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Influence of the filling factor on wave attenuation in 1-D viscoelastic phononic crystal rods made of PLA

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Introduction

- **Phononic Crystals (PnCs)**: Periodic structures designed to control elastic wave propagation through variations in material properties and geometry.
- **Bragg-Type Bandgaps**: Frequency ranges in which wave propagation is prohibited due to destructive interference caused by periodic scattering.
- **Viscoelasticity**: Material behavior combining elastic deformation and energy dissipation, leading to wave attenuation and changes in dispersion characteristics.



Figure 1. Schematic representation of (a) phononic crystals; (b) Bragg-type bandgaps; and (c–e) applications at different frequency ranges.

Objective: To investigate the influence of the PLA filling factor, ranging from 0% to 100%, on wave propagation and attenuation in 1-D viscoelastic PnCs rods.

PnC Modelling

Plane wave expansion (PWE) and extended plane wave expansion (EPWE): The longitudinal wave propagation in the 1-D viscoelastic PnC is investigated using the PWE and EPWE methods. The equation of motion for the rod is given by

$$A\frac{\partial}{\partial x}\left[E^*(x,\omega)\frac{\partial u(x,\omega)}{\partial x}\right] + \omega^2 A\rho(x)u(x,\omega) = 0$$

For a 1-D periodic structure, the first Brillouin zone (FBZ) is defined as $-\pi/Lc \leq k \leq \pi/Lc$

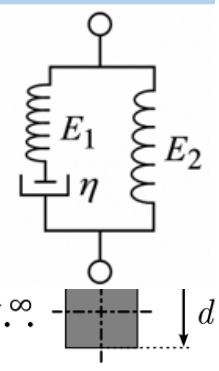


Figure 2. Standard linear solid.

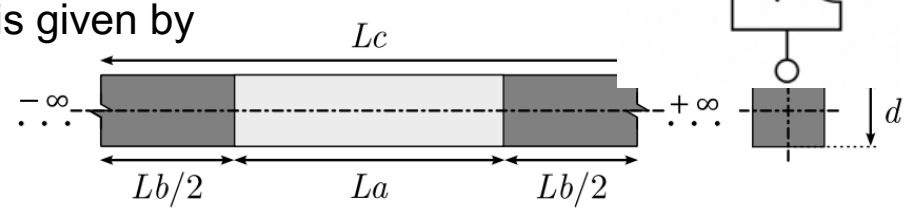


Figure 3. Unit cell of the 1-D PnC rod with material A at the center and material B at the edges.

The 1-D PnC rod consists of steel (A) and viscoelastic PLA (B), with respective properties: ρ of 7890 and 1220 kg/m³, E of 210 and 3.15 GPa, G of 81.65 and 1.141 GPa, and v of 0.275 and 0.38.

