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THE INFLUENCE OF PANEL VIBRATIONS ON SOUND PRESSURE LEVELS IN THE ENVIRONMENT

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Abstract

The prediction of noise levels from vibrating structures in the work place is one of considerable importance to the design engineer. In this paper a technique for the determination of the noise levels from vibrating panels is discussed. Information regarding the panel's vibration and acoustic characteristics and the room's dimensions and acoustic characteristics form the input to a computer programme which is used to predict equi-noise contours around the structure. The programme has been used to determine noise contours around a vibrating plate in a room in Sheffield City Polytechnic and the results are presented in the paper.

Introduction

Stiffened and unstiffened plates play an important part in engineering manufacture with examples being found in machine tool structures, ventilating systems and many other structures. During their life these panels are often subjected to vibrations of a random nature resulting from either localized or distributed loadings. The estimation of the structural response to such loadings is of importance to the design engineer for predicting for example stress and vibration levels and fatigue life.

Until recently the problem of noise radiation in the working environment was in many cases not considered to be important. As a result it received little attention at the design stage and when difficulties arose the manufactured structure was modified to reduce the noise levels.

The introduction of important legislation in the form of the Health and Safety at Work Act (1974) now ensures that noise in the working environment must be kept to acceptable levels. The prediction of noise levels from vibrating structures has therefore become a problem which must receive the attention of the design engineer.

In this paper a simple expression is developed to allow the predication of the S.P.L. from vibrating panels when they are subjected to an excitation of a random nature. Results in the form of equi-noise contours around the panel using the expression in conjunction with a computer programme have been obtained and are presented in the paper.

Theory

Noise levels around a structure which is subjected to a random excitation depends mainly on its response spectral density to such an input and the acoustic intensity around the structure.

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The response spectral density $S_d(f)$ at a point d of a vibrating structure which is subjected to a single point random excitation at a point p is given by Robson (1) as

$$S_d(f) = |\alpha(jf)|^2 \, S_p(f) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

in which $S_p(f)$ is the input spectral density of the excitation and $\alpha(jf)$ is the receptance between points d and p.

The term $|\alpha(jf)|^2$ in equation is obtained from the expression

$$|\alpha(jf)|^2 = \sum_r \frac{[\phi_r(d)\ \phi_r(p)]^2}{16\pi^2 M_r^2[(f_r^2 - f^2)^2 + \eta_r^2 f_r^4]} \quad \ldots \quad \ldots \quad (2)$$

In the above equation $\phi_r(d)$ and $\phi_r(p)$ are the deflections of the structure at points d and p when it is vibrating in its r th normal mode, f_r is the r th natural frequency of the structure, η_r is the hysteretic damping coefficient of the r th normal mode, f is a forcing function and M_r is the generalized mass.

Similar expressions to equation (1) are also given by Robson for structures subjected to multi-point and distributed random excitations.

The expression for the acoustic intensity, W, of a structure in vibration is quoted by Richards in (2) as

$$W = \rho c A \sigma_{rad} < v^2 > \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

where ρc is the impedance of the air and has a value of 414 m/sec^2, A is the area of the vibrating structure, σ_{rad} is the radiation ratio and $< v^2 >$ is the mean square velocity of the structure taken over its surface.

The sound power level, SWL, of the source is obtained from the expression given by Sharland (3) as

$$SWL = 10 \log_{10} \frac{W}{W_{ref}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

where $W_{ref} = 10^{-12}$ watts.

