Theoretical Analysis of Nonlinear Response in Vibrational Energy Harvesters

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[Introduction]

We have demonstrated piezoelectric MEMS vibrational energy harvesters (PVEHs) using $BiFO_3$ films[1]. It was found that the harvesters show nonlinear vibration with hard spring behavior. It is believed that the nonlinear resonance widen the response bandwidth of the harvester. The widen bandwidth comes from the bend in the frequency – response curves[2]. However, the demonstrated nonlinear harvesters do not show wider bandwidth and larger output power when the vibration in real environment is applied. In this study, the energy requirements of the nonlinear vibrating system to obtain the larger output and wider bandwidth are discussed by using a nonlinear electromechanical model.

[Method and Results]

Nonlinear electromechanical model based on the Duffing-nonlinear oscillator[3] is used to examine the factors affecting on the response bandwidth. The piezoelectric effect in the equation of motion results in a contribution to the total of damping and total stiffness of mechanical system. The strength of both piezoelectric damping and stiffness are a function of excitation frequency. The system equations of Duffing-type nonlinear generator for the primary frequency response were solved using the harmonic balance method.

Fig. 1 shows the calculated results of the dimensionless amplitude-frequency response of oscillators with strong or light nonlinearity and with soft or hard spring behavior. As can be seen, these four types of oscillators are obtained by changing the parameters in the model. In the point of view of practical applications, the comparison between oscillators with different response is critical to decide their application and limitation. We discuss the condition to obtain higher output power and wider bandwidth than the harvesters with linear resonance.

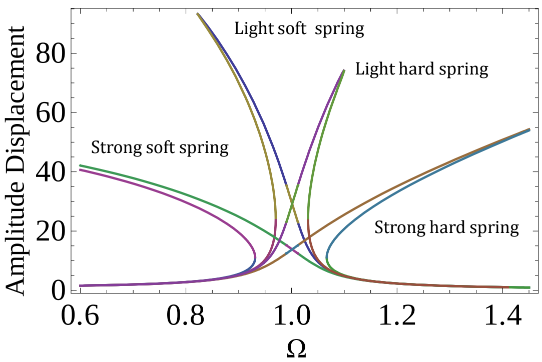

Fig.1: Dimensionless amplitude-frequency response for softening and hardening systems. Where, $\mathbf{\Omega} = \omega/\omega_0$, ω & ω_0 the excitation and resonance frequencies.

[References]

[1] T. Yoshimura et al., Appl. Phys. Exp. 6 (2013) 051501

[2] S. P. Beeby, et al., Smart Mater. Struct. **22** (2013) 075022

[3] S. Neiss et al., Smart Mater. Struct. **23** (2014) 105031

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