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Acoustic metamaterials

Acoustic metamaterials can present some extraordinary behaviour in terms of wave propagation (Fig. 2a). In locally resonant acoustic metamaterials, sound effects such as band gap formation, are governed by the internal resonance introduced by the special microstructure design [1]. So far, studies concerning metamaterials have been restricted to elastic behaviour, neglecting unavoidable losses due to material damping.

![Figure 1: (a) Illustration of the phenomenon of acoustic cloaking [2], (b) metamaterial samples [3]](image)

Recently, numerical and experimental analysis conducted by Molerón et al. [3] has showed that these effects may play a dominant role in the actual response of the material. In this work the influence of viscous losses on the metamaterial performance has been investigated.

Multicoated inclusions and complex material model

In this study, a metamaterial with multicoaxial cylindrical inclusions [4] is considered (Fig. 2) and a viscoelastic material model is used to describe the behaviour of the rubber coating.

![Figure 2: Frequency dependent response of a single-mode Maxwell model with different relaxation times (left) and the geometry of the unit cell with the schematic of a generalised Maxwell model (right)](image)

For the purpose of modeling the rubber layer, a generalised Maxwell model has been chosen which accounts for the nonlinear frequency dependence of both the real and imaginary components of the complex elastic properties (Fig. 2).

![Figure 3: Transmission spectra for shear wave for two viscoelastic metamaterials with elastic reference in the background](image)

Finally, a shift towards higher frequencies can be observed for the case with a single Maxwell model with the relaxation time $\tau = 10^{-3}$ s.

![Figure 4: Total displacement in transmission analysis at 875 Hz (the region in between band gaps)](image)

Results: the effect of viscoelasticity

Transmission spectrum analysis, where amplitudes of output and input waves are compared, shows that in the elastic case, multiple attenuation regions (band gaps) are located at low frequencies and relatively close to each other (shaded areas in Fig. 3). In viscoelastic cases, attenuation occurs in between the elastic band gaps, which is also visible in displacement maps in Fig. 4.

Conclusion

The influence of frequency-dependent material properties on the location of attenuation regions has been demonstrated. For the purpose of bridging the wave attenuation ranges, the viscosity of the rubber coating needs to be sufficiently high in the frequency region of band gaps formation.

References: