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Bin Bao, Daniel Guyomar, Mickaël Lallart

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Piezoelectric metacomposite structure carrying nonlinear multilevel interleaved-interconnected switched electronic networks

Bin Bao, Daniel Guyomar and Mickaël Lallart*
Univ. Lyon, INSA-LYON, LGEF, EA682
F-69621 VILLEURBANNE, FRANCE
*mickael.lallart@insa-lyon.fr

Abstract

In this article, a new class of piezoelectric phononic meta-composite structure carrying nonlinear multilevel interleaved-interconnected switched electronic networks is proposed, and its electro-elastic coupling between elastic waves and electrical waves is investigated. Normally, distributed multimodal resonant damping can be used to achieve several separate resonant-type band gaps for elastic wave propagation control in electromechanical phononic metamaterials. In the proposed approach, several resonant-type band gaps are induced by the peaks and valleys of electrical waves. Inductances adopted in the electronic network are besides much smaller than those required for generating resonant-type band gaps through conventional resonant circuit shunts. Such feature of requiring less or no inductance contributes to the generation of low-frequency band gaps in a semi-passive way. Numerical results show that the number of band gaps over the primitive pass band (between adjacent primitive stop bands) is determined by the level of the proposed nonlinear interleaved-interconnected electronic network. Compared with broadband wave propagation control, the proposed method is more flexible, and can easily target several discrete frequency domains of interest without significantly affecting other frequency domains. Through the theoretical and experimental investigation on low-frequency damping performance, wave control capability and damping performance are confirmed in the low frequency domain.

Keywords: elastic wave propagation; electrical wave; phononic; metamaterial; synchronized switch damping; piezoelectric.

1. Introduction

Metamaterials, originating from the field of electromagnetic and optical materials (photonic crystals - PtCs) [1, 2], are viewed at the junction of two classical categories (materials and devices), since the particularity of metamaterials is that their potent properties do not arise from the bulk behavior of the materials which compose them, but from their deliberate structure arrangement. Recently, the concept of metamaterials has been extended to many other fields, including materials that possess remarkable properties as negative dynamic modulus and/or density, superior thermoelectric characteristics, and phononic bandgaps (PnBGs). Among metamaterials, mechanical metamaterials [3, 4, 5], used for generating PnBGs (ranges of wavelengthes or frequencies within which waves cannot propagate through the structure), can be divided into two categories: acoustic metamaterials (mechanical waves passing through a gas or a liquid - [6,8]) and phononic metamaterials (mechanical waves passing through a solid - [7,9]). Furthermore, according to the type of energy flow carried by phonons,