NASA TECH BRIEF
Marshall Space Flight Center

Mechanical Impedance and Acoustic Mobility Measurement Techniques of Specifying Vibration Environments

The problem:

Component packages of rocket vehicles are traditionally qualified for acoustic environments by motion-control (or response-control) testing. Vibration environments used in this type of testing are obtained by considering the envelope of the peak amplitudes of measured or predicted response data, but ignoring effects of component-primary structure coupling. Consequently, components qualified under motion-control criteria would probably be overtested or undertested as compared to actual inflight environments. A more realistic approach would be to first determine the interaction forces between a component and its support structure, and then to test the component under the force-control environments.

The solution:

A method has been developed for predicting interaction forces between components and corresponding support structures subjected to acoustic excitations. Such force environments which are determined in spectral form are referred to as force spectra.

How it's done:

In this method, the force-spectra equation is derived based on a one-dimensional structural impedance model. By applying Thevenin's and Norton's theorems to this model, the equation which relates the force-spectra to external excitation forces as well as component impedance and dynamic properties of support structures, such as structural impedances and acoustic mobilities, is given by

$$\Phi_L(\omega) = \left|\frac{Z_L Z_S}{Z_L + Z_S}\right|^2 \cdot \left|\alpha(\omega)\right|^2 \cdot \Phi_p(\omega)$$

where Φ_L is the predicted force spectrum, Z_S is the input impedance of the support structures, Z_L is the input impedance of the component package, Φ_p is the blocked pressure spectrum, and α is the acoustic mobility of structural systems at mounting locations.

This equation provides more realistic vibration environments than the standard motion-controlled specifications. In addition, it can be extended to acquire force spectra for multidimensional structures.

The parameters employed in the computations can be obtained by two methods. In the first method, the support structure impedances are estimated by simple impedance equations developed for complex cylinders. The acoustic mobility and blocked pressure spectra are computed or predicted by methods outlined for stiffened cylindrical shells. The component package impedances could be predicted by a one-dimensional system model by employing classical multi-degree of freedom systems. The second method employs measurement techniques to acquire data on prototype or scale model structures. It employs an analog/digital data acquisition system to acquire the measured data in digital form which are subsequently analyzed to compute force environments. Good agreements between the predicted and measured data were observed by the latter approach. Such an approach can be used to specify vibration environments for new vehicles with greater efficiencies, and substantial savings in time and labor can be realized.

Note:

Requests for further information may be directed to:

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(continued overleaf)

Patent status:

NASA has decided not to apply for a patent.

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