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Design of acoustic cloaking by using topology optimization and waveguide concept

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Abstract

Acoustic cloaking is a term for describing structures capable of deviate sound waves around a particular object, so that the acoustic field behind this object is similar to the acoustic field produced without its presence. A practical example is to make soundproof internal walls in houses, or columns in concert halls, theaters and cinemas, avoiding the reflection of sound waves. However, the design of such structure is not trivial and it is necessary to develop a robust and systematic design method that can be used to design for different applications. The main purpose of this work is to use the Multiresolution Topology Optimization (MTOP) [1] together with waveguide concept in the design of acoustic cloaking structures. As the name suggests, the purpose of an acoustic waveguide is to facilitate the propagation of elastic waves through a given design domain in a desired fashion. In this work, the proposed Cummer–Schurig design for acoustic cloaking is analysed, which investigates the scattering of an acoustic plane wave incident near a rigid cylinder, immersed in water. The main objective is to design the topology of aluminium structures and their positions in the water in order to minimize the scattering from a predefined cloak-region. All the domain boundaries are perfectly matched layers to prevent reflections. The material model is based on SIMP (Solid Isotropic Material with Penalization). The optimization problem is solved by using the MMA (Method of Moving Asymptotes) algorithm and the adjoint variable method is applied for the sensitivity analysis. Through numerical examples, we present an acoustic cloak that could be physically realizable, with high resolution design and requiring a relatively low computational cost.

[1] Nguyen T.H., Paulino G.H., Song J., Le C.H. (2012), "Improving multiresolution topology optimization via multiple discretizations", International Journal for Numerical Methods in Engineering 92(6), pp. 507-530.