‘Exotic’ wave propagation in acoustic metamaterials

A.O. Krushynska, V.G. Kouznetsova, M.G.D. Geers

Introduction
Acoustic metamaterials (AM) – composites with identical coated inclusions – can attenuate waves and have negative refractive index at certain frequencies. They can be used for acoustic shielding from low-frequency noise and cloaking of objects from sound. Unusual wave propagation in AM is governed by mechanical properties of inclusions.

Aim: analyze the influence of the inclusion coating (rubber) behavior on the formation of frequency gaps – frequencies on which waves are attenuated in AM.

Method
AM is modeled as a periodic structure characterized by a unit cell (Fig.1). Wave attenuation occurs due to the local resonance effect: the energy of the wave in matrix is grabbed by inclusions vibrating at resonant frequencies (Fig.2). Frequency gaps emerge for harmonics without radial symmetry in the displacement field (Fig.3-4). The more inclusions, the wider frequency gaps.

Numerical results
Wave propagation spectrum (frequency vs. wavelength) is plotted to find frequency gaps. It is well studied for AM with a linear elastic ‘compressible’ rubber coating (Fig. 3).

For more realistic incompressible behavior for rubber (Fig.4), there is exactly one frequency gap at twice higher frequencies compared to the lowest gap in Fig.3.

Conclusion and further research
1. Mechanical properties of the rubber coating influence the wave propagation characteristics significantly.
2. Accounting for viscoelastic or nonlinear rubber behavior is required to model wave attenuation in real AM.