Scattering of obliquely incident waves by surface-piercing thick porous structures and a rigid floating structure

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1. INTRODUCTION & OBJECTIVE

An oblique wave scattering by a floating structure in the presence of two surface-piercing porous structures is studied. The effect of various parameters on the reflection coefficient, transmission coefficient and dissipation coefficient are analyzed. It is observed that with an increase in height and thickness of the porous structures, wave energy loss increases due to the dissipative nature of the porous structures.

In recent years, due to increase in human activities, there is an immense interest to use the ocean space for various activities like floating airport, floating bridge and floating entertainment facilities etc. (see[1]). However, due to many circumstances such as rise in sea level due to cyclones or tsunami-like phenomenon, many floating structures may collapse [2]. Thus, there is a need to examine various means to reduce the wave-induced forces acting on the floating structure.

We consider the irrotational motion of an inviscid and incompressible fluid over a sea-bed. We use three-dimensional Cartesian coordinate system with the xy-plane being the horizontal plane and the z-axis pointing upwards and $z = 0$ the undisturbed free surface as in Fig. 1. The floating structure is assumed to be a rectangular rigid structure of finite width L_3 and draft h_1. The porous structures are considered to have a width L and heights a_1 and a_2, and are placed between $0 < x < L$ and $L + L_1 < x < 2L + L_1$. The distance between these porous structures is L_1. The second porous structure is considered to be at a distance L_2 from the floating structure. The horizontal bottom of the sea-bed is considered at $z = -h$. Under the assumptions of linear water wave theory, velocity potential for oblique water wave in each region is given by $\Phi_j(x, y, z, t) = Re\{\phi_j(x, z)e^{i(ly-\omega t)}\}$, for j = 1,2,3,4,5,6,7,8,9, where ω is angular frequency, $l = k_0 \sin\theta$, k_0 is the wavenumber of propagating wave in region 1 and θ is the incident angle with x-axis. The spatial velocity potential ϕ_j in each fluid region satisfies the Helmholtz equation

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial z^2} - l^2\right)\phi_j = 0. \quad (1)$$

The boundary conditions on the free surface for regions 1,2,4,5,7 and 9 are given by

$$\frac{\partial \phi_j}{\partial z} - K\phi_j = 0 \text{ on } z = 0 \text{ (j=1,4,7,9)}, \quad \frac{\partial \phi_j}{\partial z} - K\gamma_j\phi_j = 0 \text{ on } z = 0 \text{ (j=2,5)}, \quad (2)$$

where $K = \frac{\omega^2}{g}$, g is the gravitational constant and $\gamma_j = m_j + if_j$ are the dimensionless porous impedance parameter.

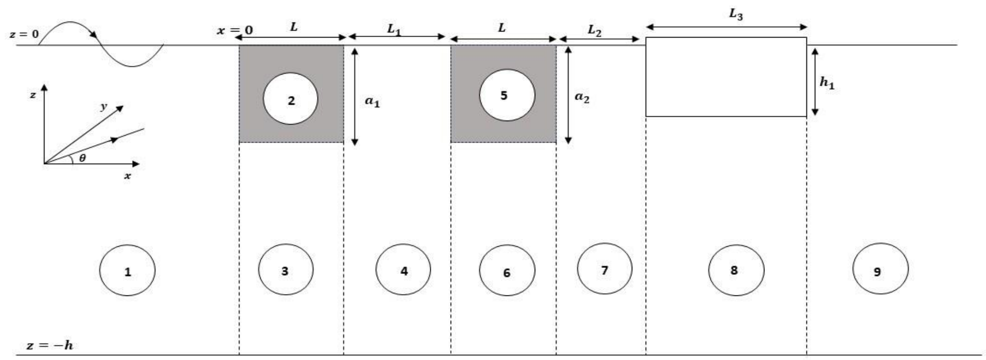

Figure 1: Schematic diagram of the problem

Boundary condition on the horizontal flat bottom is given by

$$\frac{\partial \phi_j}{\partial z} = 0 \text{ on } z = -h \text{ for j = 1,3,4,6,7,8,9.} \tag{3}$$

Boundary conditions on the vertical and horizontal sides of the floating structure are as follows:

$$\frac{\partial \phi_7}{\partial x} = 0 \quad \text{at} \quad x = 2L + L_1 + L_2, \quad -h_1 < z < 0, \tag{4}$$

$$\frac{\partial \phi_9}{\partial x} = 0 \quad \text{at} \quad x = 2L + L_1 + L_2 + L_3, \quad -h_1 < z < 0, \tag{5}$$

$$\frac{\partial \phi_8}{\partial z} = 0 \quad \text{at} \quad z = -h_1, \quad 2L + L_1 + L_2 < x < 2L + L_1 + L_2 + L_3. \tag{6}$$

In addition to the above conditions, there are some continuity conditions which altogether give rise to a system of linear equations. By solving it, we can study the reflection, transmission and dissipation coefficients.

