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TABLE OF CONTENS

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

Gennady SHUSHKEVICH[1]

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.

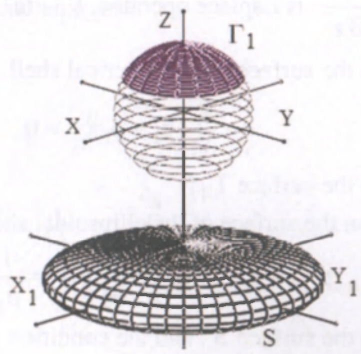

Fig. 1. Geometry of the problem

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_i 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:

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

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

[1] g_shu@tut.by, Yanka Kupala State Universy of Grodno, Belarus

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_j 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 $P_j = \mathrm{Re}\left(p_j e^{-i\omega t}\right)$. A solution of the diffraction problem is reduced to finding pressures p_j, $j=1,2,3$, which satisfy:

– Helmholtz equation [1]

$$\Delta p_j + k_j^2 p_j = 0, \tag{3}$$

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):

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

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

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

$$p_1\big|_S = p_2\big|_S, \qquad \frac{1}{\rho_2}\frac{\partial}{\partial \bar{n}} p_2\bigg|_S = \frac{1}{\rho_3}\frac{\partial}{\partial \bar{n}} p_3\bigg|_S \tag{5}$$

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]:

$$(p_c + p_1)\big|_{\Gamma\setminus\Gamma_1} = p_2\big|_{\Gamma\setminus\Gamma_1}, \qquad \frac{\partial}{\partial r}(p_c + p_1)\big|_{\Gamma} = \frac{\partial}{\partial r} p_2\bigg|_{\Gamma} \tag{6}$$

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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