Radiation by Pistons on a Rigid Sphere in a Heterogeneous Ocean Acoustic Waveguide

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Baffled piston models may be used to study radiation from a variety of underwater acoustic sources. There have been many studies involving pistons in an unbounded homogeneous acoustic domain. The classical problem of circular piston on a rigid infinite plane (L.E. Kinsler et. al, Fundamentals of Acoustics, Wiley, 2000), radiation from a curved spherical cap on a rigid prolate spheroid (R.V. Baier, JASA 51, 1705-1716, 1972) and a similar problem with rectangular piston (J.E. Boisvert and A.L. van Buren, JASA 111, 867-874, 2002) are a few examples for which analytical solutions have been obtained. Pistons set on baffles of arbitrary geometries may be studied using numerical methods such as the BEM and FEM. In an earlier paper (Vendhan et al, APS-URSI 2018), a FE model has been outlined for studying the radiation impedance of a piston on a rigid sphere located in a depth dependent ocean acoustic waveguide. The method, developed for cylindrical waveguides, consists of first expressing the time harmonic acoustic field as a Fourier series in the azimuthal coordinate. The resulting 2D Helmholtz equation for each harmonic has been solved using a finite element model involving a cylindrical waveguide truncated at a suitable radial distance (Vendhan et. al, JASA 127, 3319-3326, 2010).

The present paper aims at studying the problem of acoustic radiation from pistons on a rigid sphere in more detail. The two distinct examples considered are pistons in the form of spherical caps at the poles of the rigid sphere, and a piston in the form of a torus at the horizontal diametral plane. The truncated cylindrical fluid domain representing the waveguide is modeled using $\boldsymbol{C}_0$ type 8-node quadrilateral finite elements. The radiation boundary condition at the truncation boundary is approximated using BGT damper operators. A uniform, time harmonic velocity is imposed on the piston. A pressure release boundary condition is employed at the air-sea interface and the sea floor is assumed to be rigid. The FE solution yields acoustic pressure field over the entire fluid domain considered. The acoustic pressure on the piston may be integrated to obtain its mechanical impedance.

For the purpose of numerical study, a 100 m deep cylindrically symmetric waveguide with a depth-dependent sound speed profile has been chosen. For the spherical-cap piston problem, the cases of a single piston and two pistons operating in-phase or out-of- phase have been considered. Results for the unbounded domain problems are obtained and compared with analytical solutions. The acoustic fields when the piston is located at different depths in the waveguide are examined.