Numerical Results

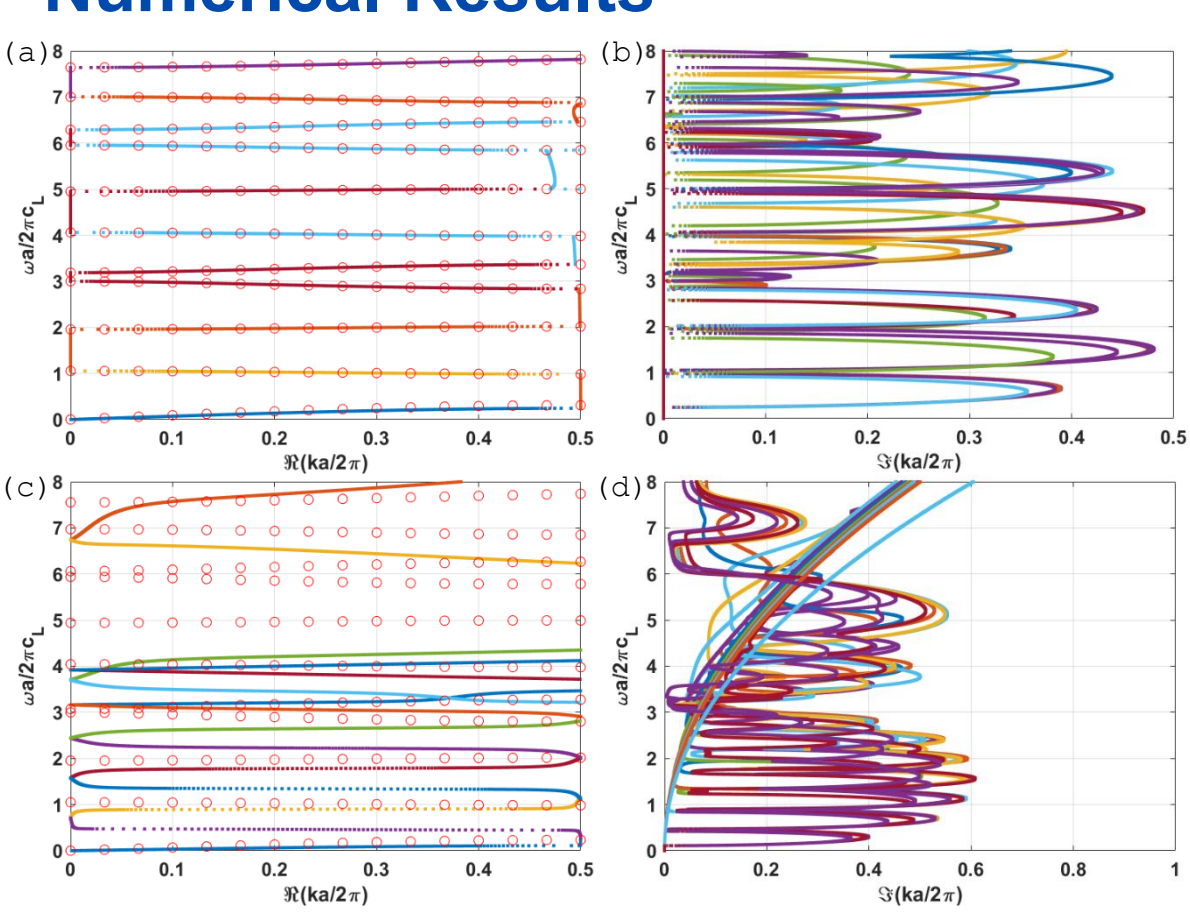


Figure 4. Dispersion diagrams for a 50% filling factor: (a,b) without and (c,d) with viscoelasticity, showing real and imaginary parts.

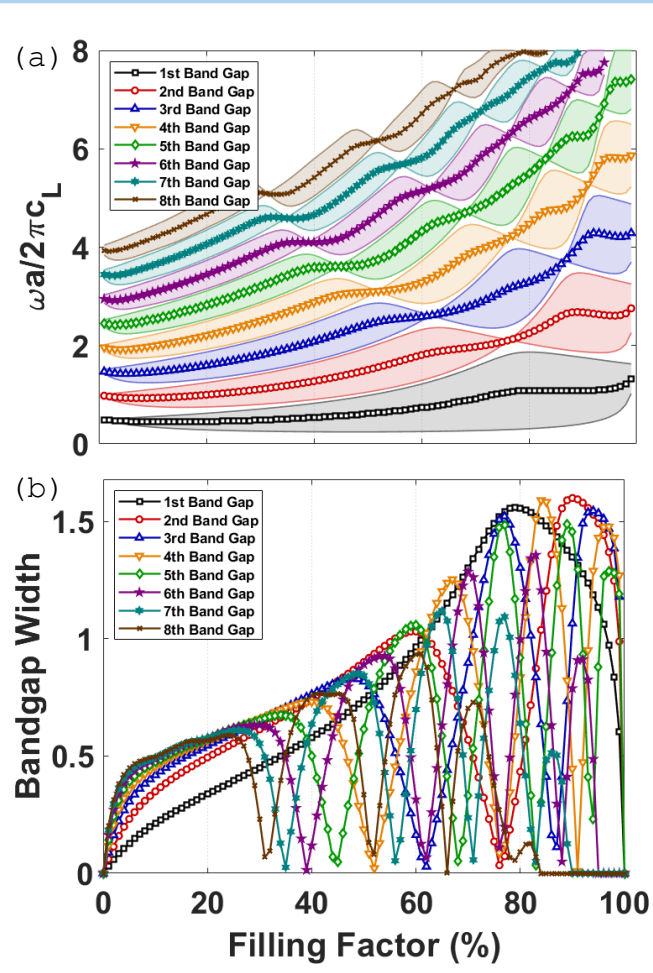


Figure 5. Influence of the PLA filling factor on the first eight bandgaps: (a) frequency ranges and (b) bandwidths.

Conclusions

The PLA filling factor significantly affects bandgap formation, with optimal values depending on the targeted frequency range. Viscoelasticity enhances wave attenuation through energy dissipation.

References

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Acknowledgments

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