inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 2.5

USE OF A CONSTRUCTED VIBROACOUSTIC TRANSFER FUNCTION FOR PREDICTING SOUND RADIATION FROM A STRUCTURE IN SITU

C. Marquis-Favre*, N. Hamzaoui, C. Boisson****

* LASH/DGCB URA CNRS 1652 - ENTPE, ENTPE, rue M. Audin, 69518, Vaulx-En-Velin, France

** LVA - INSA de Lyon, Bât. 303 - INSA, 20 av. A. Einstein, 69621, Villeurbanne, France

Tel.: 33 4 72 04 72 66 / Fax: 33 4 72 04 70 41 / Email: cathy.marquis@entpe.fr

Keywords:
VIBROACOUSTIC TRANSFER FUNCTION, RADIATION PREDICTION, GREEN'S FUNCTION, IN SITU

ABSTRACT

Our work focuses on the construction of the Green's function for structures radiating *in situ*. This function has to behave as a transfer function between the structure vibratory behavior and the sound field. The Green's functions, well-known in literature, depend mainly on the geometric shape of the vibrating surface and the surrounding acoustic field. For an arbitrarily shaped structure in ordinary room, the difficulty of predicting noise lies in expressing the Green's function. We propose an approach based on the numerical construction of this transfer function from vibroacoustic data which are acoustic pressure and normal vibratory velocity measurements defining the structure *in situ*. Some investigations are carried out in order to check whether the built function allows the radiated sound field to be predicted for a new vibratory behavior measured on the structure located on its site.

1 - INTRODUCTION

Prediction of sound radiation from irregularly shaped structures in ordinary rooms has been treated in the literature with various aims and models (see for example [1-3]). The objective of our work is to provide a tool that will allow from experimental vibratory data, the prediction of sound radiation from a complicated shape structure in its real environment. In this acoustic radiation problem, the difficulty lies in expressing analytically the Green's function which essentially depends on both the geometric shape of the structure and the nature of the surrounding sound field. The proposed approach consists in the numerical construction of this vibroacoustic transfer function from acoustic pressure and normal vibratory velocity measurements in terms of modulus and phase. This transfer function must permit the radiated sound field to be predicted for any new vibratory behavior measured on the structure located on its site. In this paper, we present some investigations concerning the ability of the built function to act as a transfer function when the vibratory behavior has been changed after the construction of the vibroacoustic transfer function. Some confrontations between calculations and measurements in terms of sound pressure and sound power levels illustrate these investigations in the case of a three-dimensional structure radiating in an ordinary room.

2 - MODEL

The model and the numerical statement of the proposed approach, dealing with the numerical construction of the Green's function for a structure radiating on its site, have been presented in detail in reference [4]. In this paper, the main stages are recalled. The radiating structure is located in a bounded acoustic medium V_e. For steady-state harmonic waves and with the time dependence $e^{j\omega t}$ omitted, the acoustic pressure $P(M)$ is given at any point M of V_e by the Helmholtz integral representation [5]. For the sound radiation of an arbitrarily shaped structure in ordinary room, solving the problem presents different difficulties: (i) the obtention of the vibratory data all over the site boundaries Σ, (ii) the surface pressure computation on Σ and on the structure surface S, and finally (iii) the expression of the finite space Green's function G for this radiation problem. It is thus necessary to introduce some simplifying hypotheses:

- the acoustic contribution due to the surface Σ is negligible compared with the one due to the vibrating surface S when the receiver point M is close to the radiating structure. This assumption limits sound radiation prediction in the vicinity of the structure.

