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Journal of Sound and Vibration 294 (2006) 580–584

JOURNAL OF SOUND AND VIBRATION

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Short Communication

Dynamic response of thermal data capture unit

N. Bhutani*

Sandia National Laboratories, P.O. Box 969, Livermore, CA 94551, USA

Received 10 August 2005; received in revised form 13 September 2005; accepted 17 October 2005
Available online 27 December 2005

Abstract

The dynamic response of a thermal data capture unit is calculated for a given missile flight test environment. Power spectral densities calculated from the analytical model were compared with the experimental results. Maximum peak displacements were used to calculate clearances required during the installation phase of system assembly.

1. Introduction

The thermal data capture unit (TDCU) is an instrumentation box that acquires and stores temperature data for missile systems. The unit experiences harsh vibration environments during test flights that can be detrimental to the internal electronics as well as to mounts where the unit is attached to the body of the missile. This paper presents the dynamic response of the TDCU to a given acceleration specification spectrum using a random vibration analysis. The analysis showed that the unit behaves like a rigid body mounted on flexible supports in the lower frequency range. The power spectral density response levels predicted by the analysis were compared with the experimental results. Maximum vibratory displacements were calculated for the dominant modes to check interference with neighboring components.

2. Model description

A TDCU is a rectangular aluminum box of dimensions $0.27\,\text{m} \times 0.18\,\text{m} \times 0.14\,\text{m}$ that houses a commercial data logger module. The vibration energy is transferred to the TDCU from the body of the missile through four elastomeric mounts that act as shock isolators. A schematic of the TDCU is shown in Fig. 1. The figure shows the TCDU mounted on the shaker table, the configuration in which the unit was tested in the laboratory. The model developed for this study is briefly outlined in what follows.

The model was simulated using the multi-body dynamics program ADAMS [1]. The TDCU was regarded as a rigid aluminum body with a total mass of 4.66 kg with the center of gravity located at the origin. The principal mass moment of inertia components were calculated as $I_{xx} = 6.0$, $I_{yy} = 4.6$, $I_{zz} = 3.1\,\text{kg}\,\text{m}^2$ and the

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*Tel.: +1 925 294 4503; fax: +1 925 294 1459.
E-mail address: nbhutan@sandia.gov.

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doi:10.1016/j.jsv.2005.10.019

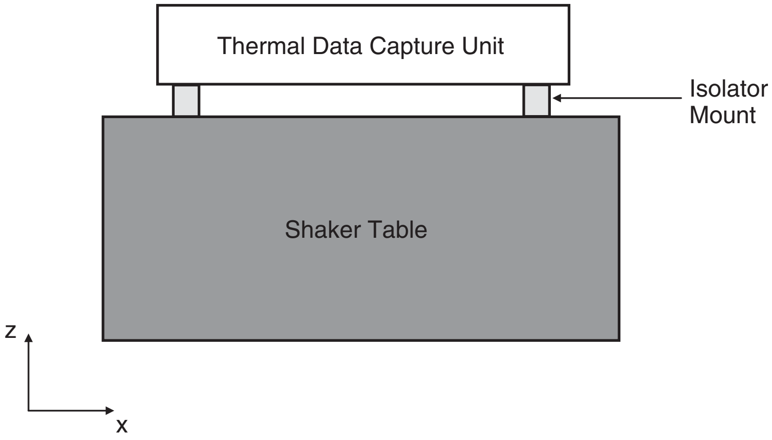

Fig. 1. Model of the TDCU.

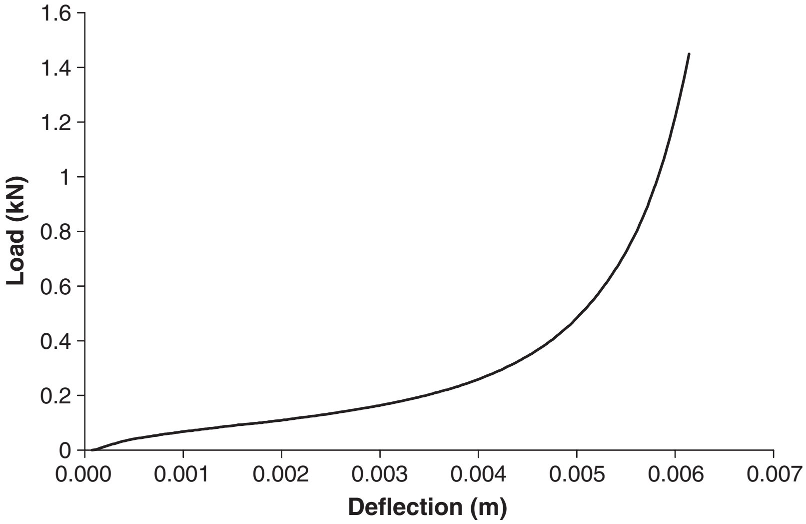

Fig. 2. Load deflection curve.

cross-product terms were assumed to be zero. These mass properties included mass and inertia of the internal electronic data module that was assumed to be in full contact with the aluminum box.

