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ESTIMATION OF COUPLING LOSS FACTORS USING STRUCTURAL INTENSITY

T Yamazaki, M Kamata & S Ohno

Engineering Research Institute, Faculty of Engineering, 2-11-16 Yayoi Bunkyo-ku, Tokyo 113,The University of Tokyo, Japan

1. INTRODUCTION

Measurement of Structural Intensity(SI) is often used to identify the transmission paths of vibrational energy and characteristics of vibrational sources. Power injected into a structure can be estimated using SI.

In Statistical Energy Analysis(SEA)[1], the basic equations deals with energy dissipation and energy flow between subsystems. Energy dissipation from a subsystem is represented by Internal Loss Factor(ILF), and energy flow between subsystems by Coupling Loss Factor(CLF). The accuracy of predictions using SEA ,therefore, depends on the estimation precision of these factors.

Finite Element Method(FEM) was used in several previous researeches to analyze the structure-borne sound transmission[2][3][4], where the vibrational energy of subsystem is calculated by nodal displacements .

In this paper, the ILFs and the CLFs are numerically estimated using the structural intensity measurement. FEM is used to calculate the vibrational energy and the structural intensity. The results show that the transmitted power between subsystems in SEA is determined by the structural intensity, and that the ILFs and the CLFs can be estimated.

2. ESTIMATION OF LOSS FACTORS USING SI

Consider a subsystem which has connections to several subsystems at each different boundary as shown in Fig.1. P_{ki} represents the transmitted net power from the subsystem k to i. From energy balance, the dissipated power is equal to the transmitted one. Therefore,

$$\sum_k P_{ki} = \omega \eta_i E_i \qquad (1)$$

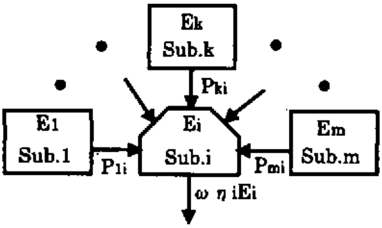


Fig.1 SEA Model - Subsystem i

Structural intensity at a point in a structure is the power transmitted per closs sectional area including the point. Therefore, the integration of SI along each boundary gives to the transmitted net power, as

$$P_{ki} = \sum_n I_n\ S_n \tag{2}$$

where, I_n is the structural intensity along a boundary and S_n is the cross sectional area. The ILF can be determined from eq.(1) and (2).

According to the basic SEA assumptions, a reciprocity relationship $n_i\eta_{ik} = n_k\eta_{ki}$ can be derived, where n_i and n_k are the modal densities of subsystem i and k, respectively. The transmitted net power from k to i is also represented.

$$P_{ki} = \omega\eta_{ki}(E_k - \frac{n_k}{n_i}E_i) \tag{3}$$

The CLF(η_{ki}) is derived from eq.(2) and (3).

Estimation of the CLF using SI measurement was reported by Craik[5], but the method was limited only to a system composed of two subsystems. Our procedure is adapted to a system composed of more than two subsystems.

To measure the structural intensity in a subsystem, the following procedures are possible: (1)measurement of the intensity around the connection boundary, (2)measurement of the mean intensity based on the wave decomposition method which was proposed in Ref[6].

3. APPLICATIONS

The procedure described above was applied to two structures which were composed of two and three plates. In FEM, mesh size was set to 0.02×0.02[m] and one subsystem was excited by a force at a point. The procedure of numerical application is as follows. First, the nodal data(displacement,rotation) and the elemental data(shear force, bending and torsional moment) are calculated by FEA at every resonance frequency of all system up to 1.4kHz using direct solution method. Second, the vibrational energy and the structural intensity are calculated. Finally, these values are summed in every one octave frequency band.

