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NOISE REDUCTION AND SOUND RADIATION EFFICIENCY OF THE ENCLOSURE FOR DIFFERENT ATTACHMENT CONDITIONS BY AIRBORNE SOUND

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INTRODUCTION

The sound radiation characteristics of the rectangular enclosure such as the acoustical box will be varied by attachment conditions (i.e. with and without glueing) to the frame. Thus, this characteristics will depend on coupling loss factors with respect to the sound radiation. Statistical energy analysis is applied to predict noise reduction and sound radiation efficiency of the rectangular enclosure, when thin panels of the enclosure are excited by airborne sound.
On this report, we investigated whether noise reduction and sound radiation efficiency vary or not due to coupling loss factors of two different attachment conditions.One of these conditions is only the case of the panel bolted to the box frame.
It is shown that by our assumption of the receiving room being the free space or the anechoic room, the external sound pressure near the panel can be obtained from the sum of the resonant sound radiation power and the non-resonant sound transmission power from the panel.

THEORETICAL CONSIDERATION

2.1 Power Balance Between Coupled Systems

On the coupled systems of two attachment conditions such as panels are bolted to frames with or without glueing, when panels of the enclosure are excited by airborne sound, we shall assume that there are no power flow between panels and frames because of equipartition of modal energy in the coupled systems. These energies stored to the coupled systems are not the energy by flexural vibration of frames, but at most will be the energy by that of panels. Thus so that we can be negligible energies stored to frames, we consider power balance only between panels and enclosure. The suitable representation for power balance is obtained as follows(see Fig.1);

$$\sum \Pi_{diss\ wj} + \sum \Pi_{wj}^{r} + \sum \Pi_{wj}^{s} = \sum \Pi_{s}^{wj} \tag{1}$$

$$\sum S_{wj}\omega\eta_{wj}^{wj} + \sum S_{wj}\omega\eta_{wj}^{r} + \sum S_{wj}\omega\eta_{wj}^{s} = S_s\omega\sum\eta_s^{wj} \qquad (2)$$

The spectrum of sound pressure within the enclosed space is obtained by the equation;

$$S_s^p = \rho c^2 S_s/V \qquad (3) \qquad\qquad S_{wj} = M_{wj}S_{wj}^v = M_{wj}\langle v_{wj}^2\rangle/\Delta f \quad (4)$$

$$\eta_{wj}^{tot} = \eta_{wj}^{wj} + \eta_{wj}^{r} + \eta_{wj}^{s} \quad (5) \qquad\qquad n_s\eta_s^{wj} = n_{wj}\eta_{wj}^{s} \qquad (6)$$

The external sound pressure without the enclosure is determined modes of the panel, i.e. the power due to the radiated sound and the mass-law transmission;

$$S_r^p A_{wj}/\rho c = S_{wj}\omega\eta_{wj}^{r} + S_s\omega\eta_s^{r} \qquad (7)$$

2.2 Radiation Loss Factor and Non-Resonant Sound Transmission

For panels of the our enclosure we consider as $\eta_{wj}^{s} = \eta_{wj}^{r} = \eta_{rad}^{2\pi}$.
The radiation loss factor to half space $\eta_{rad}^{2\pi}$ of a simply-supported panel has been derived by G.Maidanik[1].
The non-resonant power flow $S_s\omega\eta_s^{r}$ and the coupling loss factor η_s^{r} can be derived from mass-law transmission as the following two equation;

$$S_s\omega\eta_s^{r} = (S_s^p V/\rho c^2)\omega\eta_s^{r} = (S_s^p c/4\rho c^2)A_{wj}\tau \qquad (8)$$

$$\eta_s^{r} = cA_{wj}\tau/4\omega V \qquad (9)$$

2.3 Noise Reduction and Sound Radiation Efficiency

Noise reduction of the enclosure is given from Eqs.(3) and (7) as follows;

$$NR = 10 \log\ S_s^p/S_s^p \qquad (dB) \qquad (10)$$

If by flexural vibration the acoustic power radiated with surface area A is P , sound radiation efficiency σ is given as follows;

$$\sigma = P/P_0 = M_{wj}\omega\eta_{rad}^{2\pi}/\rho c A_{wj} \qquad (11)$$

$$P = M_{wj}\langle v_{wj}^2\rangle\omega\eta_{rad}^{2\pi} \qquad\qquad P_0 = \rho c\langle v_{wj}^2\rangle A_{wj}$$

But in general the practical measurements, we may measure the sound pressure due to the sum of resonant sound radiation power and non-resonant sound transmission power. Thus we introduced the apparent sound radiation efficiency follows;

$$\rho c\langle v_{wj}^2\rangle A_{wj}\sigma_{app} = M_{wj}\langle v_{wj}^2\rangle\omega\eta_{wj}^{r} + E_s^{in}\omega\eta_s^{r} \qquad (12)$$

$$\sigma_{app} = \sigma_{def} + E_s^{in}\omega\eta_s^{r}/(\rho c\langle v_{wj}^2\rangle A_{wj}) \qquad (13)$$

where E_s^{in} is the energy stored in the enclosure s and is obtained as follows;

$$E_s^{in} = \sum M_{wj} \langle v_{wj}^2 \rangle n_{wj}^s / n_s^{tot} \tag{14}$$

If it is assumed that mean modal energies between coupled systems are equal, the theoretical NR and σ may be obtained by eliminating the measured $\langle v_{wj}^2 \rangle$ in Eqs.(10) and (13).