- the Green's function verifies the following condition on S:

$$\frac{\partial G_s\left(M,M_0\right)}{\partial n_{M_0}} \approx 0,\ \ M_0 \in S \tag{1}$$

with n_{M_0} the outward normal to the structure surface S at the point source M_0.
Then, the acoustic pressure can be approximated by:

$$P\left(M\right) \approx \int\int_S j\omega\rho v_n\left(M_0\right) G\left(M,M_0\right) dS_{M_0},\ \ M \in V_e, M_0 \in S \tag{2}$$

However this last equation is not sufficient in order to determine the Green's function $G(M{,}M_0)$ for every couple of points $(M{,}M_0)$. Therefore, the following fictitious problem is considered: let us imagine a surface S', identical to S and with the same vibratory discretization, and radiating in free field the same acoustic pressure as the one radiated from S in its environment. A density function, denoted by μ, is assigned to each point source M_0, so that the sound field is the same as the one measured on the site all around the vibrating surface S. This radiation problem can be described by the following formulation:

$$P\left(M\right) = \int\int_{S'} \mu_M\left(M_0\right) g\left(M,M_0\right) dS'_{M_0},\ \ M \in V_e, M_0 \in S' \tag{3}$$

with $g\left(M,M_0\right) = e^{-jkr}/4\pi r$ the free-space Green's function. The density function is determined by solving an inverse vibroacoustic problem. This function calculated from the acoustic pressure measured close to the structure on its site will take into account the contribution of the sound radiation from the structure and the contribution of the site reaction on this latter.
As the sound field around S and S'are the same, the identification of Eqs (1) and (2) leads to:

$$\int\int_S j\omega\rho v_n\left(M_0\right) G\left(M,M_0\right) dS_{M_0} \approx \int\int_{S'} \mu_M\left(M_0\right) g\left(M,M_0\right) dS'_{M_0} \tag{4}$$

This last relation constitutes the basic model of the proposed approach, it leads to the resolution of a minimization problem and allows the vibroacoustic transfer function G to be numerically constructed. Practically, one needs a vibratory mesh undertaken on the vibratory structure surface S and an acoustic mesh carried out close to the radiating surface S.
After the construction of G, the sound radiation prediction can thus be worked out by means of Eq. (2) for a new vibratory behavior of the structure. This prediction can be done locally by computing the sound pressure level at one or different receiver points M, and globally by calculating the sound power level. This latter is calculated from the acoustic power:

$$W = \oint_{S_c} \vec{I}.\vec{n} dS_c \text{ with } \vec{I} = \frac{1}{2}\mathrm{Re}\left\{P.\vec{u}^*\right\} \tag{5}$$

where $\vec{I}$ is the active acoustic intensity vector computed at different receiver points M distributed on a closed control surface S_c, $\vec{n}$ the outward unit vector, normal to the surface S_c at M, and finally $\vec{u}^*$ the complex acoustic velocity vector conjugate. The principle of the acoustic velocity vector calculation is identical to the one used by a p-p intensity probe for measurements [6].
Our approach has been numerically validated in the case of different analytical well-known vibroacoustic structures of one-dimensional, two-dimensional and three-dimensional types such as lineic monopoles distributions, baffled plate and vibrating sphere (Cf. [4], [7]).

3 - EXPERIMENTAL VALIDATIONS

Some confrontations of computations with measurements have been carried out for a three-dimensional structure located in a non-anechoic room. The structure is an electric motor cover in glass fiber and of dimensions 0.5m length by 0.32m width by 0.2 m height. For this experiment, the structure is randomly excited from inside by a point mechanical force. Different vibratory meshes have been undertaken on the structure surface, a vibratory mesh of 48 points allows the convergence of the sound pressure computation up to 1600 Hz. Some acoustic pressure have been measured at 201 points located close to the radiating structure and distributed on two fictitious parallelepiped surfaces S_1 and S_2 encircling the cover and respectively at 0.05m and 0.15m from the structure surface. The vibroacoustic transfer function is computed by using the vibratory mesh of 48 normal vibratory velocities and the acoustic mesh of 201 pressures in terms of modulus and phase. The comparisons between measured and calculated sound pressure levels carried out at any receiver point M located inside the area delimited by the two fictitious surfaces S_1 and S_2 are in good agreement.

Then the vibratory behavior has been changed by modifying the excitation level. The Green's function, previously constructed, acts as a transfer function since it allows the sound pressure level (figure 1) and the sound power level (figure 2) to be predicted with a good agreement for a new vibratory behavior of the cover.

