

Technical University of Denmark



Balanced Design of Resonant Shunted Piezoelectric Vibration Control

Høgsberg, Jan Becker; Krenk, Steen

Publication date:
2012

[Link back to DTU Orbit](#)

Citation (APA):

Høgsberg, J. B., & Krenk, S. (2012). Balanced Design of Resonant Shunted Piezoelectric Vibration Control. Abstract from 8th European Solid Mechanics Conference, Graz, Austria.

DTU Library
Technical Information Center of Denmark

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Balanced Design of Resonant Shunted Piezoelectric Vibration Control

Jan Høgsberg, Steen Krenk

Department of Mechanical Engineering, Technical University of Denmark
Nils Koppels Allé, building 403, 2800 Kgs. Lyngby, Denmark
jhg@mek.dtu.dk, sk@mek.dtu.dk

ABSTRACT

Shunting of piezoelectric transducers and suitable electric circuits constitutes an effective passive approach to resonant vibration damping of structures. Most common design concepts for resonant RL shunt circuits rely on either maximization of the attainable modal damping or minimization of the frequency response amplitude, see [1, 2, 3]. However, the maximum modal damping is sub-optimal near resonance, where it leads to constructive interference of two modes with identical frequency, while frequency response minimization leads to reduced implemented damping.

Assuming that the vibrations of the structure are dominated by a single mode, the equations of motion for the series RL electromechanical system can be written as, see e.g. [2],

$$(-\omega^2 + 2i\zeta_s\omega_s\omega + (1 + \kappa^2)\omega_s^2)x = \kappa^2\omega_s^2\xi + f \quad (1)$$

$$(-\omega^2 + 2i\zeta_e\omega_e\omega + \omega_e^2)\xi = \omega_e^2x, \quad (2)$$

where x is the response amplitude, ξ is the normalized charge, ω_s is the natural frequency of the structure, ζ_s is the corresponding structural damping, κ is the generalized electromechanical coupling coefficient and ω_e and ζ_e are the frequency and damping ratio of the shunt circuit, respectively. For the parallel shunt circuit the right side of (2) is replaced by $(\omega_e^2 + 2i\zeta_e\omega_e\omega)x$.

The present paper proposes an explicit fully pole placement based design procedure for both series and parallel RL circuits. The procedure relies on equal modal damping and sufficient separation of the complex poles to avoid constructive interference of the two modes. It follows the procedure explained for the tuned mass damper in [4] and developed for a family of resonant control formats in [5]. It leads to the following expressions for the series circuit

$$\omega_e = (1 + \kappa^2)\omega_s, \quad \zeta_e = \sqrt{\frac{\kappa^2}{2(1 + \kappa^2)}}, \quad (3)$$

while for the parallel circuit it gives

$$\omega_e = \omega_s, \quad \zeta_e = \frac{\kappa}{\sqrt{2}}. \quad (4)$$

Figure 1 shows (a) the frequency response amplitude of the structure, (b) the frequency amplitude of the control, (c) the root locus trajectories and (d) the modal damping ratio. By comparison with existing design procedures it is demonstrated that the present calibration leads to a balanced compromise between large modal damping and effective response reduction with limited damping effort.

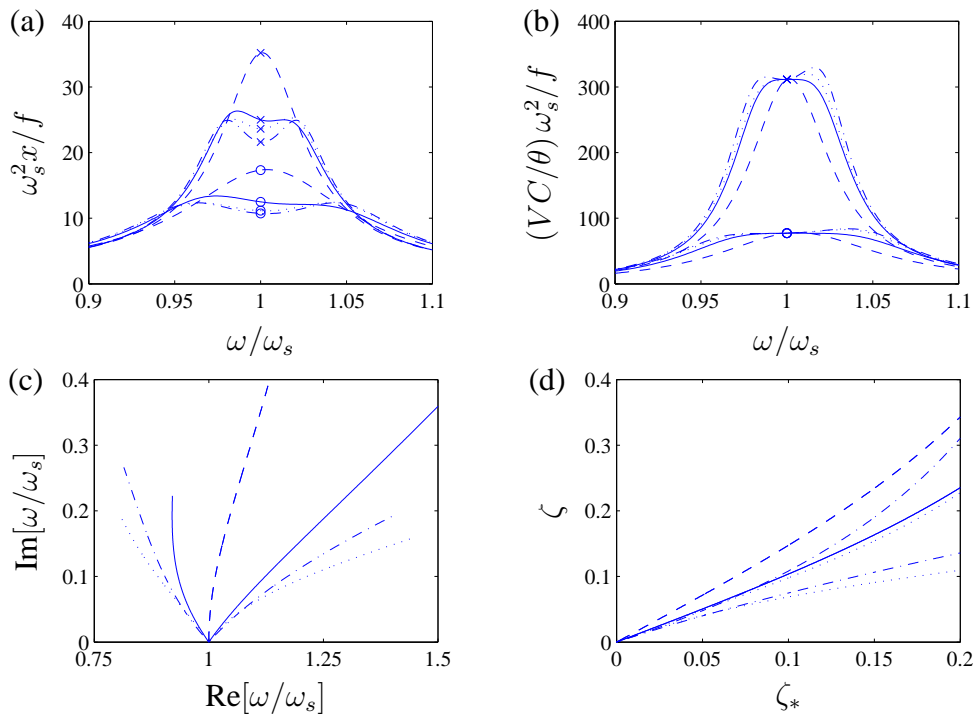


Figure 1: Series *RL*: (a) Response amplitude, (b) voltage amplitude, (c) root locus, (d) damping ratio. Balanced design (—), maximum damping (---), minimum amplitude (·····), fixed point (- · - · -). Design damping ratio $\zeta_* = 0.02$ (\times) and 0.04 (\circ) in (a,b) and $\zeta_* = 0 \dots 0.2$ in (c,d).

References

- [1] N.W. Hagood and A. von Flotow, Damping of structural vibrations with piezoelectric materials and passive electrical networks. *Journal of Sound and Vibration*, 146:243-268, 1991.
- [2] G. Caruso, A critical analysis of electric shunt circuits employed in piezoelectric passive vibration damping. *Smart Materials and Structures*, 10:1059-1068, 2001.
- [3] K. Yamada, H. Matsuhisa, H. Utsuno and K. Sawada, Optimum tuning of series and parallel LR circuits for passive vibration suppression using piezoelectric elements. *Journal of Sound and Vibration*, 329:5036–5057, 2010.
- [4] S. Krenk, Frequency analysis of the tuned mass damper. *Journal of Applied Mechanics*, 72:936-942, 2005.
- [5] S. Krenk, and J. Høgsberg, Equal modal damping formats for resonant vibration control. *Technical University of Denmark*, Lyngby, Denmark, 2012.