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Quasiperiodic energy harvesting in a delayed and excited Rayleigh-Duffing harvester device near secondary resonances

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Abstract. This paper studies quasiperiodic vibration-based energy harvesting in a delayed and excited Rayleigh-Duffing oscillator coupled to piezoelectric harvester device. Analytical investigation is performed using the multiple scales method to obtain approximation of periodic and quasiperiodic amplitude responses as well as the corresponding power output near secondary resonances of order 3. The influence of different parameters of the harvester on the amplitude of solutions and powers is examined. Results show that for moderate values of the amplitude of the external forcing, time delay can substantially improve quasiperiodic vibration-based energy harvesting in the vicinity of a secondary resonance.
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Introduction

We consider a harvester device consisting in a delayed and excited Rayleigh-Duffing oscillator coupled to an electrical circuit through a piezoelectric device.The corresponding equation of motion for the harvester is given in the non-dimensionalform by

$$\ddot{\eta}(t) + \omega_0^2\eta(t) - \alpha(1-\dot{\eta}(t)^2)\dot{\eta}(t) + \gamma\eta(t)^3 - \theta v(t) = Fcos(\omega t) + D_p\eta(t-\tau) + D_v\dot{\eta}(t-\tau)$$
$$\dot{v}(t) + \beta v(t) + \kappa\dot{\eta}(t) = 0$$

where $\eta(t)$ is the relative displacement of the rigid mass $m, v(t)$ is the voltage across the load resistance,α is the mechanical damping ratio, θ is the piezoelectric coupling term in the mechanical attachment, κ is the piezoelectric coupling term in the electrical circuit, β is the reciprocal of the time constant of electrical circuit, F and ω are, respectively, the amplitude and the frequency of the external excitation, τ is the time delay, while Dp, Dv are, respectively, the position, the velocity feedback gains. Investigation of quasiperiodic vibration-based energy harvesting for this harvester device has been carried out near the principal resonance in [1]. The purpose here is to study quasiperiodic vibration-based energy harvesting performance near the secondary resonances of order 3. Analytical investigation is performed using perturbation methods [2, 3].

Results shown that for small value of delay amplitudes, quasiperiodic vibration-based energy harvesting can be extracted in a broadband of frequencies not only near the principal resonance [1], but also in a broadband of frequencies around the secondary resonances of order 3.

References

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