Having obtained the sound power level of the vibrating structure, the sound pressure level, SPL, at any point distance r from the structure is given by Sharland (3) as

$$SPL = SWL + \log_{10} \left[\frac{Q_\theta}{4\pi r^2} + \frac{4}{R_c} \right] \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

where Q_θ is the directivity factor of the source in the direction of r

R_c is the room constant = $S\bar{\alpha}/(1 - \bar{\alpha})$
S is the surface area of the room
$\bar{\alpha}$ is the average absorption coefficient of the room

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Results

Using equations (3), (4) and (5), the sound pressure level can be calculated at any point distance, r, from the vibrating structure. The determination of the acoustic coefficient in equation (3) requires the calculation of $< v^2 >$. When a structure is subjected to a random vibration, $< v^2 >$ depends on its response spectral density which depends on the excitation spectral density, as shown in equation (1). The response spectral density can only be determined by experiment and the results which are presented in this paper are for a simply supported rectangular plate 0.38 mm thick having dimensions 560 mm x 150 mm excited by a P.R.B.S. signal having a flat spectrum. It has been shown by McNulty (4) that, for such a spectrum, when the natural frequency f_r dominates, $< v_r^2 >$ can be obtained from the expression

$$< v^2 > = 0.25\ \pi^3\ f_r^{\ 3}\ S_d\,(f_r) \quad \dots \quad \dots \quad \dots \quad \dots \quad (6)$$

Hence when equation (6) is substituted into equation (3) for the panel under consideration

$$W = 3210\ A\ \sigma_{rad}\ f_r^{\ 3}\ \eta_r\ S_d\,(f_r) \quad \dots \quad \dots \quad \dots \quad (7)$$

Having obtained the acoustic intensity of the panel, its sound power level can be calculated from equation (4) and the result substituted into equation (5) to determine the sound pressure level at any point around the structure. A computer programme has been developed which uses equation (5) to calculate equi-noise contours in a room around a structure. The programme has been used to predict noise contours in Committee Room 1 of Sheffield City Polytechnic and the results are shown in figure 1.

Conclusions

The technique of noise mapping using computer graphics as shown in figure 1 has the designer of noise generating structures in mind. Given a knowledge of the structure's natural frequencies and mode shapes, its damping characteristics and the input spectral density of the random excitation, he can determine the response spectral density for equation (1). This information can then be used to determine the mean square velocity of the structure for the determination of its acoustic intensity from equation (3). Finally, the sound pressure level at any point in the environment resulting from the vibrations can be determined using equation (5). As information is normally required for many points in the work place, equation (5) has been used to develop a computer programme which can plot a large number of points in the form of equi-noise contours. The design engineer, therefore, has available, in minutes, information which would otherwise require many weeks of work and thereby allowing a much quicker design to be obtained.

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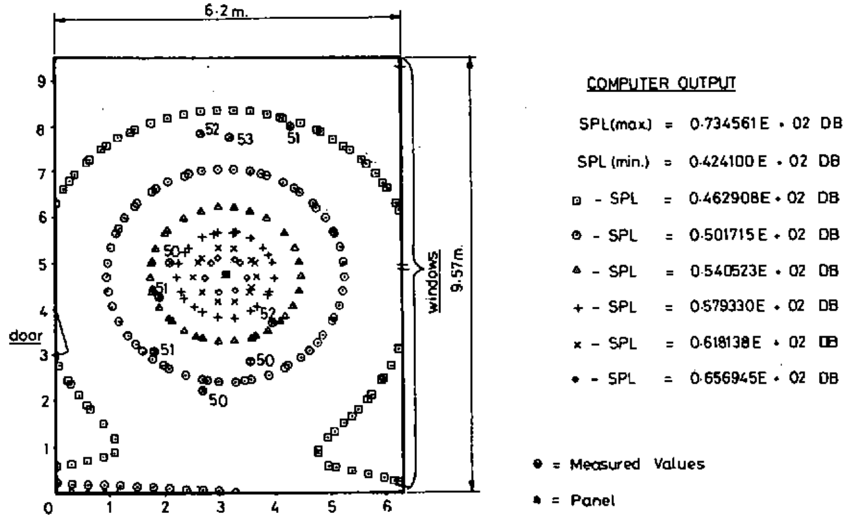

Figure 1. Noise Contours from Vibrating Panel Located at the Centre of Committee Room 1, Sheffield City Polytechnic.

References

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