Acoustic Cloak based on Pentamode Material with Graded Microstructure

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Acoustic cloak using anisotropic density or pentamode (PM) material is capable of concealing target from any detective acoustic wave. The pentamode material scheme is more promising due to its solid phase feature and broadband efficiency [1, 2]. However, perfect PM material in theory doesn’t have static stability, and therefore some imperfection in practically designed microstructure PM material (see Fig.1) is unavoidable [3, 4]. This imperfection is crucial for shielding effect of acoustic cloak using microstructure PM material. In this paper, we will examine the influence of PM microstructure on the cloaking efficiency. We have designed the first PM cloak with graded microstructure (see Fig.2) and investigated its wave steering ability through direct acoustic/solid coupling simulation with COMSOL Multiphysics. Total scattering cross section (TSCS), which accounts for the scattered pressure in all directions, is chosen to evaluate the cloaking effect quantitatively.

The simulation results show a significant reduction in TSCS over a large frequency range when a rigid cylinder (2D) is covered with the designed microstructure cloak, while some peaks in TSCS are also unexpectedly observed at specific frequencies. These peaks have been investigated thoroughly through the homogenized multi-layer PM model, and are found to be caused by imperfection in practically designed PM material, which is unavoidable for static stability requirement. Further investigation shows that these peaks originate from standing shear wave confined by the inner and outer cloak layer boundary. These narrow resonance peaks can be significantly suppressed through introduction of damping effect into the constituent material of PM microstructure, and prominent broadband invisibility (see Fig.3) is ultimately obtained finally. These findings pave the wave for practical design of acoustic cloak based on PM materials.

Keywords(optional): Acoustic cloak, Pentamode, Imperfection, Shear resonance

References(optional)