The elastomeric isolators that mount the TDCU onto the missile were modelled as massless linear bushing elements [1] with only diagonal stiffness and damping coefficients. The spring constant for each bushing was calculated from the load deflection curve obtained from a static compression test shown in Fig. 2. The isolators showed characteristics of a typical viscoelastic material [2,3] and agreed well with the specifications obtained from the vendor [4]. A nominal spring constant of 70 k N/m was obtained by linearizing the load deflection curve for the weight of the TDCU. A damping constant of 87 N s/m was estimated for each of the four bushings by equally distributing 17% modal damping obtained from the test power spectral response (discussed in the next section). The results from the model and their correlation with the test is discussed in the following section.

3. Discussion of results

A random response analysis was performed using the large mass method [5,6]. The TDCU was supported by bushing elements that were not grounded, but were attached through a multipoint constraint to a very large mass (shaker mass), about 10^6 times the size of the mass of TDCU, essentially forming a two mass system. An environment input spectrum of $8.54\,g_{\mathrm{rms}}$, where g_{rms} is the root mean squared acceleration in g's, shown in Fig. 3, was applied as an enforced kinematic motion to the large mass.

The analytical results were compared to those obtained from the shaker test. The power density response correlation is shown in Figs. 4–6. The TDCU behaved like a rigid mass supported by elastic mounts with dominant frequencies at 33, 45, 64 Hz in x, y and z directions. The spring and damping coefficients were adjusted from the nominal values to 53, 105, 210 k N/m and 87, 17, 140 N s/m in x, y and z directions, respectively. These values were obtained based on sensitivity studies performed by varying stiffness and damping coefficients attributed to the nonlinear characteristics of the mounts. Test results also showed internal modes of the electronic module in a frequency range of 100–120 Hz, but were not of interest in this study.

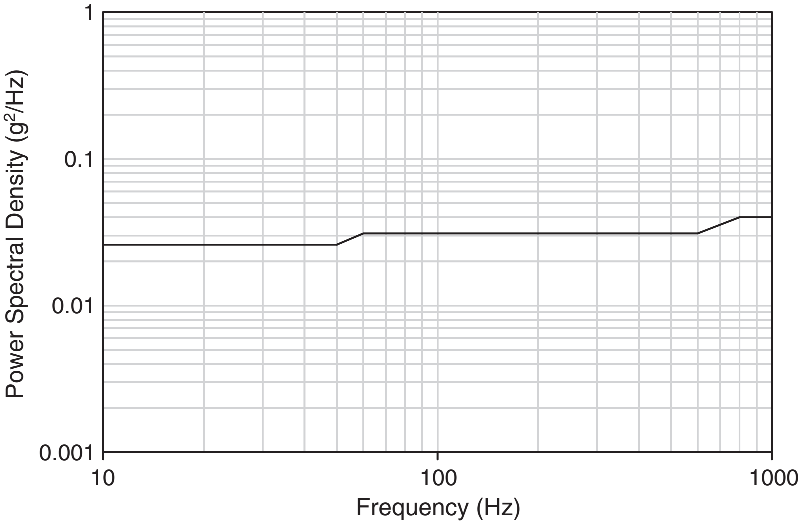

Fig. 3. Input spectrum specification.

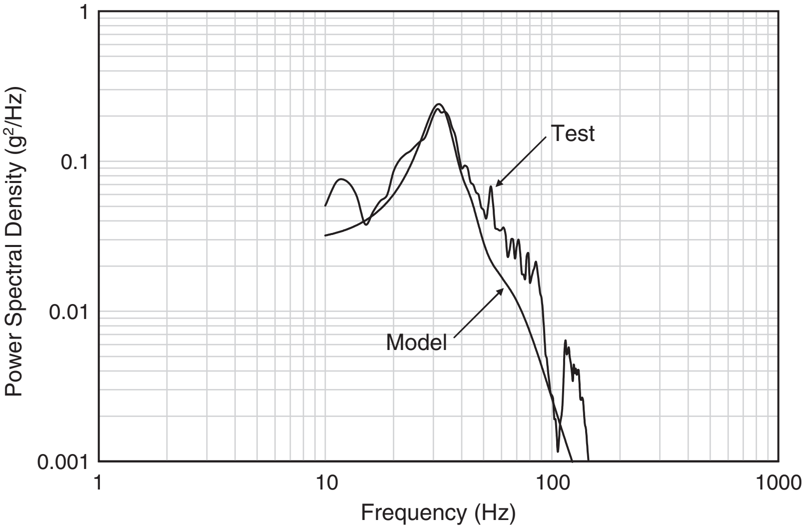

Fig. 4. Acceleration spectral density response in the x direction.

