Vibration mitigation by two parametric anti-resonances in high-Q resonators: a preliminary case study

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Abstract. The anti-resonance is a well-known phenomenon for two degrees of Freedom (DOF) systems; this contribution presents a potential application of this concept to cancel the transient vibrations. The technique applies two pulses of parametric excitation adequately tuned at the anti-resonance frequencies. A simulation experiment of an array of microelectromechanical systems (MEMS) with three DOF is presented.

Introduction

MEMS with a high-quality factor ($Q = \omega_i/\gamma_i$) have been used in many applications; they have high damping; nevertheless, their transition time to a steady state (t_{ss}) is too long. In [1,2] is presented a technique to reduce t_{ss} using the anti-resonance effect. This contribution describes an improvement and extension of this technique.

Results

The simplified dynamic model of a high-Q MEMS for a beam can be described by $\ddot{x} + \gamma_1\dot{x} + \omega_1^2 x = 0$; here, the free enveloped response presents a long $t_s s$, as is shown in Fig 1 a). Then, if two beams with a very close natural frequency are added and coupled by a periodic signal, the resulting system can be described by
Let the system of equations:

$$\ddot{x} + \Gamma\dot{x} + (\Omega + B_1\beta_1\eta(t) + B_2\beta_2\nu(t))\, x = 0 \tag{1}$$

where $\Gamma = \begin{bmatrix}\gamma_1 & 0 & 0\\ 0 & \gamma_2 & 0\\ 0 & 0 & \gamma_3\end{bmatrix}$, $\Omega = \begin{bmatrix}\omega_1^2 & 0 & 0\\ 0 & \omega_2^2 & 0\\ 0 & 0 & \omega_3^2\end{bmatrix}$, $B_1 = \begin{bmatrix}0 & b_{12} & 0\\ b_{21} & 0 & 0\\ 0 & 0 & 0\end{bmatrix}$, $B_2 = \begin{bmatrix}0 & 0 & b_{13}\\ 0 & 0 & 0\\ b_{31} & 0 & 0\end{bmatrix}$, $\eta(t) = \cos(\omega_{p_1} t)$ and $\nu(t) = \cos(\omega_{p_2} t)$. Then, the system (1), is coupled by two parametric excitation signals at frequencies $\omega_{p_1} = \omega_2 - \omega_1$ and $\omega_{p_2} = \omega_3 - \omega_1$. The parametric excitation signals are applied in a short period t_{pulse}, named pulses. [1] provides a formula to compute t_{pulse}. Simulating the equations for some values of γ_i, ω_i and b_{ij} in the Fig. 1 the results are shown. Fig. a) depicts the free enveloped response of the system in the first mode $x_1(t)$, which can be observed as $t_{ss} = 0.1$ sec. Fig b) presents the response under the pulses of parametric excitation $\eta(t)$ and $\nu(t)$, where the t_{ss} is reduced to 6.6 ms. The excitation pulse's effect is rapidly transferring the vibrations from the first mode to the other two modes acting as dampers once the excitation pulse is over.

References

[1] Ramírez-Barrios M., Dohnal F., Collado J.(2020). Enhanced vibration decay in high-Q resonators by confined of parametric excitation. *Archive of Applied Mechanics* **90**:1673–1684.

[2] Ramírez-Barrios, M., Dohnal, F., Collado, J. (2020). Transient Vibrations Suppression in Parametrically Excited Resonators. LASIRS 2019. Mechanisms and Machine Science, vol 86. Springer, Cham.

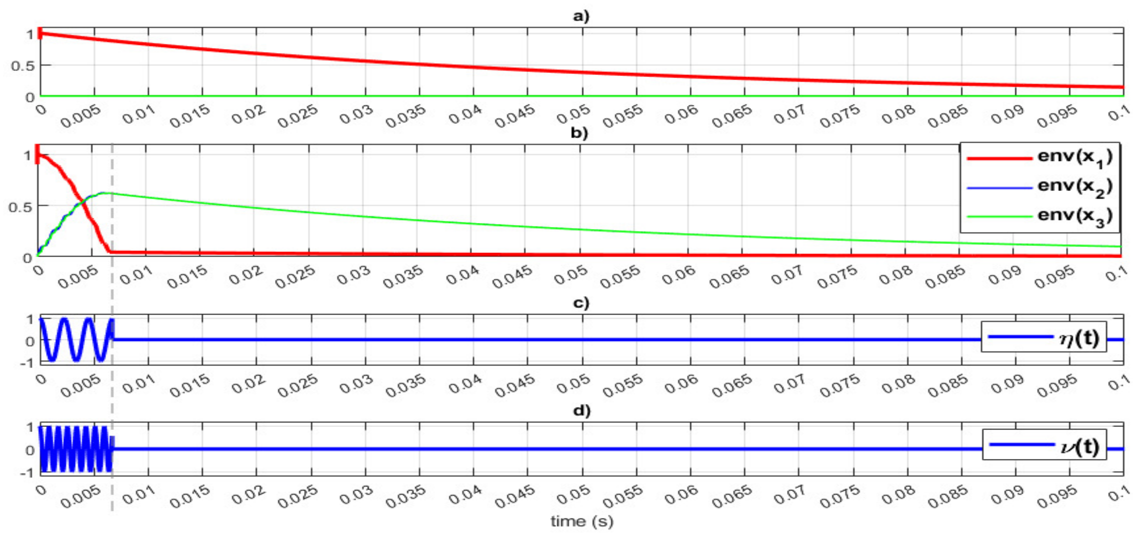

Figure 1: