Time Domain Construction of Acoustic Scattering By Elastic Targets Through Finite Element Analysis

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Abstract

Acoustic scattering by underwater objects in complex environments is a problem for which analytical solutions are often not known. In such cases, finite element models provide a representative way of approximating the scattering. Though COMSOL Multiphysics® is capable of solving three dimensional scattering problems, it has previously been shown by Zampolli et. al. that 3D problems involving axisymmetric targets can be solved more efficiently through a 2D geometry in COMSOL, using an axial wavenumber decomposition technique to simulate incidence from off-axis sources.

Presently, the 2D finite element model for scattering from elastic, axisymmetric 3D targets is extended to the time domain through Fourier synthesis. Transformation to the time domain is particularly useful for separation of early reflective contributions from late, elastic target scattering, which may interfere in the frequency domain. Elastic spheres and cylinders are considered for this study, as the analytical solutions for scattering from these targets are known and may be used to test modeled results. The success of the model to characterize the time domain scattering from these targets will speak to its applicability to more complex targets and geometries.

Elastic targets in this study are modeled through user-input weak form PDE physics interfaces in COMSOL. The surrounding water is modeled as a fluid through the Pressure Acoustics, Frequency Domain interface of the Acoustics module. Acoustic sources are treated as plane waves to simulate incidence from far field point sources. Off-axis incident plane waves are modeled in the 2D axisymmetric geometry through decomposition in the axial wavenumber domain over a range of frequencies, and resulting scattered fields are transformed to the time domain through Fourier synthesis. The geometry remains small by enforcing the Sommerfeld radiation condition at the boundaries through use of Bérenger Perfectly Matched Layers (PMLs), as described by Zampolli et. al. Far field calculations are obtained by finding the solution on the PML inner boundary, and extending it to the far field through the use of the free space Green's function in water.

Figure 1 shows benchmark solutions for scattering from a (a) rigid sphere and (b) copper sphere, ensonified by a plane wave, single cycle sinusoidal pulse at ka = 21.5, where k is the wavenumber and a is the sphere radius. The envelope of the scattering is plotted against dimensionless time, which is real time scaled by the time of flight of sound through a distance of one sphere radius in water. The results show the exact solution for sphere scattering given by Marston, transformed to the time domain through Fourier synthesis.

References:

M. Zampolli et. al., "A computationally efficient finite element model with perfectly matched layers applied to scattering from axially symmetric objects," J. Acoust. Soc. Am. 122, 1472-1485 (2007).

P. Marston, "Acoustic beam scattering and excitation of sphere resonance: Bessel beam example," J. Acoust. Soc. Am. 122, 247-252 (2007).

Figures used in the abstract

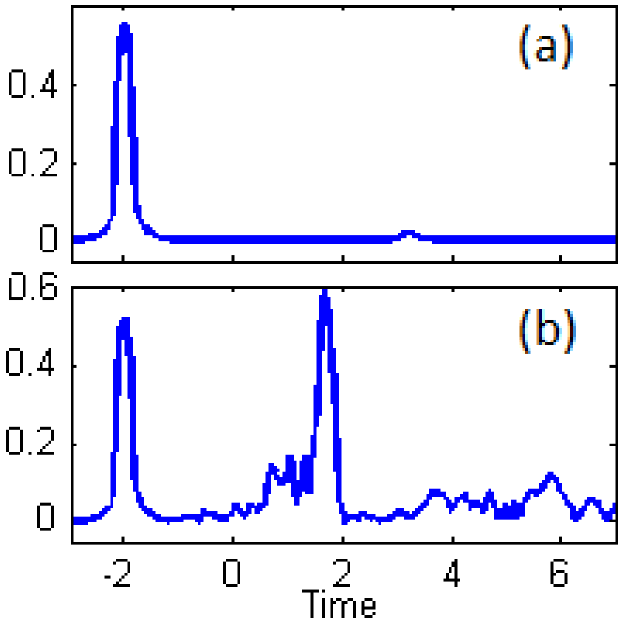

Figure 1: Backscattering from a (a) rigid and (b) copper sphere in the time domain