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Vibrations, Shocks and Noise

Model of flexural wave scattering from an acoustic black hole in an infinite thin plate

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1. Introduction

The Acoustic Black Hole (ABH) is an effective passive device for reducing vibrations of mechanical structures without adding mass [1], [2]. In practice, it is realized in plates by manufacturing a pit of quadratic profile giving rise to a gradual decrease in thickness as a function of the radius, according to a power law and by placing a thin layer of viscoelastic material in the central zone. The presence of the ABH in the plate constitutes an inhomogeneity, which give rise to complex scattering mechanisms for bending waves. Characterization of the scattering properties of this particular scatterer constitutes the main objective of this work.

The presence of viscoelastic film induces an inhomogeneous damping that is added to that of the material constituting the plate. The study of the dissipation mechanisms is conducted in two steps. The first step consists in developing an analytical model of reference, characterizing the ABH behavior in the absence of viscoelastic coating. The second step is to study numerically with the finite difference method the scattering by the black hole with the viscoelastic film, and extend the results of the reference configuration to realistic configurations which are not accessible analytically.

2. Statement of the problem

Let's consider a flexural plane wave propagating toward an acoustic black hole of internal and external radii a and b respectively, implemented in an infinite plate of constant thickness h_0 (Fig.1-(a)). This plate is made with a material of complex Young modulus E^* , Poisson's ration ν and mass density ρ . The thickness inside the black hole varies according to the power law $h(r) = h_0 \left(\frac{r-a'}{b-a'} \right)^m$. The where he distance a' , shown in Fig.1-(b) defines the point where the thickness truncation is equal to zero: $h(a') = 0$. In a practical realization, the truncation thickness at the extremity is always non zero. For representing this practical situation, we consider that the edge is located at a distance $a > a'$ from the center.

The equation of transvers motion of plates of variable thickness is given by [3]:

$$\rho h(r) \frac{\partial^2 W(r, \theta)}{\partial t^2} = (1 - \nu) \diamond^4 \{D(r), W(r, \theta)\} - \nabla^2 [D(r) \nabla^2 W(r, \theta)], \quad (1)$$

where $D(r)$ represents the variable flexural rigidity.

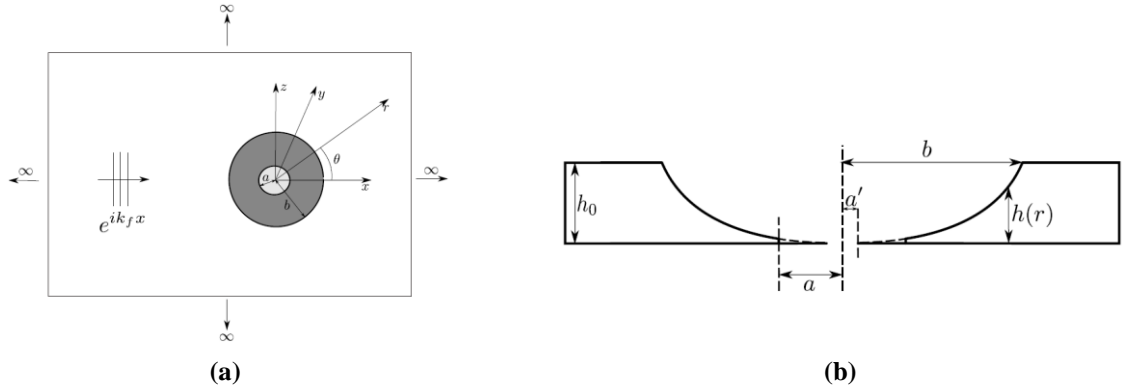


Fig. 1: (a) Incident flexural plane wave in plate with an ABH, (b) Thickness profile of the ABH plate.

Concluding remarks

This document is a summary of modeling of the propagation of flexural waves in an infinite thin plate, containing an ABH. The flexural wave scattering by the acoustic black hole is studied analytically considering an ABH without viscoelastic absorbing layer, and numerically by the finite difference method taking account an ABH with viscoelastic absorbing layer. The models allow quantifying the dispersion and analyzing the behavior of bending waves inside the black hole. They provide the scattered displacement field and the scattering properties. Two examples of results for the analytical model, obtained for an aluminum plate are presented in Fig.2. The other results will be presented during the XIXth symposium on Vibrations, Shocks and Noise (VISHNO 2014).

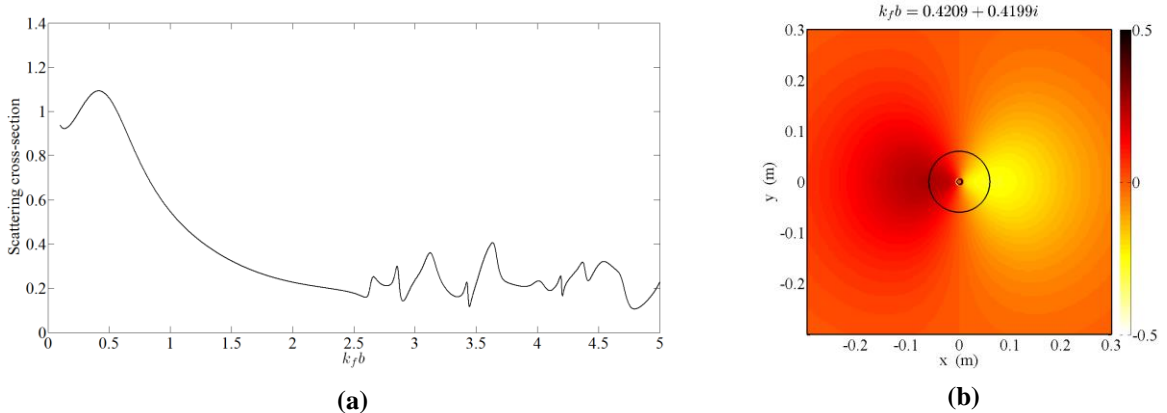


Fig. 2: (a) ABH scattering cross-section versus the dimensionless flexural wavenumber $k_f b$. (b) Example of a trapped mode generated by the presence of the ABH in the plate. This mode occurring at complex wavenumber is the origin of the local increasing of the scattering cross-section at $k_f b \approx 0.42$.

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