Loss Factor at Boundary of Single-Leaf Wall Under Vibrational Field of Diffused Bending Waves

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Abstract: The internal loss factor \( \eta_{int} \) is an important parameter in the case of calculating the transmission loss of panel by using SEA (statistical energy analysis). Though energy loss at the edge is fairly large in practical walls, \( \eta_{int} \) have been ordinary treated including the edge loss. So it must be necessary to treat quantitatively the energy loss at boundary of wall. In this paper, assuming that panel in excitation is two-dimensional vibration field of diffused bending waves, we deduce a formula of decay time of panel. The subject for experimental study is aluminum panel mounting in the opening between transmission suite. Panel is excited by piezo-electric ceramic diaphragm. Vibrational decay time is measured by impulse response method. Calculation method of energy absorption coefficient and loss factor at perimeter is indicated by using measured values of decay time and sound radiation.

INTRODUCTION

It is necessary to clarify many problems such as coupling loss factor and internal loss in the case of calculating the transmission loss of panel by using SEA (statistical energy analysis). And there are many points which are not clear such as the mechanism of energy loss at the edge of wall. In order to quantify the loss factor at boundary of single-leaf wall, reverberation time of vibration is deduced assuming that panel in excitation is vibrational field of diffused bending waves. The subject for experimental study is aluminum panel mounting in the opening between transmission suite. Panel is excited by piezo-electric ceramic diaphragm[1]. Vibrational decay time is measured by impulse response method. Radiation coefficient is also measured by intensity measurement. Calculation method of energy absorption coefficient and loss factor at perimeter is experimentally investigated.

REVERBERATION TIME AND LOSS FACTOR OF PANEL ASSUMING VIBRATION FIELD OF DIFFUSED BENDING WAVES

Assuming that panel is two-dimensional diffuse field, the relation between energy per unit area \( E_v (J/m^2) \) and incident power per unit length of perimeter \( I_v (W/m) \) is obtained as follows [2]:

\[
I_v = \frac{C_g}{\pi} E_v \quad (1), \quad C_g = 2c_b (1-\alpha), \quad c_b = \frac{\pi c_f h f}{\sqrt{3}} \quad (1-b)
\]

where \( C_g \) = group velocity of bending wave (m/s), \( c_b \) = phase speed of bending wave (m/s), \( c_f \) = longitudinal wave speed (m/s), \( h \) = panel thickness (m), \( f \) = frequency (Hz).

When the input power to panel of area \( S \) by excitation is \( W (W) \), the growth or decay of the total energy \( E_v \cdot S \) in the panel may be expressed as follows, considering the absorption at edge, the sound radiation loss from both sides of plate and the dissipation in plate:

\[
W - \alpha_p \cdot \frac{C_g}{\pi} L \cdot E_v - 2\eta_r \omega \cdot E_v \cdot S - \left(1-(1-a_m)C_g\right) E_v \cdot S = S \cdot \frac{dE_v}{dt} \quad (2)
\]

where \( \alpha_p \) = absorption coefficient of perimeter, \( L \) = perimeter length (m), \( \eta_r \) = loss factor due to sound radiation from one side of the panel, \( \omega = 2\pi f \) (1/s), \( a_m = \) dissipation rate per unit length of panel during propagation (1/m). Here \( a_m \ll 1 \), so that \( \left(1-a_m\right)C_g \approx 1-a_m \cdot C_g \). The reverberation time, defined for a decay by 60dB, is obtained as follows:

\[
T = \frac{13.8}{C_g \left( \frac{L}{\pi S} \cdot \alpha_p + a_m + \frac{2\eta_r \omega}{C_g} \right)} \quad (3)
\]

Thus, the panel's total loss factor \( \eta_{tot} \) is given by Eq.(4).
The loss factor at boundary $\eta_p$ and the radiation loss factor from one side of panel are given by Eq.(5) and Eq.(6) respectively\cite{2}\cite{3}, where $\rho$ = density of air(\text{kg/m}^3), $c$ = speed of sound in air(\text{m/s}), $\rho_p$ = density of panel(\text{kg/m}^3), $\sigma_{rad}$ = radiation efficiency of one side of panel.

**MEASUREMENT OF RADIATION COEFFICIENT AND TOTAL LOSS FACTOR**

The aluminum panel (@3.0mm, 860 x 1770mm) is attached to the opening between transmission suite by nailing at 15mm interval. The piezo-electric diaphragm (41mm diameter, 0.4mm thick, 5.4g weigh) is pasted on panel for excitation. Fig.1 shows the radiation factor measured by the intensity method. The measurement result agrees well with the theoretical curve by Crocker\cite{4}. Fig.2 shows the total loss factor measured by the impulse response method.

**CALCULATION OF ENERGY ABSORPTION COEFFICIENT AND LOSS FACTOR AT EDGE**

According to the measurement result of the total loss factor $\eta_{tot}$ (Fig.2), Fig.3 shows the converted values of reverberation time by using of Eq.(4). The solid line in Fig.3 indicates the calculated $T$ using Eq.(3) with the parameter $\alpha_p$. Fig.4 shows the calculated values $\alpha_p$ due to Eq.(3) using measured values $T$ and $\eta_r$. Then using Eq.(5), the loss factor at edge $\eta_p$ can be calculated. The results $\eta_p$ are illustrated in Fig.2. $\eta_{tot}$ is decided by $\eta_p$ below the coincidence frequency. And, $\eta_p$ is nearly constant over wide frequency range.

**REFERENCES**