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Characteristics of Wave Propagations through Phononic Structure Having Cloaking Zone

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1. Introduction

Using the analogy between the electromagnetic wave and elastic wave, researches for phononic crystal waveguide have been performed[(1)]. Phononic crystals are composed of periodic lattices and have spectral regions where the propagation of elastic or acoustic wave is forbidden. The frequency regimes that the waves cannot propagate along any direction are called phononic band gap. Thus, the manipulation of band gap could provide a capability applicable to the acoustic filter or acoustic lens. A typical method to control the acoustic wave is using an arrangement of defect mode in the phononic crystal, or using inclusions for pass band[(2)]. In the present work, cloaking concept is introduced to control the acoustic waves. The characteristics of wave propagation through phononic crystal are investigated, where the influence of the variation in the lattice geometry on the band structure is studied. Also, the effect of cloaking on the acoustic wave propagation is discussed.

2. Wave propagation

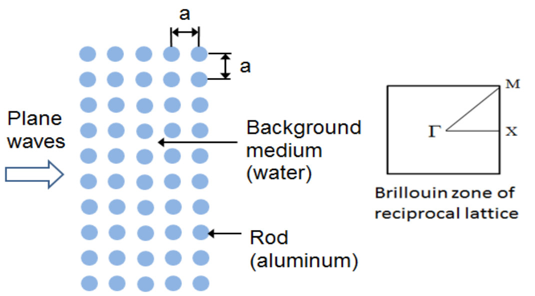

Fig. 1 Schematic diagram of phononic crystals composed of circular rods.

2.1 Band structure

For two dimensional wave propagation, square array type of lattice is considered (Fig. 1). A solid material such as aluminum is used for periodic material. The size of rod is fixed (5mm radius) and lattice spacing (a) is varied from 12.5 to 40mm. Fig. 2a is the band structure of this lattice using transverse magnetic (TM)-like mode. As the lattice spacing increases, both the band gap frequency and band gap range increase, but after certain spacing, the band gap becomes to decrease. Fig. 2a represents the largest band gap at 25mm spacing. Without cloak, wave propagation starts to be hindered from 25kHz, and

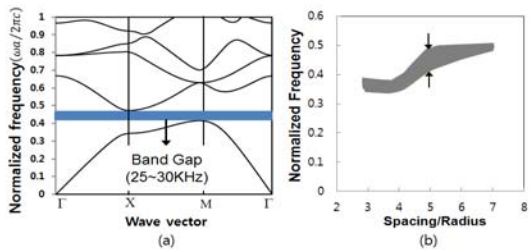

Fig. 2 Band structure: (a) band gap at spacing/radius=5, (b) range and size of band gap.

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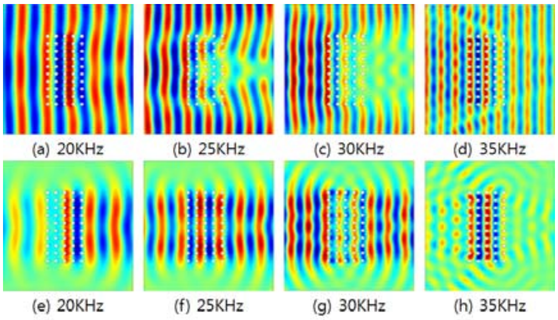

Fig. 3 Wave propagation: (a)~(d) total acoustic pressure field, (e)~(h) scattered pressure field.

at around 30kHz, most waves do not propagate showing strong scattering (Fig.3).

2.2 Effect of cloak on the band gap

To make the effect of acoustic cloak in the phononic structure, cloaking material is constructed such that rods be inclosed by multilayer concentric cylindrical shells (Fig. 4). The material properties of each layer is determined by coordinate transformation method and N layered approximation[3]. The density and wave speed in the cloak material increase as r approaches R_1

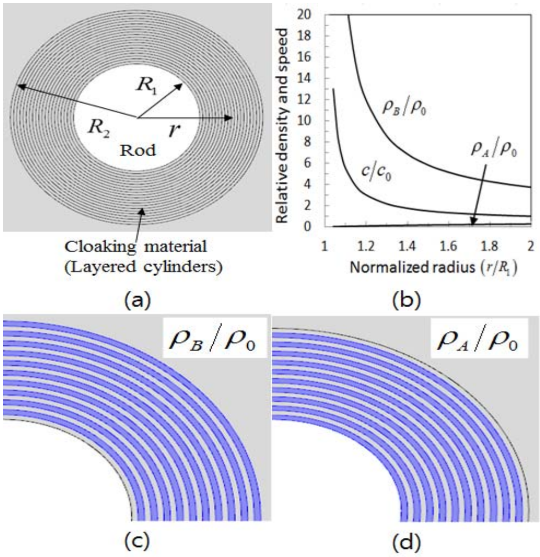

Fig. 4 Cloak system: (a) layered cloak structure, (b) material properties of cloaking material, (c) and (d) outer and inner parts in each layer.

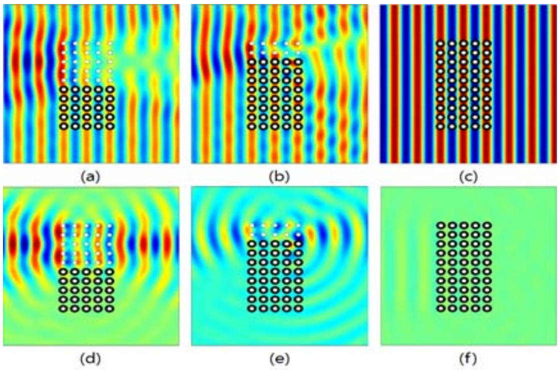

Fig. 5 Cloak effect on the band gap: (a)~(c) total pressure field, (d)~(f) scattered pressure field.

(Fig. 4b), where the subscript "A" and "B" denote inner and outer parts in each layer (Fig. 4c and 4d), As shown in Fig. 5, even at strong band gap frequency (30kHz), the band gap and scattering could be disappeared by using cloaking material, and the waves could propagate through the lattice.

3. Conclusion

The propagation of acoustic waves in phononic crystals was investigated through band structures, and the wave propagation and band gap could be controlled by using cloak system.

Acknowledgement

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