

# FINITE-ELEMENT DESIGN OF METAMATERIAL BEAMS FOR BROADBAND WAVE ABSORPTION

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## ABSTRACT

Metamaterials were first introduced for dealing with electromagnetic waves. By creating a material with negative magnetic permeability and electric permittivity, it is possible to manufacture perfect optical lenses, electromagnetic absorbers, technologies for rendering objects invisible and so on. Later researchers began to look into metamaterials for dealing with acoustic waves. This thesis presents the modeling and analysis techniques for design of metamaterial beams as elastic wave absorbers.

An acoustic metamaterial beam is designed by attaching tiny subsystems to an isotropic beam at separate locations. Each unit cell consists of a beam segment and a mass-spring-damper subsystem so that it could be modeled as a discrete system of two degrees of freedom. By integration, the idealized model becomes a dispersive medium with a frequency stopband. The work shows that the metamaterial beam uses the local resonance of subsystems to generate inertia forces to work against the external load and prevent elastic waves from propagating forward. Dispersion analysis and frequency response analysis are conducted to find the stopband of a metamaterial beam. Moreover, the working mechanisms of the metamaterial beam, the concept of negative effective mass, and acoustic and optical modes are presented. This concept is also extended to design a multi-frequency vibration absorber that works for absorbing broadband elastic waves. Numerical simulations by using finite elements validate the design and reveal a set of optimized parameter values. This work shows that, for a multi-frequency vibration absorber, a high damping ratio for the secondary absorber combines two stopbands into a broad one while a low damping ratio for the primary absorber guarantees quick response to the coming excitation elastic wave.