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PROPAGATION OF THE SOUND WAVE BY AN UNCLOSED SPHERICAL SHELL AND A PENETRABLE ELLIPSOID

Gennady SHUSHKEVICH¹

Let homogeneous space R^3 contain a thin unclosed spherical shell Γ_1 located on a sphere Γ of radius d with the center at point O and an ellipsoid shell S (Fig. 1). We denote by D_1 the area of space bounded by the sphere Γ and by D_3 the area of space bounded by the ellipsoid shell S then $D_2 = R^3 \setminus (D_1 \cup \Gamma \cup D_3 \cup S)$ holds. The distance between points O and O_1 is equal to h_1 .

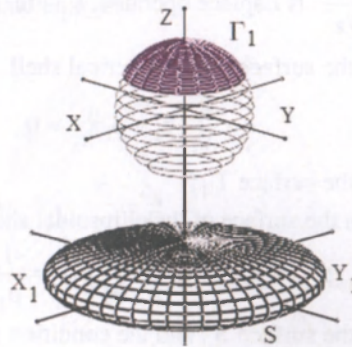


Fig. 1. Geometry of the problem

Point radiator of sound waves oscillating with an angular frequency ω is located at the point O . Areas D_j , $j=1, 2, 3$, are filled with material in which shear waves are not spread. Let denote density of medium by ρ_j and the speed of sound by c_j in D_j , $j=1, 2, 3$, $\rho_1 = \rho_2$.

To solve this problem we introduce spherical coordinates with point O and point O_1 . The spherical shell Γ_1 and the ellipsoid shell S are described as follows:

$$\Gamma_1 = \{r = d, 0 < \theta < \theta_0 < \pi, 0 < \varphi < 2\pi\}, \quad (1)$$

$$S = \{r_1 = r(\theta_1), 0 < \theta_1 < \pi, 0 < \varphi < 2\pi\}, \quad (2)$$

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where: $r(\theta_1) = a / \sqrt{1 - v \sin^2 \theta_1}$, $v = e^2 / (e^2 - 1)$ stands for a prolate ellipsoid of rotation, $v = e^2$ is used for an oblate ellipsoid of rotation, e is the an eccentricity of the ellipse.

Let p_c be pressure of primary point radiator of sound field, p_1 be pressure of secondary sound field in the area D_j , $j=1,2,3$, then the real sound pressure is calculated by the formula $P_j = \text{Re}(p_j e^{-i\omega t})$. A solution of the diffraction problem is reduced to finding pressures p_j , $j=1, 2, 3$, which satisfy:

– Helmholtz equation [1]

$$\Delta p_j + k_j^2 p_j = 0, \quad (3)$$

where: $\Delta = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$ is Laplace operator, $k_j = \omega / c_j$ is wave number,

– boundary condition on the surface of the spherical shell Γ_1 (acoustically hard shell):

$$\frac{\partial}{\partial \bar{n}} (p_c + p_1) \Big|_{\Gamma_1} = 0, \quad (4)$$

where: \bar{n} is the normal to the surface Γ_1 ,

– boundary conditions on the surface of the ellipsoidal shell S :

$$p_1 \Big|_S = p_2 \Big|_S, \quad \frac{1}{\rho_2} \frac{\partial}{\partial \bar{n}} p_2 \Big|_S = \frac{1}{\rho_3} \frac{\partial}{\partial \bar{n}} p_3 \Big|_S \quad (5)$$

where: \bar{n} is the normal to the surface S , and the condition at infinity [1,2].

The condition of the continuity of pressure on the open part of the spherical shell $\Gamma \setminus \Gamma_1$ and normal derivative on the surface of the sphere Γ are given by [3]:

$$(p_c + p_1) \Big|_{\Gamma \setminus \Gamma_1} = p_2 \Big|_{\Gamma \setminus \Gamma_1}, \quad \frac{\partial}{\partial r} (p_c + p_1) \Big|_{\Gamma} = \frac{\partial}{\partial r} p_2 \Big|_{\Gamma} \quad (6)$$

The pressure of the scattered sound field represented as a superposition of basic solutions of Helmholtz equation in spherical coordinates taking into account the condition at infinity. Using the addition theorem for spherical wave functions and fulfilling boundary conditions (5)-(6) we get to infinite system of linear algebraic equations of the second kind. The numerical results for various values of the problem parameters have been also obtained.

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