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A Study on Transmission Loss Characteristics of Honeycomb Panel for Offshore Structures

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Abstract

Honeycomb panel is consisted of 3 layers that are double-faced sheets and honeycomb-shaped core. It is highly desirable for ship, railway, and aerospace industry. The reason is that honeycomb panel excels in strength and in its weight. However in terms of insulation, it is a little bit insufficient to commonly use sandwich-panel. In this paper, Moor's theory is used to predict sound transmission loss (STL). The theory is assumed that core layer is homogeneous orthotropic. And to calculate STL, it is evaluated in terms of the symmetric and anti-symmetric panel impedances, and the characteristic impedance of air. After that predicted data are compared with experiment data.

Keywords

Honeycomb Panel, Sound Transmission Loss (STL), Orthotropic Core

1. Introduction

A honeycomb panel has good mechanical properties. So the honeycomb panels are widely used in diverse industries from its low weight and high strength. In addition to this merits, we want more insulation performance. To do this we predict STL of honeycomb-panel. That is compared with experiment data.

A study of transmission loss for the unbounded orthotropic sandwich panel with honeycomb core was investigated by Wang Shengchun [1]. An analysis of the transmission loss in the sandwich panels with orthotropic cores was presented by Moore and Lyon [2].

It is used for multi-layered system later on methodology for analyzing the multi-layered system come from one general method by Brouard, Lafarge and Allard [3] [4].

2. Theory

Honeycomb have different stiffness moduli in planes perpendicular and parallel to the direction of the cells, and

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can be characterized as orthotropic with nine independent stiffness constants. Equation (1) is express relation of stress, strain, and stiffness constants [5].

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_z \\ \tau_{yz} \\ \tau_{xz} \\ \tau_{xy} \end{Bmatrix} = \begin{bmatrix} E_{11} & E_{12} & E_{13} & 0 & 0 & 0 \\ & E_{22} & E_{23} & 0 & 0 & 0 \\ & & E_{33} & 0 & 0 & 0 \\ & & & E_{44} & 0 & 0 \\ & & & & E_{55} & 0 \\ & & & & & E_{66} \end{bmatrix} \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_z \\ \gamma_{yz} \\ \gamma_{xz} \\ \gamma_{xy} \end{Bmatrix} \tag{1}$$

where σ_x, σ_y and σ_z are the normal stresses in the x, y, and z directions, respectively. τ_{yz}, τ_{xz}, τ_{xy} are the shear stresses [6] [7]. The strains are defined with respect to the particle displacements u, v, w in the x, y, z directions, respectively, as follows:

$$\begin{aligned} &\epsilon_x = \frac{\partial u}{\partial x}, \quad \epsilon_y = \frac{\partial v}{\partial y}, \quad \epsilon_z = \frac{\partial w}{\partial z}; \\ &\gamma_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}, \quad \gamma_{xz} = \frac{\partial u}{\partial z} + \frac{\partial w}{\partial x}, \quad \gamma_{yz} = \frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}. \end{aligned} \tag{2}$$

The stored elastic potential energy density, W, for a given strain field is:

$$2W = E_{11}\epsilon_x^2 + 2E_{12}\epsilon_x\epsilon_y + 2E_{13}\epsilon_x\epsilon_z + E_{22}\epsilon_y^2 + 2E_{23}\epsilon_y\epsilon_z + E_{33}\epsilon_z^2 + E_{44}\gamma_{xy}^2 + E_{55}\gamma_{xz}^2 + E_{66}\gamma_{xy}^2 \tag{3}$$

The Equation (4) is total elastic potential energy that is stored in a body of finite volume is computed as the integral of the potential energy density over the volume of the body. Kinetic energies are similarly defined in terms of volume integrals as follow Equation (5)

$$P.E. = \int_{\text{Vol}} W \mathrm{dVol} \tag{4}$$

$$K.E. = \frac{1}{2} \int_{\text{Vol}} \rho \left(\dot{u}^2 + \dot{v}^2 + \dot{w}^2 \right) \mathrm{dVol} \tag{5}$$

The Equation (6) is a Lagrange's equation that is utilized to generate the system equations describing the dynamics of the sandwich panel [8].

$$\frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\partial KE_{\text{TOT}}}{\partial \dot{q}_r} \right) - \frac{\partial KE_{\text{TOT}}}{\partial q_r} + \frac{\partial PE_{\text{TOT}}}{\partial q_r} = Q_r, \quad r = 1, 2, \cdots \tag{6}$$

where q_r is the generalized displacements, Q_r is the generalized forces per unit area. Applying Lagrange's equation to the expressions for the kinetic and potential energies for symmetric, antisymmetric motions, and then we know the symmetric and antisymmetric impedances. The acoustic transmission coefficient is defined as the ratio of the transmitted to incident acoustic intensities. It is evaluated in terms of the symmetric and antisymmetric panel impedances, and the characteristic impedance of air.

$$\tau(\theta, \phi) = \left| I_{\text{trans}} / I_{\text{inc}} \right|^2 = \left| \frac{(\rho_0 c_0 / \cos\theta)(Z_s - Z_a)}{(Z_s + \rho_0 c_0 / \cos\theta)(Z_a + \rho_0 c_0 / \cos\theta)} \right|^2 \tag{7}$$

$$\bar{\tau} = \frac{\int_0^{2\pi} \int_0^{\theta_{\lim}} \tau(\theta, \phi) \sin\theta \cos\theta \,\mathrm{d}\theta \,\mathrm{d}\phi}{\int_0^{2\pi} \int_0^{\theta_{\lim}} \sin\theta \cos\theta \,\mathrm{d}\theta \,\mathrm{d}\phi} \tag{8}$$

$$\text{TL} = -10\log_{10}(\bar{\tau}) \text{ dB} \tag{9}$$

Equation (7) is the acoustic transmission coefficient, Equation (8) is the averaged transmission coefficient, and Equation (9) is the transmission loss.

3. Numerical Results and Discussion

The sound transmission loss of a honeycomb panel is present in **Figures 1-4**. The material properties are listed in **Table 1**. The core of honeycomb is aluminum and the face sheet is steel. Sound Transmission Class (STC) of 15 mm theory and experiment is same as 21 dB. STC of 25 mm theory and experiment is 21 dB, 23 dB, respectively. STC of 30 mm theory and experiment is 21 dB, 23 dB, respectively. STC of 40 mm theory and experiment is 22 dB, 24 dB, respectively.

According to the each thickness of panel, there are some differences in frequency but theory value and experiment value can be right within 2 dB in other frequency excepting for a certain frequency.

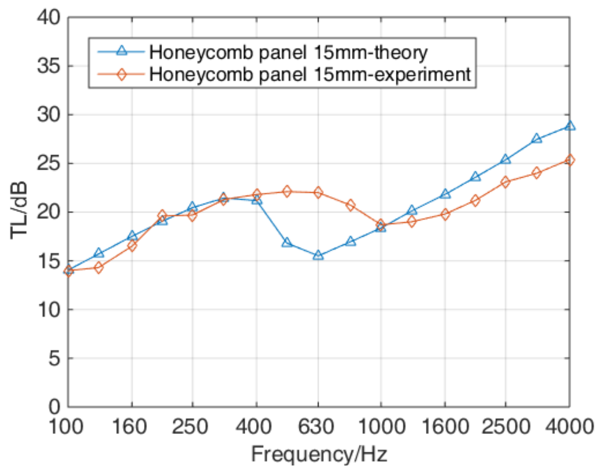

Figure 1. The STL of the honeycomb panel 15 mm-theory and the honeycomb panel 15 mm-experiment.

