Dispersion diagram alteration through the application of an external state of prestress in inertially amplified phononic crystals

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Abstract. We report about the effect of the application of a state of prestress on the band structure of a periodic phononic crystal characterized by an inertial amplification mechanism. Through a numerical example, we show the possibility of inducing negative group velocity in an isolated branch of the dispersion diagram. A *2-step Updated Lagrangian scheme* is adopted to calculate the dispersion diagram of the structure. The proposed method include (i) the static geometrically nonlinear analysis of a representative unit cell undergoing the action of an applied external load and (ii) the Bloch-Floquet decomposition applied to the linearized equations of the acousto-elasticity for the unit cell in the deformed configuration.

Introduction

Considerable progress has been made in the field of wave control since the introduction of phononic crystals and elastic metamaterials few decades ago. However, one of the main limitations of these structures is represented by the fact that once designed, their unusual dynamic properties are fixed in terms of operational frequency [1,2]. The present work reports about the possibility of altering the dispersion diagram of an inertially amplified phononic crystals through the application of an external state of prestress. Dispersion curves are calculated via a *2-step Updated Lagrangian scheme*.

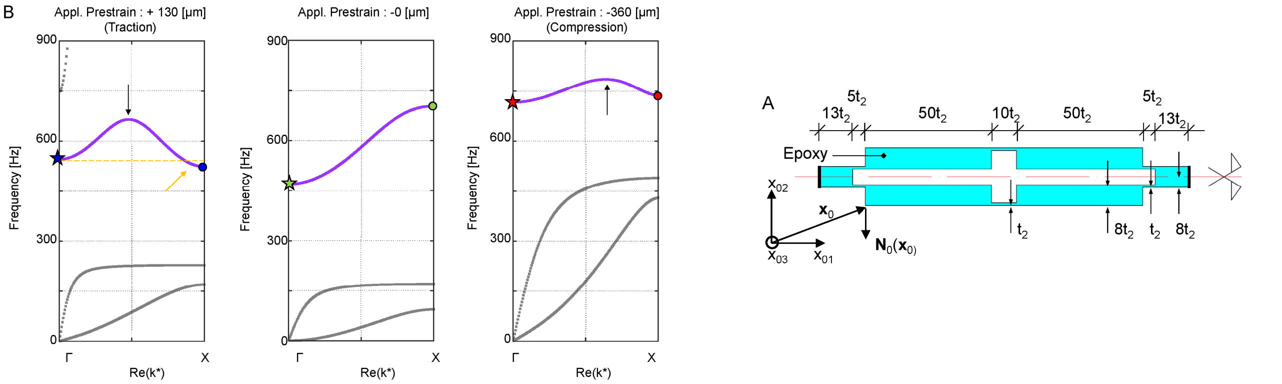

Figura 1: (A) Schematic representation of the considered unit cell along with its position with respect to the original reference systems. (B) Plots of the reduced wavenumber k* along the Γ-X irreducible path as a function of the frequency for +130 μm (left panel), 0 μm (central panel) and -360 μm (right panel) prestrain conditions.

Results and discussion

Figure 2B reports the plots of the reduced wavenumber **k*** along the Γ-X irreducible path as a function of the frequency (in the 0-900 Hz range) for different pre-solicitation states.

We focus our attention on the dispersion branch highlighted in purple, which, in contrast to the other branches reported in gray, besides a general shift, undergoes a group velocity inversion for some values of the reduced wavenumber **k*** (see the black arrows).

This study may represent a practical solution for reducing one of the limitations of phononic crystals / metamaterials, represented by the fact that once designed, their unusual dynamic properties are fixed in terms of operational frequency.

Future research directions will include the possibility of including additional states of stress to control the dispersion diagrams, such as exploiting the tensegrity paradigm [3].

References

[1] Mazzotti, M., Bartoli, I., Miniaci, M., 2019. Modeling bloch waves in prestressed phononic crystal plates, Frontiers in Materials 6, 74.

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[3] Fraternali, F., Carpentieri, G., Amendola, A., 2015. On the mechanical modeling of the extreme softening / stiffening response of axially loaded tensegrity prisms," Journal of the Mechanics and Physics of Solids 74, 136--157.