INFLUENCE OF MEAN FLOW ON TRANSMISSION LOSS OF SANDWICH STRUCTURE WITH POROUS MATERIAL CORE

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Summary A theoretical model for sound transmission loss (STL) of porous material cored sandwich plates in the presence of external mean flow is developed. Sound propagation in the porous material is described by adopting an equivalent fluid model, with fluid-structure coupling conditions accounted for to ensure displacement continuity at fluid-structure interfaces. The model is used to quantify how the mean flow affects acoustic transmission across the whole structure.

INTRODUCTION

With double-leaf thin plates filled with porous absorbent materials increasingly used as outer skins of airplanes and trains [1-2], it is important to investigate the sound transmission characteristics of such sandwich constructions especially in the presence of external flow. Numerous studies have been carried out to investigate the transmission loss of sound across double-leaf plates filled with porous absorbent materials. For instance, Lauriks *et al.* [3] developed a model for the transmission loss through double-leaf plates with inserted porous layers using the classical Biot theory, and Brouard *et al.* [4] proposed a general method to model sound propagation in layered systems with fluid-saturated porous layers. The aim of the present study is to formulate a theoretical model to examine the effects of external mean flow on sound transmission loss across double-leaf plate filled with porous materials.

THEORETICAL MODEL

The sound transmission process through the considered sandwich structure is schematically illustrated in Fig. 1. A harmonic plane sound wave is assumed to penetrate through the sandwich structure, together with external mean flow moving along the x-axis.

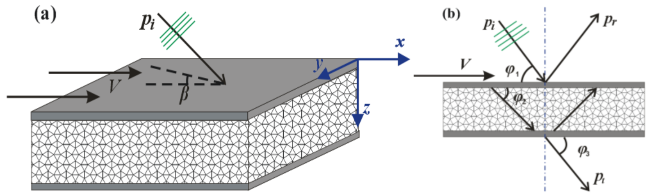

Fig.1. Schematic of sound transmission through double-leaf plate filled with porous material in the presence of external mean flow: (a) global view; (b) side view.

Sound pressures in the incident side, porous material and transmitted side may be expressed as:

$$p_1 = P_{1i} e^{i\omega t - i(k_{1x}x + k_{1y}y + k_{1z}z)} + P_{1r} e^{i\omega t - i(k_{1x}x + k_{1y}y - k_{1z}z)} \quad (1)$$

$$p_2 = P_{2i} e^{i\omega t - i(k_{2x}x + k_{2y}y + k_{2z}z)} + P_{2r} e^{i\omega t - i(k_{2x}x + k_{2y}y - k_{2z}z)} \quad (2)$$

$$p_3 = P_{3t} e^{i\omega t - i(k_{3x}x + k_{3y}y + k_{3z}z)} \quad (3)$$

To determine the unknown parameters of the acoustic field, the following fluid-structure coupling conditions are enforced: (a) displacement continuity condition between plate particle and adjacent fluid particle; (b) driving relation between incident sound and plate dynamic response, i.e.,

$$\delta_1 = w_1 = \delta_2,\ \delta_3 = w_2 = \delta_4 \quad (4)$$

$$P_{1i} + P_{1r} - P_{2i} - P_{2r} = Z_{p1} \dot{w}_{10}$$
$$P_{2i} + P_{2r} - P_{3t} = Z_{p2} \dot{w}_{20} \quad (5)$$

where (w_1, w_2) are the displacements of the two plates, (δ_1, δ_4) represent the fluid particle displacements adjacent to the outer side of the two plates, (δ_2, δ_3) represent the porous material particle displacements adjacent to the inner side of the plates, respectively, and (Z_{p1}, Z_{p2}) represent separately the panel impedances of the upper and lower plates (Fig. 1).

The sound transmission loss (STL) across the double-leaf plate filled with porous material is derived as:

$$STL = -10 \log \tau(\varphi_1, \beta) \quad (6)$$

where $\tau(\varphi_1, \beta)$ is the acoustic transmissivity given by:

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$$\tau(\varphi_1, \beta) = \frac{\rho_1 c_1}{\rho_2 c_2} \left| \frac{P_{3t}}{P_{1i}} \right|^2 \quad (7)$$

NUMERICAL STUDY OF SOUND TRANSMISSION LOSS

The predicted influence of external mean flow (Mach number) on *STL* across double-leaf plates with filling porous materials is presented in Fig. 2. It is seen that the *STL* value increases as increasing Mach number over a wide frequency range below the coincidence resonance frequency. This can be attributed to the added-mass effect of the convected fluid loading , which remarkably increases as the fluid speed is increased.

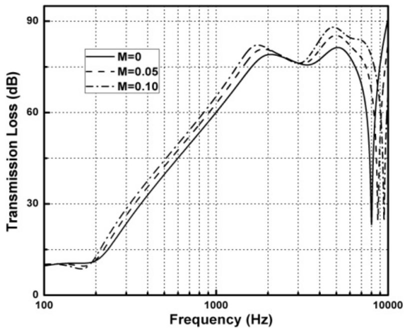

Fig.2. Sound transmission loss plotted as a function of frequency for double-leaf plate with inserted porous material at selected Mach numbers, with φ_1 = 30°, β_1 = 0° and H =0.08 m.

The predicted influence of Mach number on the coincidence resonance frequency of the sandwich structure is presented in Fig. 3. With increasing Mach number, the coincidence resonance frequency increases almost proportionally. This can be attributed to the enhanced refraction effect of external mean flow as the Mach number is increased.

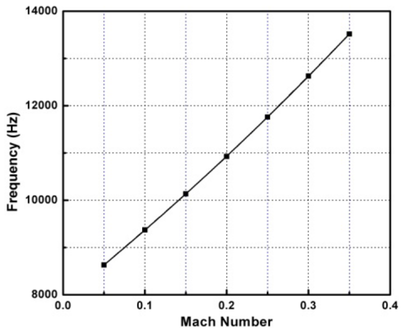

Fig.3. Effect of Mach number on coincidence frequency of double-leaf plate with inserted porous material, with φ_1 = 30°, β_1 = 0° and H = 0.08 m.

CONCLUSIONS

A theoretical model is developed to investigate the influence of external mean flow on sound transmission loss across double-leaf plates with inserted porous materials. Numerical examples carried out using the model demonstrate that, at frequencies below the coincidence resonance, the added-mass effect of external mean flow leads to increased sound transmission loss as the speed of flow is increased. The coincidence resonance frequency also increases due to the enhanced refraction effect of the mean flow.

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