Equivalence of grounded and non-grounded NES's tuning and performance in mitigating transient vibrations

Kevin Dekemele*, Lennert De Knop*, Patrick Van Torre** and Mia Loccufier *

*Department of Electromechanical, Systems and Metal engineering, **Department of Information Technology, Ghent University Belgium

Abstract. Nonlinear energy sinks can serve as more robust vibration absorbers than linear counterparts. In literature, the most popular NES is the non-grounded NES (NGNES), where a mass is connected to a mechanical system through a highly nonlinear spring. Less know is the grounded NESs (GNES), which is connected to the mechanical system through a weak nonlinear spring spring, but grounded through a highly nonlinear spring. Although a heavier NGNES increase vibration mitigation performance, the NGNES has to belightweight, as it rests on a mechanical system. GNES design is not limited by its mass as it rests on the ground. Furthermore, the weak connecting spring increases the design flexibility compared to the NGNES. In this abstract, it will be shown that tuning and estimation prediction of the GNES performance is highly similar as previously discovered for the NGNES.

Introduction

When a highly nonlinear nonlinear energy sink (NES) is attached to a mechanical system, the vibration energy is irreversibly transferred from the mechanical system to the NES through targeted energy transfer (TET). This occurs because of highly localized nonlinear normal modes, where the vibration energy is mainly localized in the NES. At first, grounded NESs (GNESs) (Figure 1a) were investigated as the redistribution of energy between a highly nonlinear and a highly linear oscillator, connected by a weak linear stiffness [2]. Later, non-grounded NESs (NGNESs) (Figure 1b) were given more attention in literature, primarily as vibration absorbers. As a NGNES rests on the vibrating mechanical system, the NES mass is typically only a fraction of the mechanical system, e.g. 2 %. Yet in [3], it was shown that increasing the NES mass expedited vibration transfer. GNESs do not have this limitation, and additionally have extra tuning freedom with the weak connecting spring. In the paper that follows, tuning and performance prediction of both NESs will be compared.

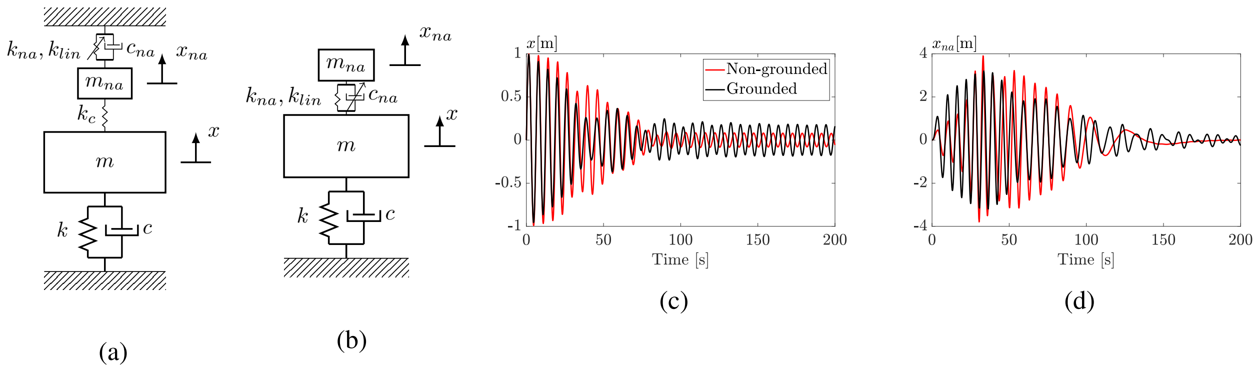

Figure 1: The non-grounded (a) and grounded (b) NES coupled to an SDOF system. Mechanical system's (c) and NES's vibration.

Results and discussion

A first numerical simulation is presented in Figures 1c and 1d. Here the mechanical system has a mass m = 1 kg, a stiffness k = 1 N/m and no damping and an initial speed of $x(0) = 1$ m/s. The NGNES has a NES mass $m_{na} = 0.02$ kg, a damping $c_{na} = 0.002$ Ns/m, and a cubic nonlinear stiffness of $k_{na} = 0.004\ \mathrm{N/m^3}$ and the GNES $m_{na} = 0.04$ kg, $c_{na} = 0.002$ Ns/m, and $k_{na} = 0.004\ \mathrm{N/m^3}$. For these particular set of coefficients, the vibrations are highly similar. In the full paper, it will be shown that their slow invariant manifolds (SIM) are equivalent, and that the GNES has more tuning freedom. The SIM describes the slow evolution of the vibration envelopes. The performance of both NESs is also predicted by simple analytic formulae similar to those found in [3].

References

[1] Gendelman O. V. (2001) Transition of Energy to a Nonlinear Localized Mode in a Highly Asymmetric System of Two Oscillators. *Nonlinear Dyn* **25**(13):237-253.

[2] Kerschen G., Lee S. L., Vakakis A. F., McFarland D. M. and Bergman L. A. (2006) IRREVERSIBLE PASSIVE ENERGY TRANSFER IN COUPLED OSCILLATORS WITH ESSENTIAL NONLINEARITY. *Siam J. Appl. Math* **66**(2):648-679.

[3] Dekemele K., De Keyser R. and Loccufier M. (2018) Performance measures for targeted energy transfer and resonance capture cascading in nonlinear energy sinks. *Nonlinear Dyn* **93**(2):259-284.