

Porous Materials FE Modeling Scheme Using Experimentally Measured Acoustic Impedance for Predicting Panel Sound Radiation

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ABSTRACT

This paper describes the porous materials FE modeling scheme inside vehicle cabin using measured acoustic impedances to reduce the size of the matrices of the FE model while keeping the accuracy. The technique of measuring acoustic impedance using PU probe in a free field is introduced. Next, the surface acoustic impedance of the seat by the side of front is measured using this technique. And the vehicle cabin acoustic field is modeled by FEM using the measured surface acoustic impedance. For the accuracy verification of this model, the acoustic transfer characteristics inside vehicle cabin with and without the front seat are compared with the predicted and the measured transfer function. Moreover, finally the worth of this modeling method is considered.

INTRODUCTION

It has been developed that the FE modeling scheme including porous materials as well as acoustic cavity for predicting 200 - 1000 Hz frequency range interior cavity sound pressure level. From the point of view of modeling and calculation time, it is necessary to minimize the size of the model. Porous materials are applied in the vehicle interior cavity for satisfying the costumer demands in quietness. When FE-modeling the porous materials using the Biot parameters, the size of the model is

enlarged drastically. This leads time consumption for modeling and calculation. To reduce the size of the matrices of the model, some of the applied porous materials are modeled using experimentally measured acoustic impedance in the free field by PU probe instead of full Biot model.

FREE FIELD METHOD WITH PU-PROBE

There are many measurement techniques for evaluation of the acoustic impedance or the absorption coefficient of materials. The most known technique is the method using the impedance tubes [1, 2]. This method has merits like short measuring time and small specimen size. However the method is not suitable for the poroelastic material like foamed rubber that the measurement data are affected by the specimen size, or a specimen can not be cut out from a body. Therefore the in-situ measurement techniques should be applied to measure the acoustic properties of the poroelastic materials. A typical in-situ method is called the transfer function method using the sound pressures at two microphones [3, 4]. Recently PU-Probe was developed [5, 6], which can measure the sound pressure and the particle velocity at the same point simultaneously. Since PU-Probe can estimate the acoustic impedance at one point, the measuring technique with PU-Probe can be expected to be more accurate than the two-microphone method. In this paper, the normal specific acoustic

impedance and the normal absorption coefficient of trim samples (the roof and the seat inside the car) are measured by the in-situ measurement technique using PU-Probe. This technique is called “surface impedance method” [7, 8]. These values are also compared with the measured data by the impedance tube with the diameter 40mm.

SURFACE IMPEDANCE METHOD - There are a sound source S (loudspeaker), an image source S' and a receiver R (PU-Probe) on the z axis shown as Figure 1. It assumes that R is near by the specimen, the distances r and r' are sufficiently large compared to the wavelength and the surface of the specimen is locally reacting surface.

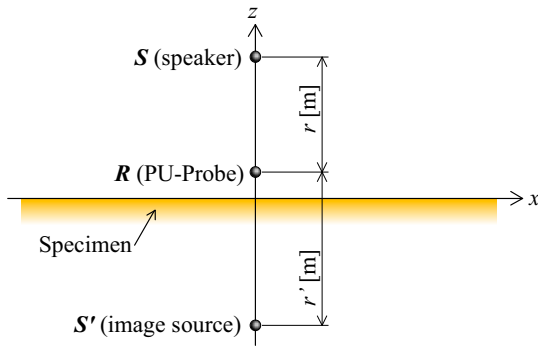


Figure 1: Arrangement of a sound source (speaker) S and a receiver (PU-Probe) R for the surface impedance method

Since the normal specific acoustic impedance $Z_n(\mathbf{R})$ is the ratio of the sound pressure $p(\mathbf{R})$ and the $-z$ directional particle velocity $u_n(\mathbf{R})$, which are measured by PU-Probe at $\mathbf{R}$, the reflection coefficient R_p of the specimen for the plane wave is given by [7, 8]

$$R_p = \frac{\frac{\exp(-jkr)}{r} \cdot \frac{Z_n(\mathbf{R}) \frac{1+jkr}{jkr} - \rho c}{\frac{\exp(-jkr')}{r'} \cdot \frac{Z_n(\mathbf{R}) \frac{1+jkr'}{jkr'} + \rho c}}, \quad (1)$$

where k is the wavenumber, ρ is the density of air and c is the sound speed in air. The normal specific acoustic impedance and the normal absorption coefficient are derived from R_p .

MEASUREMENT PROCEDURE – The measurement is done in a hemi-anechoic room shown as Figure 2. The distances between the loudspeaker and the specimen (the roof trim and the seat of the vehicle) are 0.5m. PU-Probe receives the impulse responses of the sound pressure $p(t)$ and the particle velocity $u(t)$. To eliminate extra reflected waves from other subjects except for the target and the diffracted waves caused by the edge of the specimen, the raised cosine time window is applied to the impulse responses.

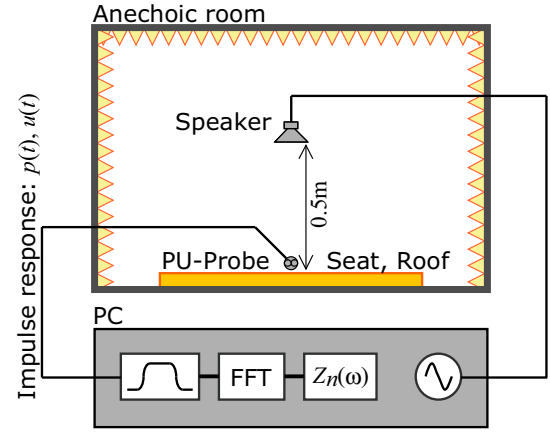


Figure 2: The apparatus of the measurement

In addition to use of the raised cosine time window, several impulse responses measured at different points on same target surface area are averaged in time domain. This operation (is called “spatial average” in this paper) is also expected to eliminate the unwanted reflected waves. Figure 3(a) shows 9 impulse responses at different points on the same surface and Figure 3(b) shows the averaged impulse response. It is found that the averaged impulse response is smoothed and eliminated the extra reflected waves by the spatial average.

After applying the spatial average and the raised cosine time window to the impulse responses, the specific acoustic impedance $Z_n(\mathbf{R})$ is estimated by applying FFT to the averaged impulse response of $p(\mathbf{R})$ and $u_n(\mathbf{R})$, then the reflection coefficient R_p is obtained by Eq. (1) substituted $Z_n(\mathbf{R})$. PC operates the calculation and average of the impulse responses.