Vibration Damping in Periodic 1D-Structures
by R-Shunted Piezoelectric Elements
Jan Høgsberg
Department of Mechanical Engineering
Technical University of Denmark, DK-2800 Kongens Lyngby, Denmark
e-mail: jhg@mek.dtu.dk

ABSTRACT

The design of periodic structures with deliberate inhomogeneous inserts or voids has been investigated extensively with the goal of creating structures with large band gaps that optimally eliminate the existence waves at a given wavelength. Thus, the optimal design of band gaps has a direct application in the form of effective spatial filters for wave and noise problems [1]. The particular layout of the periodic structure depends on the specific engineering problem and for example topology optimization has been used to design the optimal geometry of the underlying unit cell of the periodic structure.

The present paper specifically addresses the vibration damping of one-dimensional periodic structures by piezoelectric elements placed in the unit cell and then shunted with a pure resistance. The purpose of the R-shunt is to maximize the damping of the vibrational response and wave propagation in the periodic structure. It is well known that an R-shunted piezoelectric element acts as an equivalent Maxwell element, with a spring and dashpot placed in series and thus the R-shunt modifies both stiffness and dissipative properties of the piezoelectric elements in the unit cell.

The aim is to formulate explicit solutions for the complex natural frequency of the unit cell (and thus the periodic structure) for a given wavenumber. Hereby, the imaginary part of the complex natural frequency can be maximized, which gives optimal attenuation properties. The approach is based on an augmented modal representation associated with a given wavenumber. In classic structural dynamics, the vibrational response of the damped structure with a finite resistance is alone represented by the vibration form associated with short-circuit conditions. This simplified approach unfortunately omits the change in mode shape due to the presence of the shunt. In the present case the structural motion at a piezoelectric element is instead augmented by an additional flexibility that is calibrated to secure the correct natural frequency for open-circuit electrodes. This two-term modal representation therefore provides the exact vibrational characteristics in the two limits associated with vanishing and infinite shunt resistance, and it can therefore be used as basis for the solution of the intermediate problem with finite resistance and thus damping. This approach has been used in [2] for viscoelastic damping of flexible structures and the present paper demonstrates that this solution technique can be readily applied in damping of periodic structures.

A classic 1D spring-mass structure is considered [1], in which piezoelectric disks are placed in the unit cell. For various configurations the optimal shunt resistance is determined based on the proposed two-term representation and compared with the actual optimum, obtained by a full numerical search procedure. It is investigated how much damping can be introduced and how well this corresponds with the estimates obtained by the proposed explicit solution format. In future work the concept can be extended to resonant RL-shunts or shunts with either negative capacitance or pure inductance, whereby the band structure may be altered more drastically.

REFERENCES