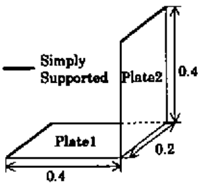


Fig.2 L-Shaped Structure

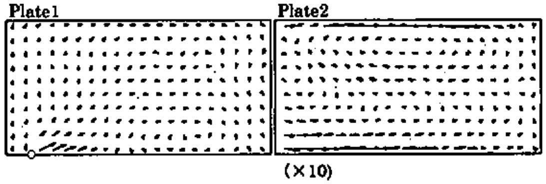
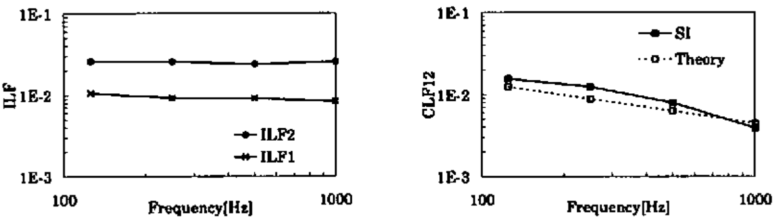


Fig.3 Structural Intensity - 500Hz Band



(a) Internal Loss Factors(η_1, η_2) (b) Coupling Loss Factor(η_{12})
Fig.4 Loss Factors in L-Shaped Structure

· L-Shaped Structure

An L-shaped steel structure shown in Fig.2 which was composed of two plates (plate1:0.4×0.2×0.002[m],plate2:0.4×0.2×0.001[m]) was first dealt with. Plate 1 and 2 have material damping of 0.03, 0.01, respectively.

The vibrational energy and the intensity were calculated on the condition that the plate 1 was excited. An example of the calculated intensity is shown in Fig.3. The symbol o in the figure represents the position of excitation. The results of the estimated loss factors are shown in Fig.4(a) and (b). Fig.4 shows that there are good agreement between them and the material dampings or theoretical determined CLFs[1].

The vibrational energy level of each subsystem was predicted using these factors in the case that the plate 2 was excited. Fig.5 shows the predicted energy ratio and the one calculated by FEM. The agreement between their ratios is very good except 125Hz band, where the number of modes is small.

· J-Shaped Structure

A J-shaped structure shown in Fig.6 was next dealt with. Plate 1(0.2×0.2×0.001) has material damping 0.001, plate 2(0.3×0.2×0.002) 0.002 and plate 3(0.4×0.2×0.003) 0.003. The loss factors were estimated from the vibrational energy and the intensity(as an example shown in Fig.7) on the condition that the plate 3 was excited. The energy ratios in the case that the plate 1 was excited were predicted using these factors. The results are shown in Fig.8. In this case, the predicted

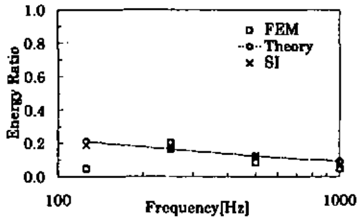


Fig.5 Energy Ratio (E_1/E_2)
in L-Shaped Structure

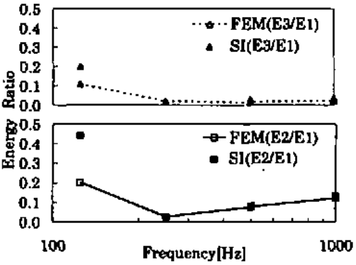


Fig.8 Energy Ratio
in J-Shaped Structure

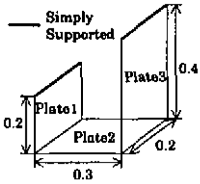


Fig.6 J-Shaped
Structure

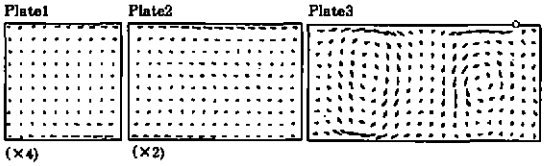


Fig.7 Structural Intensity - 1000Hz Band

energy ratios are also in good agreement with the ratio calculated by FEM except 125Hz band.

4. CONCLUSION

In this paper, the structural intensity measurement was used in order to estimate the loss factors of SEA. The validity of this technique was numerically shown in the case of L- and J- shaped structures. We consider that the measurement method using the mean intensity can be also applied to measure the structural intensity in a subsystem, though the intensity around the boundary was considered in this paper.

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