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Prediction of Vibration Response of Satellite Equipment Panel in Consideration of Robustness

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Summary

In this paper, the vibration response of the satellite equipment panel during the launch phase is predicted in consideration of the robustness. By using a simplified model consisted of a panel and an acoustic cavity, Monte Carlo simulation in which analytical parameters are changed at random in the conceivable range of variation is done. From the result, the acceleration power spectral density (PSD) of the satellite equipment panel is obtained. After statistical processing, the effect of variation on the vibration response is estimated and the proper design criteria of the equipment are defined.

Introduction

During the launch phase, spacecraft structures are submitted to the heavy acoustic excitation mainly generated by the engines and the aerodynamic forces over the vehicle. In the design of the space satellite, it is necessary to define the design criteria so that the installed equipment doesn't get broken in the severe vibration environment. As to the random vibration of the equipment, the acoustic vibration has less effect on the equipment than the vibration of the satellite equipment panel (where the equipment is installed) excited by acoustic vibration. Therefore, the vibration response of the satellite equipment panel needs to be predicted before designing the equipment. However, the accurate prediction is difficult due to the lots of uncertainties in the design phase such as the arrangement and the natural frequency of the equipment, workmanship of materials etc. On the one hand, their effects have to be taken into the consideration, but on the other hand, overengineering the equipment leads to the increase in cost. The aim of this research is to define the proper design criteria of the equipment based on the robustness.

Vibro-Acoustic Simulation

In order to predict the vibration response of the satellite equipment panel, vibro-acoustic analysis is realized. Satellite equipment panel is simplified as a model consisted of a panel and an acoustic cavity las shown in fig1. Detail of simplification is below.

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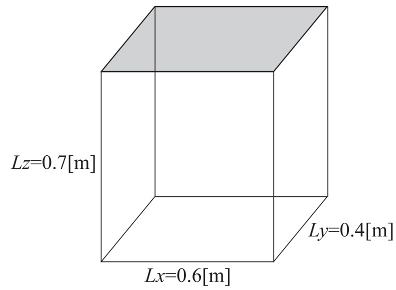

Figure 1: Simplified model

[Simplification of the honeycomb panel]

The satellite equipment panel is made of the honeycomb panel. And the honeycomb panel is approximated by an equivalent homogeneous plate. The bending stiffness of this homogeneous plate is written as [1]

$$D = \frac{E_s t_s (t_s + t_c)^2}{2(1 - \nu_s^2)}. \tag{1}$$

Where E, t and ν are Young's module, thickness and Poisson ratio. $_s$ and $_c$ represent skin and core of the honeycomb panel. The equivalent thickness and density of the homogeneous plate is obtained from

$$t_{eqv} = \frac{2\sqrt{3}}{C_L}\sqrt{\frac{\hat{m}}{D}}, \tag{2}$$

$$\rho_{eqv} = \frac{\hat{m}}{t_{eqv}}. \tag{3}$$

Where C_L is phase velocity of longitudinal wave and $\hat{m}$ is area density of the honeycomb panel.

[Variation of materials]

Regarding the effect of the workmanship of materials, the coefficient of variation for strength, which equals the standard deviation σ divided by the mean μ, is less than 0.05 [2]. By using this relation, the bending stiffness is defined as a normal random number. Hence, $\mu = D$ and $\sigma = 0.05D$.

[Modeling of the equipment]

When the equipment whose mass is M_c is installed on the panel, NASA Lewis method [3] enables to assume the panel and the equipment as a homogeneous plate. The equivalent density and Young's module is written as

$$\acute{\rho}_{eqv} = \rho_{eqv} + \frac{M_c}{t_{eqv}}, \tag{4}$$

$$\acute{E}_{eqv} = C_L^2 \acute{\rho}_{eqv}. \tag{5}$$

M_c is defined as an uniform random number in the range of $10 \leq M_c \leq 100$[kg].

Using this model that is coupled with an acoustic cavity, Monte Carlo simulation is done.

[Result]

The result of Monte Carlo simulation is shown in fig2. The simulation is done 1000 times.

From the results, probability distributions are calculated and the envelope curve of the PSD is defined.

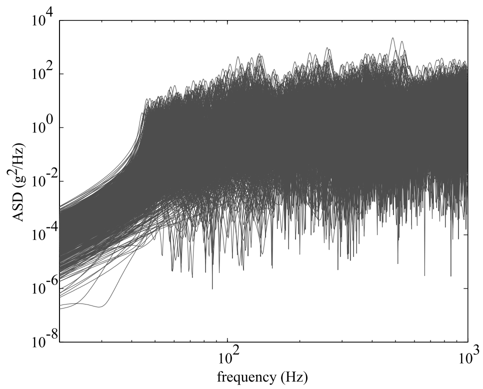

Figure 2: Result

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