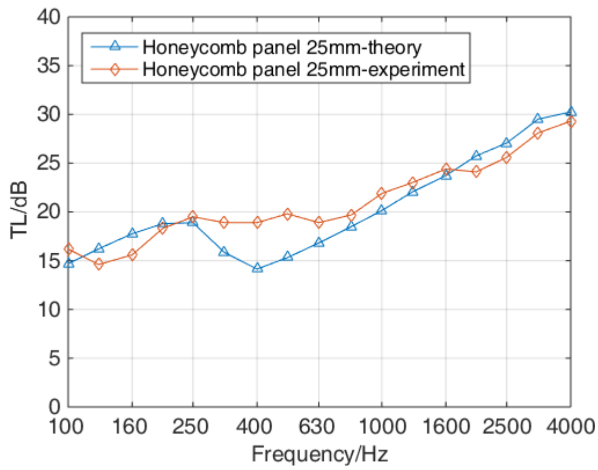

Figure 2. The STL of the honeycomb panel 25 mm-theory and the honeycomb panel 25 mm-experiment.

Table 1. The material properties of honeycomb panel.

Honeycomb	The face sheet	The core
Thickness, mm	0.6	15, 25, 30, 40
Density, kg/m^3	7850	2770
Young's modulus, GPa	195	71
Poisson coefficient	0.3	0.33

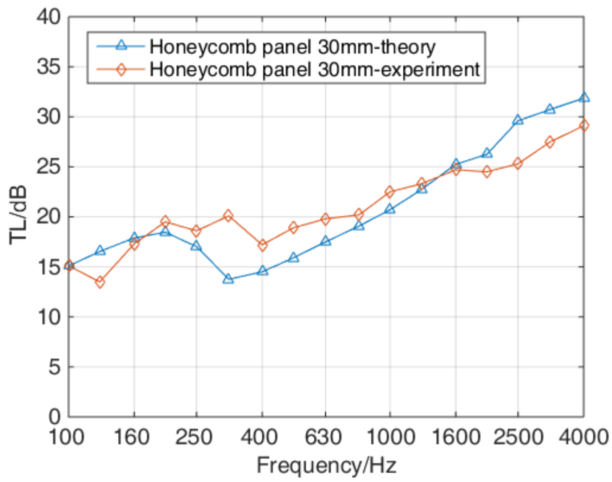

Figure 3. The STL of the honeycomb panel 30 mm-theory and the honeycomb panel 30 mm-experiment.

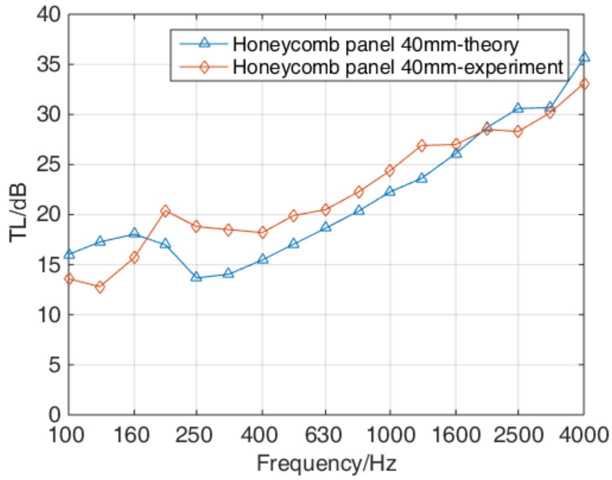

Figure 4. The STL of the honeycomb panel 40 mm-theory and the honeycomb panel 40 mm-experiment.

4. Conclusions

The honeycomb panel theory is derived by Moore. Through this theory, the STL of honeycomb panel is predicted. And it is compared with experiment result according to thickness.

And then for better insulation performance, mineral wool is added to honeycomb panel. In terms of thickness both panels are same. One is a single honeycomb panel (40 t). Another is composite panel (honeycomb 15 mm + mineral wool 10 mm + honeycomb 15 mm—theory).

This paper considers only honeycomb panel. But many elements will be studied and added on the honeycomb panel.

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