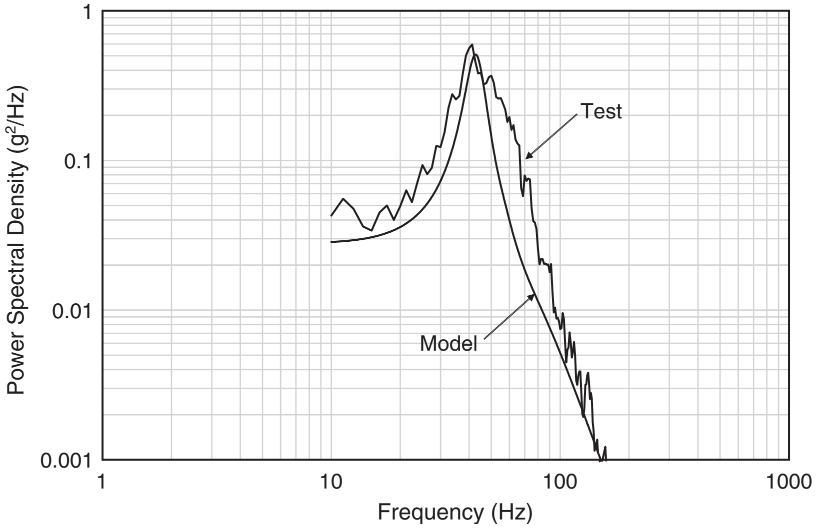

Fig. 5. Acceleration spectral density response in the *y* direction.

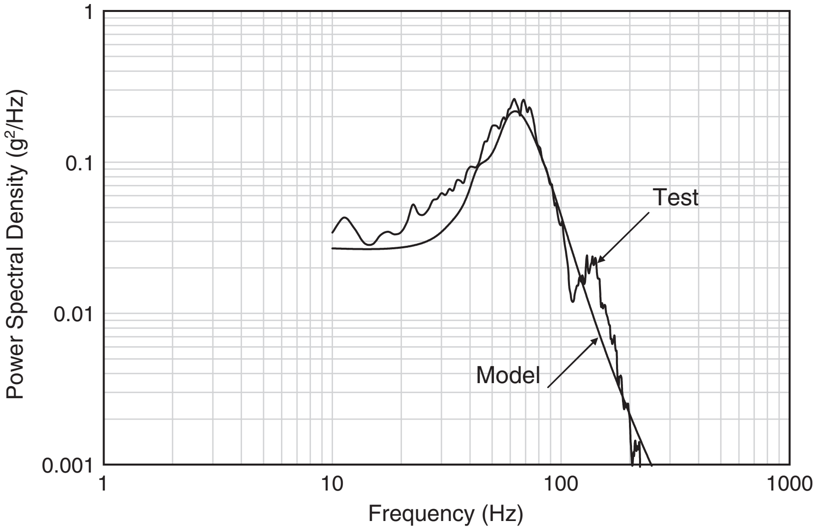

Fig. 6. Acceleration spectral density response in the *z* direction.

Table 1
Root mean squared acceleration response

Response direction	Dominant mode (Hz)	g_{rms}		
		Test	Model	Ref. [7]
x	33	2.4	2.1	2.1
y	45	3.6	2.8	2.4
z	64	3.4	3.2	2.9

The root mean squared acceleration levels for these plots are presented in Table 1. The table also shows the response computed using Miles formulation [7], which calculates g_{rms} as $\sqrt{(\pi/2)\,Q\omega_n a_{\mathrm{input}}}$, for an equivalent single degree of freedom system. In this formulation, a_{input} is the input acceleration spectral density, ω_n is the natural frequency and Q is the transmissibility factor. Table 1 shows g_{rms} values for an input a_{input} of $0.028\,\mathrm{g}^2/\mathrm{Hz}$ (from Fig. 3) and a Q of 2.94 based on 17% modal damping.

The corresponding root mean squared displacements were computed as 548, 442, 206 μm in x, y and z directions, respectively. For a conservative design, the peak 3σ displacement of 1644 μm was calculated from the x displacement. This peak value was used as a vibratory clearance for TDCU during the installation phase of the system assembly to ensure non-interference with the neighboring components.

4. Conclusions

The response of the thermal data capture unit was calculated by constructing a dynamic model. Results from the model agreed well with those obtained from the laboratory shaker test. Vibratory response levels from this study were used to calculate clearances required during the installation phase of the system assembly.

Acknowledgments

The author gratefully acknowledges the funding received from the project group and sincerely thank John Van Scyoc, Al Ver Berkmoes, James P. Lauffer and Alvin Leung for their support during the course of this study. This study was performed by Sandia, a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

References

[1] Manual: MSC/ADAMS, ADAMS Solver, The MSC Software Corporation, 2005.

[2] R.S. Rivlin, D.W. Saunders, Large elastic deformations of isotropic materials, VII, Experiments on the deformation of rubber, *Philosophical Transactions of the Royal Society of London* 243 (series A) (1951) 251–288.

[3] O.H. Yeoh, Some forms of the strain-energy function for rubber, *Rubber Chemistry and Technology* 66 (1993) 754–771.

[4] Manual: Barry Controls, Shock and Vibration Specification for Low Profile Mount Isolators, 2004.

[5] W.T. Thomson, M.D. Dahleh, *Theory of Vibrations with Applications 5e*, Simon & Schuster, New York, 1997.

[6] Manual: MSC/NASTRAN, Basic Dynamic Analysis User's Guide, The MSC Software Corporation, 2004.

[7] J.W. Miles, On structural fatigue under random loading, *Journal of the Aeronautical Sciences* (1954) 753.