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Nonlinear dynamical analysis of 3D textiles based on second order gradient homogenized media

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Abstract

The general objective of this contribution is the analysis of wave propagation phenomena within architecture media, relying on an effective substitution continuum obtained by homogenization. The proposed methodology is quite general and applicable to any 3D repetitive network of beam-like structural elements, considering beams undergoing large transformations. Based on the writing of the equations of motion of a nonlinear second order gradient continuum, we analyze the nonlinear wave propagation in the obtained homogenized nonlinear second order gradient continuum. The resulting wave equations are of Boussinesq type, the solution of which being elliptic functions. The influence of the degree of nonlinearity on the dispersion relations is analyzed, highlighting subsonic and supersonic modes propagating respectively with a velocity lower (resp. higher) than the velocity of linear non-dispersive waves. Subsonic and supersonic modes correspond respectively to regimes of high and low nonlinearity characterized by the so-called universal constant. The three modes of propagation (longitudinal, vertical and horizontal shear) are compared in terms of dispersion relations, phase and group velocity diagrams.
The existing anisotropy of wave propagation becomes more marked when the degree of linearity increases. The horizontal and vertical shear modes disappear successively when increasing the wavenumber.

Keywords: second gradient nonlinear continuum models; nonlinear wave propagation; homogenization methods; wave dispersion effects; subsonic and supersonic modes, textile structures.

1. Introduction

Architectured materials, and especially repetitive network materials made of structural elements like beams, constitute a wide class of structures having the capacity to filter waves in certain directions and frequency range. The mechanical response of such networks has fostered a lot of research activity in the literature, but the evaluation of their dynamical and acoustic properties [1,2] remains a scientific challenge [3-9]. The dynamic response and wave propagation properties of periodic lattices and structures have raised numerous studies especially in aeronautics, for the objective of reducing or absorbing vibrations, shock and sound in structural components [1,2]. Materials [10,11], structures and devices [12] exploiting spatial periodicity are involved in a growing number of areas, such as ultra light architectured materials [10,11,13], phononic crystals [8,5,14-22], or acoustic metamaterials [3-7] and [23-25]. These structures raised in the recent