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LOCALLY RESONANT ACOUSTIC METAMATERIALS WITH DIFFERENT INCLUSIONS

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Recently developed [1] locally resonant acoustic metamaterials have a great potential as low-frequency noise isolators. Practically important are metamaterials with a ternary system consisting of hard inclusions in a soft coating embedded in a hard matrix. Local resonances of inclusions give rise to forbidden gaps of acoustic waves, existing independently of the periodicity and orderness of the inclusion distribution. Many works investigating band gap structures (dispersion spectra) of these metamaterials for various combinations of constituting materials have been presented (for references, see [2]). However, up to now, an optimal configuration for obtaining the possibly widest low-frequency band gap has not yet been proposed. Another important issue in engineering applications of acoustic metamaterials is to tune the band gaps to desired frequencies, *e.g.* for shielding higher overtones of acoustic sound, which can still locate in a low-frequency range.

In this work, practical recommendations for optimization of the affected frequency range for locally resonant acoustic metamaterials are given based on the analysis of their dispersion properties.

We consider locally resonant acoustic metamaterials made of steel or tungsten circular cylinders covered with rubber and embedded in epoxy matrix. To calculate the band structure for the metamaterials, finite element modal analysis was applied.

First, we analyzed configurations with identical inclusions arranged periodically or quasi-randomly by constructing dispersion spectra for a primitive unit cell that represents 2D cross-section of a bulk material. In each case, a low-frequency band gap was found, which is opened at a resonant frequency corresponding to cut-off frequency of the lowest propagating circumferential mode in a rubber-coated cylinder. The value of this frequency can be evaluated analytically by calculating eigenfrequencies of a coated cylinder with a clamped boundary [3]. It has been also shown that the incompressibility of rubber plays essential role in determining the structure of the dispersion spectrum of a metamaterial.

Next, the dependence of the width and location of the band gap on geometric sizes of the core and coating, as well as filling fraction of inclusions, was studied in detail. The obtained results allowed suggesting optimal parameters for acoustic metamaterials to shield the widest possible range of frequencies.

We also found also that for any combination of metamaterial parameters there exists only one practically important low-frequency band gap. Hence, to obtain several band gaps in that frequency range, acoustic metamaterial should comprise inclusions of different sizes. We analyzed configurations with two types of rubber-covered cylindrical inclusions of various sizes. The evolution of the dispersion spectra due to the presence of different inclusions was investigated, and optimal parameters for metamaterials with inclusions of comparable sizes were determined. If the size of one type of inclusions is about one order smaller than that of another type, the corresponding metamaterial could be utilized to attenuate both fundamental frequencies and overtones of low-frequency noise. Possible structures for such a metamaterial were proposed.

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