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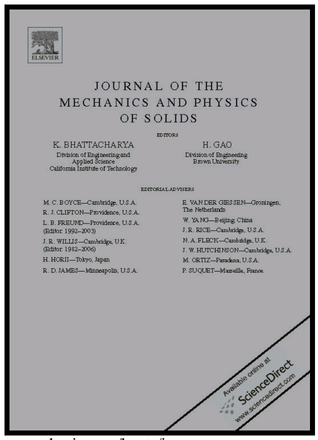

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Universality of the frequency spectrum of laminates

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UNIVERSALITY OF THE FREQUENCY SPECTRUM OF LAMINATES

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Abstract

We show that the frequency spectrum of two-component elastic laminates admits a universal structure, independent of the geometry of the periodic-cell and the specific physical properties. The compactness of the structure enables us to rigorously derive the maximal width, the expected width, and the density of the *band-gaps* – ranges of frequencies at which waves cannot propagate. In particular, we find that the density of these band-gaps is a universal property of classes of laminates. Rules for tailoring laminates according to desired spectrum properties thereby follow. We show that the frequency spectrum of various finitely deformed laminates are also endowed with the same compact structure. Finally, we explain how our results generalize for laminates with an arbitrary number of components, based on the form of their dispersion relation.

Keywords: Laminate, Bloch-Floquet waves, Dispersion relation, Band-gap, Phononic crystal, Wave propagation, Frequency spectrum, Finite deformations

1 Introduction

Wave propagation in heterogeneous media has fascinated the scientific community for decades. The inhomogeneity causes multiple scattering, and, in turn, wave interferences that give rise to intriguing phenomena in various fields. Of particular interest are the transition of conducting to isolating behavior of electronic crystals, localization of electromagnetic waves in dielectrics (Yablonovitch, 1993), and attenuation of mechanical motions in elastic media (Kushwaha et al., 1993, Ruzzene and Baz, 1999, Garcia-Pablos et al., 2000, Henderson et al., 2001, Kim and Yang, 2014). The significance of the latter stems from its central role in numerous applications; transducers (Smith and Auld, 1991), waveguides (Miyashita, 2005), vibration filters (Khelif et al., 2003), acoustic imaging for medical ultrasound and nondestructive testing (III and El-Kady, 2009), noise reduction (Elser et al., 2006) and cloaking (Milton et al., 2006, Colquitt et al., 2014) are just a few examples. The mathematical and physical richness of elastic waves in heterogeneous materials emanates from their vectorial nature, and their spatial dependency on additional constituents parameters.