Nonlinear resonator based metastructures for vibration attenuation and energy harvesting

P V Malaji*, T Mukhopadhyay ** and S S Chappar*

*Department of Mechanical Engineering, BLDEA'sV P Dr P G halakatti College of Engineering and Technology, Vijayapur, Karnataka, India

**Department of Aerospace Engineering, IIT Kanpur, Kanpur, Uttar Pradesh, India

Abstract. This article reports simultaneous enhancement of the frequency band gap of main structure and bandwidth of energy harvested in metamaterials based finite structure via nonlinear attachments. The nonlinear attachments act as an attenuator as well as the harvester forms a unit cell. When subjected to excitations of various intensities these nonlinear unit cells exhibit linear, softening, and hardening nonlinear dynamics. This results in attenuation of resonant band gaps at low amplitudes and attenuation due to wideband chaotic vibrations at large amplitudes. To demonstrate the concept a linear spring mass chain with nonlinear attachments is analyzed numerically. The band gap and bandwidth offered by proposed structure will be wider than that of the structure with linear resonant unit cells.

Introduction

Mitigation of structural vibration in machines, buildings, aircraft structures is a serious concern for most of the practical applications across different disciplines. Keeping structures safe and improving durability are crucial to the economic progress and sustainability [1]. The vibration absorbers or tuned mass dampers are the conventional methods for suppressing vibrations. This approach of vibration mitigation is effective only at frequency they have been tuned. The nonlinear energy sinks use cover wider range of frequencies for vibration mitigation [2] but have limitation from weight point of view. A metamaterial with number of unit cells as absorbers has the flexibility of tuning many parameters to attain the desirable band gap [3]. These absorbers, when used as nonlinear resonators, can enhance the band gap to a much wider range than single absorber. However, the literature on metastructure for vibration attenuation and energy harvesting with nonlinear resonators is limited. The present work considers linear primary system with nonlinear resonators attached with piezoelectric patches to analyse its capability to mitigate vibration and harvest electric energy.

Results and discussion

The proposed work will focus on using multiple nonlinear resonators for vibration mitigation and energy harvesting simultaneously as shown in Fig. 1 (a). The metastructure consists of main mass m and unit cell with nonlinear resonators of mass m_r, K_n is the cubic stiffness. Piezo patch is attached to resonators with piezoelectric coefficient θ, capacitance C and resistance R for energy harvesting. Runge-Kutta method is used for numerically simulation. Non-dimensional results of primary mass amplitude for a single unit cell with spring softening is shown in Fig. 1(b). Amplitude reduction at second mode with nonlinear resonator can be observed which was the primary objective the work. Power output and results with multiple resonators will be reported in full length paper.

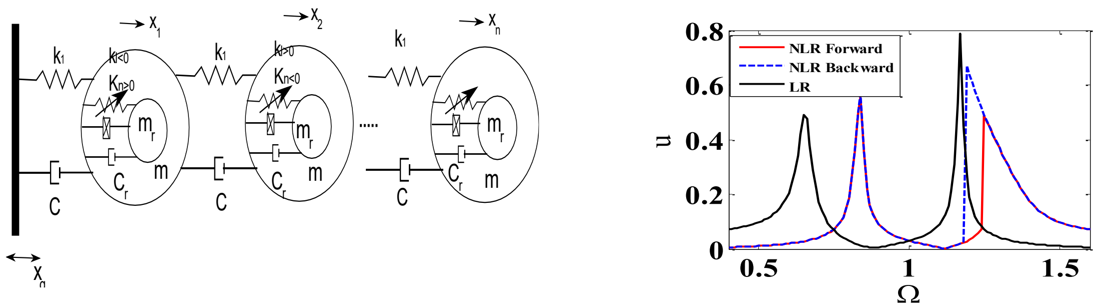

Figure 1: (a) Schematic of a metastructure with main system and unit cell consisting of nonlinear resonator with piezo transducer, (b) Non-dimensional displacement of Primary(main) mass with local resonators (NLR- Nonlinear Resonators, LR- Linear Resonators)

References

[1] Ali S F and Ramaswamy A (2009) Optimal Dynamic inversion Based Semi-active Control of Benchmark Bridge using MR Dampers, Structural control and Health Monitoring. 16, 564- 585.

[2] Vakakis A F, Gendelman O V, Bergman L A, McFarland D M, Kerschen G and Lee Y S (2009) Nonlinear Targeted Energy Transfer in Mechanical and Structural Systems, Springer, Dordrecht, Netherlands.

[3] Zhu R, Liu X, Hu G, Sun C, Huang G A (2014) Chiral Elastic Metamaterial Beam for Broadband Vibration Suppression, Journal of Sound and Vibration, 333(10), 2759–2773.