MEASUREMENT METHOD

The acoustical enclosure and the panel used to the measurement are shown as follows; a) enclosure dimensions 900×600×600 mm, frame(angle steel); 30×30×3 mm, exciter; speaker. b) panel; steel(0.8 mm thick), plywood (3.0 mm thick). The rectangular enclosure was made with five panels, and these were bolted to frame (with abolt spaceing of 150 mm) with or without of glueing.
The internal and external sound pressure of the enclosure, and the acceleration of panels were measured by averaging in time and space. The loss factor associated with panels were obtained from measurements of vibration decay time T at frequencies f as $\eta = 2.2/f \cdot T$. Experimental values of the apparent sound radiation efficiency are given in logarithmic form as follows;

$$10\log \sigma_{app} = L_p - L_v \quad (dB) \tag{15}$$

L_p ; external sound pressure level

L_v ; velocity level of panel (ref. 5×E-8 m/s)

EXPERIMENTAL RESULTS

As compared with two curves of the total loss factor due to difference between attachment conditions in Fig.3, these curves show a similar tendency. Experimental values of noise reduction by two difference attachments shown in Fig.4 almost agree, and also these agree well with theoretical results. Fig.5 shows sound radiation efficiencies containing the non-resonant sound transmission power. There is a little difference in these efficiencies by two different attachments.
It will be suitable to consider as the panel glued and bolted to the frame reduce the radiation efficiency, because of the difficulty for the radiation due to the glued panel.

CONCLUSION

As the results, noise reduction could not be found the difference between two attachment conditions with and without glueing, but sound radiation efficiency existed in a little difference. In case of two different attachment conditions, S.E.A. is applied to predict noise reduction and approximate sound radiation efficiency.

REFERENCES

[1] G.Maidanik, J. Acoust. Soc. Am. 34, 809-826, (1962).
[2] E.Eichler, J. Acoust. Soc. Am. 37, 995-1007, (1965).

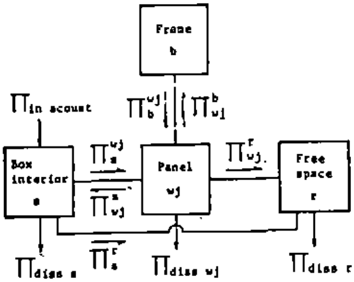

Fig. 1 Block diagram representing power flows between coupled systems of transmission suite.

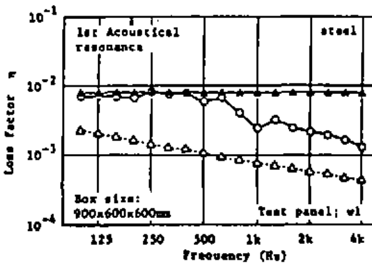

Fig.2 Total, internal and radiation loss factor. The panel are bolted to the box frame.

—o— Experimental values of $\eta_{wj,tot}$.
--△-- Theoretical curve of η_{wj}^{rad}.
—▲— Theoretical curve of the estimated values η_{wj}^{rad}.

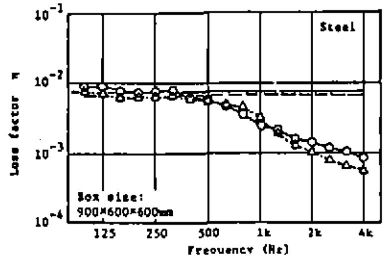

Fig.3 Experimental total loss factor of the box panel by attachment condition.

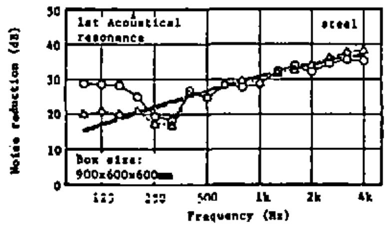

Fig.4 Experimental noise reduction of the rectangular box by attachment condition, exciting by airborne sound.

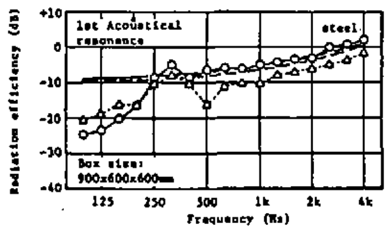

Fig.5 Experimental radiation efficiency of the rectangular box by attachment conditions, exciting by airborne sound.

—o— With the panel bolted to the box frame.
--△-- With the panel glued to and bolted to the box frame.