Energy pumping of mechanical oscillators in an array configuration under impulse and parametric excitation.

P Arjun*, Vinod V*

**Department of Mechanical Engineering, Mar Baselios College of Engineering and Technology, APJAKTU, Thiruvananthapuram, KERALA, INDIA, ORCID:0000-0003-3897-3388 #*

Abstract. The simplest form of a passive nonlinear sink in a vibrating system consists of two linear oscillators with a strong nonlinear attachment connected to one linear oscillator [1]. The energy pumping is unidirectional, i.e. absorbing vibrational energy from the linear to nonlinear oscillator. For better understanding of this energy pumping phenomenon we had considered a large number of oscillators in the form of array (chain) network. The main objective is to investigate the robustness of energy pumping towards the passive nonlinear sink at one end from the farthest oscillator in the other end of the chain. Furthermore, energy pumping in this large chain is investigated when subjected to parametric excitation in spring element instead of impulse excitation.

Introduction

In this paper, we present a model of 'N' oscillators with same linear natural frequency in a chain. In this chain, the first oscillator is having a strong nonlinear attachment (m_1) in its spring element which is presumed to act as a energy reservoir in the chain. The oscillators in the chain are arranged in such a way that the vibration energy under impulse excitation (F) from one end of the chain will have to traverse to the other end of the chain during the energy transfer. The computer simulations in MATLAB are done using Runge Kutta ode45 solver with time step of 10^{-3} used for integration and integration times of nearly 100 cycles.

Results and discussion

Energy transfer in a chain under impulse excitation

The results presented here are in a chain having $N = 10$. Here we initiate the analysis by giving an impulse (F) as initial velocity to an intermediate linear oscillator in the chain (m_5). For F = 1.5, no energy transfer occurs as major part of energy is stored in the excited oscillator. By increasing the initial energy level to say F = 2.2, there occurs an irreversible transfer of energy from m_5 to m_1 as in Figure.1(a) . The reason behind this energy transfer is due to the internal resonance capture studied in [2]. An interesting point to be noted is even at F = 2.2 or any higher value, it is impossible to have such an energy pumping from the two ends of the chain i.e. m_{10} to m_1. To analyse the energy pumping phenomenon from m_{10}, we give a slight frequency mismatch to m_1 in its linear natural frequency, We note that, in contrast to Figure.1(a), the energy pumping occurs from one end to other end of the chain as shown in Figure.1(b). This shows that a slight perturbation in frequency triggers the nonlinear energy transfer due to modal interaction. Also the energy pumping towards m_1 can be enhanced by bringing in self-oscillatory term in damping instead of spring cubic nonlinearity in the model.

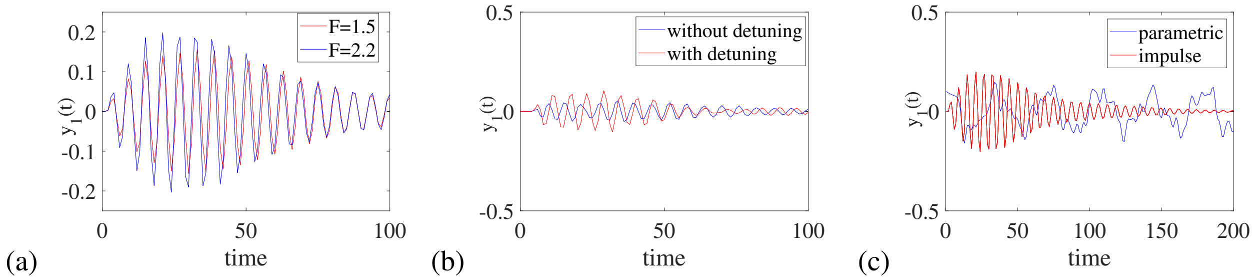

Figure 1: (a) Energy transfer towards m_1 at F=2.2 (b) Spatial spread of energy transfer from m_{10} via frequency detuning (c)Predominant energy pumping towards m_1 in a chain under parametric excitation.

Energy transfer in a chain under parametric excitation

Here also we consider the same $N = 10$ chain network. The parametric excitation $k_{pe}\cos\omega t$ is given to the stiffness term of m_5 and m_{10} as two seperate simulation cases.In the first 200 seconds, no energy transfer occurs as the value of k_{pe} is kept zero. After 200 seconds the parametric stiffness excitation is turned on by increasing the value of k_{pe} to 0.2. This initiates the energy pumping from all oscillator nodes towards m_1. Morover the energy transfer due to this parametric resonance is more robust when compared with impulse excitation as in Figure.1(c). Frequency detuning in the nonlinear sink is not required here to pump energy from m_{10} to m_1.

References

[1] O. Gendelman, L. I. Manevitch, A. F. Vakakis, R. M'Closkey (2001) Energy Pumping in Nonlinear Mechanical Oscillators: Part I—Dynamics of the Underlying Hamiltonian Systems. *J. Applied Mechanics, ASME Trans.* **68**:34-41.

[2] O. Gendelman, A. F. Vakakis (2001) Energy Pumping in Nonlinear Mechanical Oscillators: Part II—Resonance Capture. *J. Applied Mechanics, ASME Trans.* **68**:42-48.