

Dual frequency vibration absorber

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1. Introduction

One way of vibration suppression of mechanical systems is traditionally the usage of vibration absorber. It consists of one mass attached by spring, damper and also an actuator into the vibrating mechanical system. The actuator is usually used for precise tuning of tonal vibration suppression. Such vibration absorber can suppress one frequency in tonal way or some interval of frequencies in the vicinity of tuned frequency.

The paper describes the way how to achieve dual tonal frequency vibration suppression by one mass vibration absorber. Previous attempts [1-2] were using delayed feedback and they suffer from difficult tuning combined with stability analysis. This paper describes another approach with straightforward and simple tuning and stability analysis. The feedback law of force actuator is increasing the single mass dynamics in such way that two tonal frequencies can be placed into the vibration absorber. The paper then investigates the stability regions of dual frequency vibration absorber and the resulting vibration suppression of the overall mechanical system.

2. Formulation

The system of primary mass (mass m_b , stiffness k_b , damping b_b) with active vibration absorber (mass m_a , stiffness k_a , damping b_a) in Fig. 1 is described by the equation of motion

$$m_a \ddot{x}_a = b_a (\dot{x}_b - \dot{x}_a) + k_a (x_b - x_a) + u, \quad (1)$$

$$m_b \ddot{x}_b = -b_b (\dot{x}_b) - k_b (x_b) - b_a (\dot{x}_b - \dot{x}_a) - k_a (x_b - x_a) - u + F. \quad (2)$$

In order to achieve dual frequency vibration absorber it is needed to place two frequencies ω_1 , ω_2 into absorber (1) by the control u . It can be achieved by the control law PDII² in bellow.

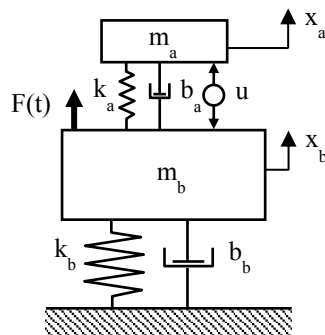


Fig. 1. Primary system m_b and vibration absorber m_a

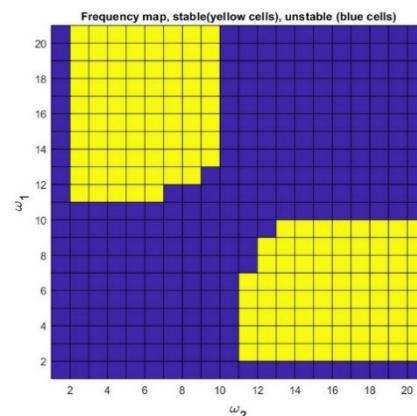


Fig. 2. Frequency map of $(\omega_1$ and ω_2), each frequency is ten times the current grid

$$u = -k_p x_a - k_d \dot{x}_a - k_1 \int x_a dt - k_2 \iint x_a dt dt, \quad (3)$$

$$u = -k_p x_a - k_d \dot{x}_a - k_1 \int x_a dt - k_2 \iint x_a dt dt + e_b \dot{x}_b + d_b \ddot{x}_b + k_{1b} \int x_b dt + k_{2b} \iint x_b dt dt. \quad (4)$$

Then, the vibration absorber (1)-(3) with the primary system (3) are stable in some intervals of frequencies ω_1 , ω_2 but not overall, so there is no guaranteed stability. This means that the combined system for some tuned frequencies ω_1 , ω_2 is stable and for another ones unstable. The regions/islands of stability are in the plane ω_1 , ω_2 . The ω_1 , ω_2 are parameters of the stability of overall combined system. For some values stable, for another unstable.

3. Results

The proposed control law (3)-(4) has been used by two approaches. First case I was with tonal vibration absorber where $\alpha_{1a} = 0$ and $\alpha_{2a} = 0$, (absorber can be tuned to poles $-\alpha_{1a} \pm j\omega_{1a}$, $-\alpha_{2a} \pm j\omega_{2a}$) using partial feedback with gains (db=10 and eb=-1500, k1b=0, k2b=0). The map of stable/unstable frequencies is in Fig. 2 and resulting complete vibration suppression in Fig. 4 above. Second case II was with non-tonal vibration absorber where $\alpha_{1a} = -0.001$ and $\alpha_{2a} = -0.001$ are non-zero. But the partial feedback gains are zero (db=0 and eb=0, k1b=0, k2b=0). The map of stable/unstable frequencies is in Fig. 3 and resulting vibration suppression in Fig. 4 below.

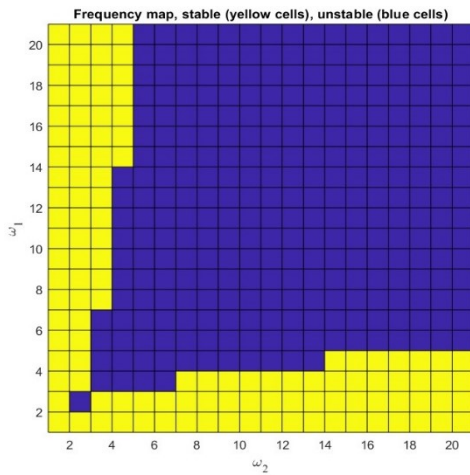


Fig. 3. Frequency map of (ω_1 and ω_2) case II, each frequency is ten times the current grid

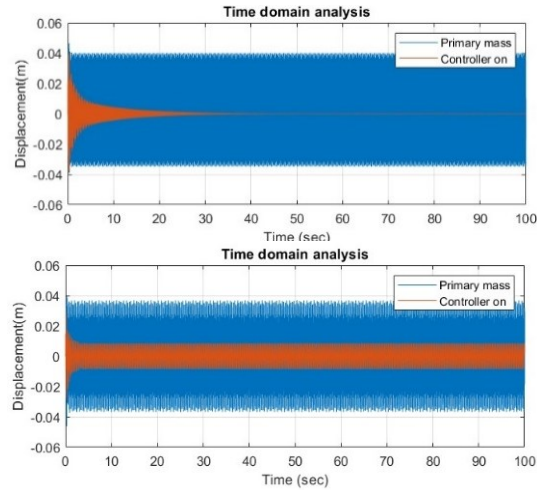


Fig. 4. Resulting vibration response

4. Conclusions

The dual frequency vibration suppression is achieved using two case studies. First case study with tonal damping shows good suppression whereas in the second case the degree of suppression is satisfactory. Apart from that, the number of stable and unstable frequencies are localised and plotted in the frequency map.

Acknowledgement

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References

- [1] Valášek, M., Olgac, N., New concept of active multiple-frequency vibration suppression technique, In Smart Structures, Springer, Dordrecht, 1999, pp. 373-382.
- [2] Valášek, M., Olgac, N., Neusser, Z., Real-time tunable single-degree of freedom, multiple-frequency vibration absorber, Mechanical Systems and Signal Processing 133 (2019) 1-14.