. (2017). Piezomagnetoelastic energy harvesting from vortex-induced vibrations using monostable characteristics. *Applied Energy*. **203**: 142-153.

[5] Z. Lai, S. Wang, L. Zhu, et al. (2021). A hybrid piezo-dielectric wind energy harvester for high-performance vortex-induced vibration energy harvesting. *Mechanical Systems and Signal Processing*. **150**:107212

[6] H. Li, A. Li (2021). Potential of a vibro-impact nonlinear energy sink for energy harvesting. *Mechanical Systems and Signal Processing*. **159**: 107827.

[7] H.Li, A.Li, X.Kong, et al. (2022). Dynamics of an electromagnetic vibro-impact nonlinear energy sink, applications in energy harvesting and vibration absorption. *Nonlinear Dynamics*. **108(2)**: 1027-1043.