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VIBRATION MONITORING OF PANELS FOR ACOUSTIC RADIATION CALCULATIONS

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Abstract

The determination of noise levels from vibrating structures in the working environment is of considerable importance to the engineer. Structural vibrations arise frequently from stimuli of a random nature and the excitation signal's spectral density is required for the determination of the sound power levels. A technique using a mini-computer, for the on-line determination of the excitation spectral density is discussed in the paper.

Introduction

Noise radiation from panels in vibrating structures in the working environment is a problem which confronts the engineer, with examples being found in machine tools and ventilating systems. With the introduction of the Health and Safety at Work Act (1974), a great deal of progress has been made in reducing these noise levels to acceptable limits in existing structures.

The legislation also makes it important for the engineer to be able to make predictions, at the design stage of noise levels from structures, which are likely to be subjected to vibrations. The determination of the noise levels at any point in the work place, resulting from a vibrating structure, depends on the room's acoustic characteristics and dimensions and the structures vibration and acoustic characteristics.

In many cases the vibration stimulus is of a random nature. When a structure is stimulated by random inputs its vibrational characteristics are determined from its response spectral density. The response spectral density depends directly on the spectral density of the random exciting force which can only be obtained experimentally. The most realistic information regarding input spectral densities is best obtained from existing structures and is invaluable to the designer.

A technique using a mini-computer for on-line monitoring of random excitations and the determination of their spectral densities is discussed in this paper. Results of response spectral densities of a simple structure, excited by a P.R.B.S. input with a flat spectrum, have been obtained using the technique and are presented in the paper.

Spectral Density and Sound Power Calculations

When a structure is subjected to a single random input at a point, p, of spectral density, $S_p(f)$, its response spectral density, $S_d(f)$, at any point, d, is determined from the expression given by Robson (1) as

$$S_d(f) = |\alpha(jf)|^2 S_p(f) \qquad \dots \qquad \dots \qquad \dots \qquad (1)$$

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In the above equation $\alpha(jf)$ is known as the structural receptance at the output point, d, and is obtained from the expression

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

The expressions ϕ_r (d) and ϕ_r (p) in equation (2) are the deflections of the structure at points d and p when it is vibrating in its r th normal mode, fr is the r th natural frequency, η_r is the hysteretic damping factor in the r th normal mode, f is a forcing frequency and M_r is the generalized mass of the structure.

When a structure is vibrating its acoustic intensity, W, is given by Richards (2) as

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

in which A is the area of the structure, σ_{rad} is the radiation ratio, ρc is the impedence of the air with a value of $414 ms^{-1}$ and $< v^2 >$ is the mean square velocity of the structure taken over its surface.

The sound power level of the vibrating structure is obtained from the expression which is given by Sharland (3) as

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

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

The sound pressure level at any point distance, r, from the structure can be calculated from the following expression given by Sharland (3)

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

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.

Computer Monitoring of Random Signals

The sound power level at any point in a room may be obtained by substituting equation (3) into equation (4) which is in turn substituted into equation (5) to give the required result. To obtain the acoustic intensity from equation (3), the mean square velocity $< v^2 >$ must be known. When a structure is subjected to a random input, $< v^2 >$ is obtained from the response spectral density $S_d(f)$. As can be seen from equation (1) a knowledge of the spectral density, $S_p(f)$, of the random input is required for the determination of $S_d(f)$, and $S_p(f)$ can only be determined experimentally.

The current availability of mini-computers provides a convenient method of determining experimentally spectral densities directly from the signal which is fed on-line to the computer and its spectral density determined using previously developed software.

The technique was used to determine, experimentally, the response spectral density of a cantilever beam with added damping when it is excited by a P.R.B.S. signal with a flat spectrum. Details of the experimental apparatus are shown in figure 1 and results, covering the first three modes of the beam, together with calculated results are shown in figure 2.

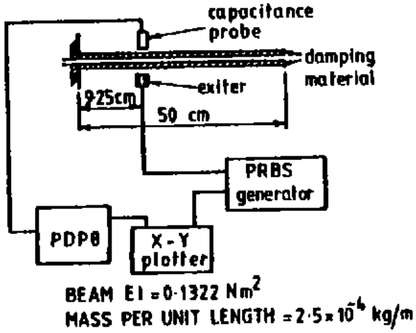

Fig. 1. Experimental Apparatus

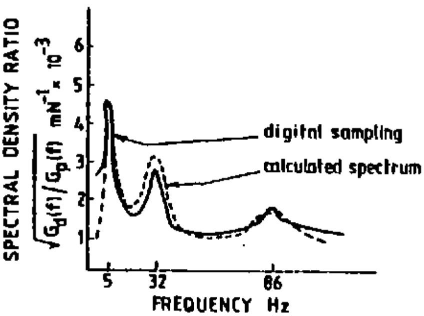

Fig. 2. Spectral Density of Response

Conclusions

The experimental results of the spectral density of the response at a point on the beam were obtained using P.R.B.S. excitation with a flat spectrum. The P.R.B.S. excitation allowed for repeatability of the results. The flat input spectrum of known magnitude, for the excitation of a simple beam, the vibrational characteristics of which can be easily determined, enabled the response spectral density at any point to be calculated accurately. These calculated values were then used as a basis of comparison with the results obtained by digital sampling and processed by the mini-computer. It can be seen from figure 2 that the experimental results compare favourably with the calculated results.

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In practical situations, when structures are excitated by random inputs the spectral density of the excitation signal can only be found by experimental techniques. Hence the techniques which are discussed in this paper for the determination of the response spectral density can also be used to determine the spectral density of an excitation signal. The technique discussed of using a mini-computer to process a signal on-line is, therefore, useful to the designer for the calculation of response spectral densities for subsequent use in estimating for example stress levels in the structure and levels of noise emission.

References

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