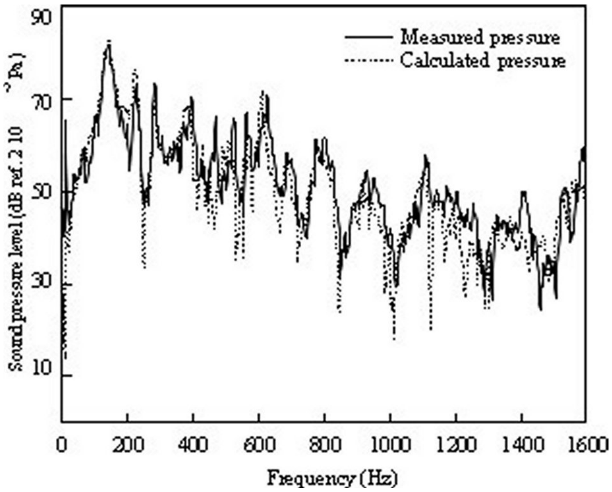

Figure 1: Sound pressure level radiated by the cover at a point M located in the area delimited by the two fictitious parallelepiped surfaces S_1 and S_2 encircling the cover; the computation is carried out after modification of the excitation level.

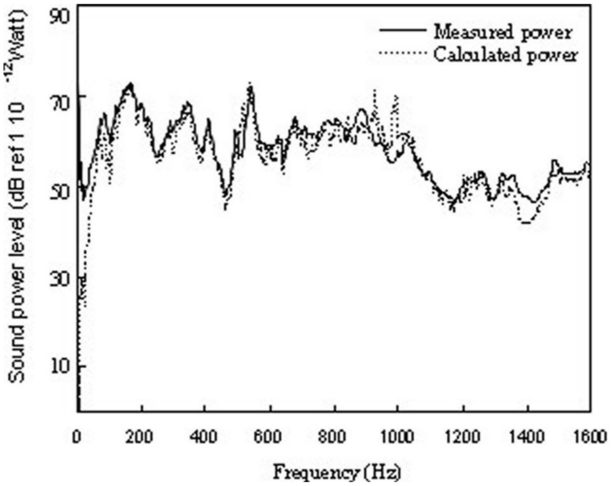

Figure 2: Sound power level radiated by the cover; the computation is undertaken after modification of the excitation level; the closed control surface S_c is a parallelepiped one between the two fictitious surfaces S_1 and S_2.

4 - CONCLUSIONS

The prediction of acoustic radiation from complicated shape structures in their real surroundings is then possible to be worked out from normal vibratory velocities data only and from the numerical construction of an appropriate Green's function. Numerical confrontations in the case of the vibrating sphere sound radiation [7] have shown the ability of the built Green's function to allow the sound radiation to be computed from vibratory data only, in case of multipoles contributions. The presented investigations, carried out for a real three-dimensional structure in an ordinary room, show the ability of this function to act as a transfer function since it allows sound pressure and sound power levels to be predicted for a new vibratory behavior measured after modification of the excitation level.

REFERENCES

1. **Fahy F.J.**, The vibro-acoustic reciprocity principle and applications to noise control, *Acustica*, Vol. 81, pp. 544-558, 1995
2. **Bobrovnitskii Y.I.**, A solution to the noise prediction problem at low frequencies, In *2nd International Congress on recent Developments in air- and structure-borne sound and vibration, Auburn, USA*, pp. 847-850, 1992
3. **Weinreich G. and Arnold E.B.**, Method for measuring acoustic radiation fields, *J. Acoust. Soc. Am.*, Vol. 68 (2), pp. 404-411, 1980
4. **Marquis C.**, *Construction de la fonction de transfert vibroacoustique pour la prédiction du rayonnement acoustique d'une structure sur site*, Thèse de doctorat: Institut National des Sciences Appliquées de Lyon, pp. 231, 1997
5. **Lesueur C.**, *Rayonnement acoustique des structures vibroacoustiques, interactions fluide structure*, Ed. Eyrolles, Paris, pp. 591, 1988
6. **Fahy F.J.**, Sound intensity, *Elsevier Science Publishers, London*, pp. 274, 1989
7. **Marquis C., Hamzaoui N. and Boisson C.**, The construction of the vibroacoustic transfer function of a structure on its site, In *Euro-Noise'95, Lyon, France*, pp. 447-452, 1995