The velocity potential $\phi_1(x,z)$ in region 1 can be written in the following form:

$$\phi_1(x,z) = \left(e^{ip_0 x} Z_{0,1}(k_0,z) + \sum_{n=0}^{\infty} R_n e^{-ip_n x} Z_{n,1}(k_n,z)\right),$$

where $Z_{n,1}(k_n,z) = -(ig/\omega)(\cosh k_n(z+h) / \cosh(k_n h))$ with $p_n = \sqrt{k_n^2 - l^2}$ for $n = 0,1,2,...$, R_0 is the unknown complex reflection coefficient along with the unknowns R_n. Here, k_0 is the real root and k_n for $n = 1,2,3,...$are the purely imaginary roots of the dispersion equation $k \tanh kh = K$.

In a similar manner, the other velocity potentials $\phi_2, \phi_3, \phi_4, \phi_5, \phi_6, \phi_7, \phi_8$ and ϕ_9 can be obtained.

2. RESULTS & HIGHLIGHTS

Figures 2, 3 and 4 show the variation of the reflection coefficient $|R_0|$, transmission coefficient $|T_0|$ and dissipation coefficient k_d against incident wave angle θ for the different values of the porosity of the first and second thick porous structures. It depicts that when porosity ϵ_2 of the second porous structure is less than the porosity $\epsilon_1$of the first porous structure, we get higher wave energy dissipation and this cause lower reflection and transmission coefficients, and when porosity of the first porous structure is less than the porosity of the second porous structure, lower dissipation coefficient is obtained.

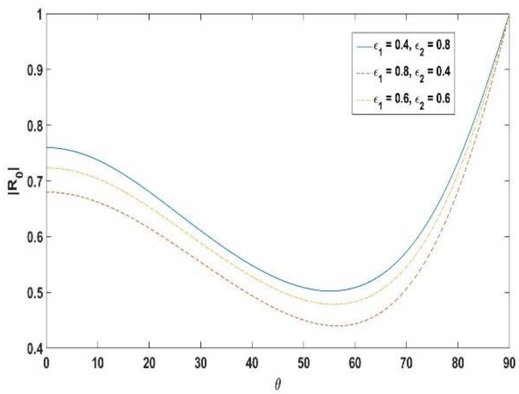

Figure 2: $|R_0|$ against θ for different values of the porosity of the first and second porous structures

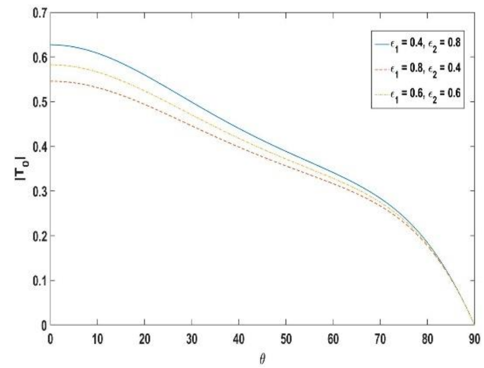

Figure 3: $|T_0|$ against θ for different values of the porosity of the first and second porous structures

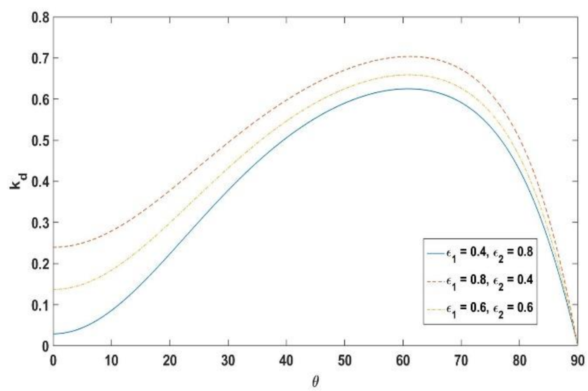

Figure 4: k_d against θ for different values of the porosity of the first and second porous structures

As shown above, the effect of various other parameters on wave reflection, transmission and dissipation coefficients are analyzed. It is concluded that an optimal width and height of the porous structures along with an optimum porosity yields the desired results.

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