A broadband magnet-induced cantilever piezoelectric energy harvester coupled to nonlinear energy sink

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Abstract. A broadband magnet-induced cantilever piezoelectric energy harvester (PEH) is designed, realized and coupled to a nonlinear energy sink (NES). The cantilever beam has a magnet attached to the tip and is coupled to the NES through magnetic force. The NES consists of a spring, a slider, and an oscillator mass with a magnet. The magnets generate nonlinear attractive or repulsive force between the cantilever and NES make the structure monostable or bistable. The structure are simulated and tested to observe the energy harvesting performance. Compared with simple piezoelectric cantilever beam, the NES enhanced version has a wider energy frequency band. The distance between magnets is adjusted to observe its effect on the harvested power.

Introduction

The NES has a variable natural vibration frequency, which can produce a series of resonance captures with the primary structure, effectively achieving a wider vibration absorption frequency band compared to linear absorbers. By combing the NES with a vibration energy harvester, it can effectively absorb the vibration energy from the primary structure and convert the vibration energy into electrical energy in a wider frequency band. In 2014, Ahmadabadi and Khadem [1] first proposed the concept of a vibration energy collection system consisting of NES and piezoelectric vibration energy collector, and optimized the system parameters globally, obtaining satisfactory energy harvesting effect. Fauve and Heslot [2] pointed out that stochastic resonance phenomenon can significantly enhance the vibration response of piezoelectric vibrator under low frequency and small amplitude mechanical vibration source, and increase the charge output. Therefore, here we will explore the use of NES to capture small amplitude low-frequency vibration, and then the NES vibrator excited the piezoelectric energy capture device (Figure 1), which generated high-frequency vibration and improved the capture efficiency of vibration energy.

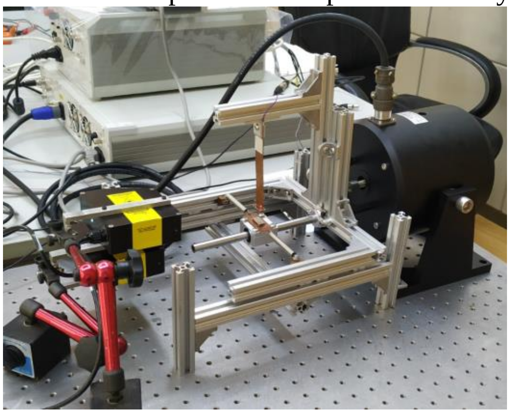

Figure 1: The Experimental Setup.

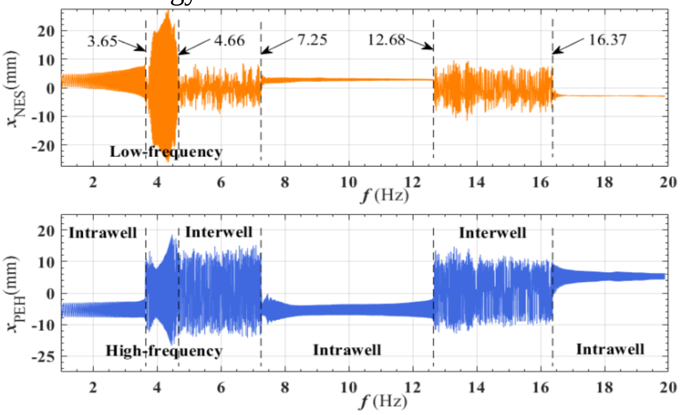

Figure 2: Oscillators Displacement versus Frequency (a = 0.3g, d = 13 mm)

Results and discussion

Figure 2 shows the displacement of the oscillators when the distance of the magnets d is 13 mm under 0.3g acceleration. Sinusoidal forward sweep is adopted for excitation. In the range of 1~3.65Hz, the displacement of NES oscillator and PEH oscillator stay in one stable state, that is, intrawell vibration. Within 3.65~4.66Hz, the NES oscillator has a large amplitude of low-frequency vibration, while the PEH oscillator is excited to generate high-frequency vibration, meanwhile, the power generated is also the highest. Within 4.66~7.25Hz, the vibration will continuously switching between monostable and bistable states, resulting in interwell vibration. It turns to intrawell vibration within 7.25~12.68 Hz. Due to the PEH resonance, it turns to interwell vibration in the range of 12.68~16.37Hz.

References

[1] Nili Ahmadabadi Z, Khadem SE. (2014) Nonlinear vibration control and energy harvesting of a beam using a nonlinear energy sink and a piezoelectric device. *Journal of Sound and Vibration*, **333**(19): 4444-4457.
[2] Fauve S, Heslot F. (1983) Stochastic resonance in a bistable system. *Physics Letters A*, **97**(1-2): 5-7.