Damping Effects on Shock Response Spectra

Part 3:
1-INCH DISK DRIVES

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INTRODUCTION

This is the third in a series of papers that discuss the effects of shock on small portable hard disk drives, a topic especially critical for portable electronics that require large amounts of memory. Here we focus upon the 1-inch hard disk drive (HDD). The aim of this white paper series is to provide guidance for engineers as they design shock protection schemes for the hard drives in their products.

Half-Sine Acceleration and Modeling the System

Shock calculations were conducted utilizing computer algorithms for simulating half sine acceleration shock pulses. The half sine acceleration pulse was chosen since it is the most commonly used in industry and is easily simulated with a drop table. Various elastomeric springs were evaluated based upon their loss factor and the effect loss factor has upon G level and sway space. The shock load applied to the 1-inch disk drive was a 2000 G half-sine acceleration pulse of three durations: 0.0005 sec, 0.001 sec and 0.002 sec. The mass of the hard drive is considered to be 0.016 kg. Three levels of damping were included in the analysis: loss factor h = 0.1, 0.5 and 1.0. The h = 0.1 value would correspond to elastomers such as natural rubber or neoprene and the h = 1.0 value would correspond to E-A-R Specialty Composites ISODAMP® material. The hard drive-isolation system is assumed to be a single degree of freedom system (1DOF). The HDD and mounting foundation are assumed to be infinitely rigid. The model for this system is shown in Figure 1.

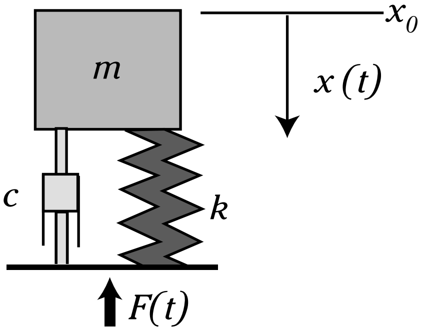

Figure 1: Single Degree of Freedom System

The variable m represents the mass of the hard drive and F(t) represents the forcing function. For a half sine acceleration pulse of duration T:

$$F(t) = F \sin\left(\frac{\pi t}{T}\right) \text{ for } 0 \leq t \leq T$$

and

$$F(t) = 0 \text{ for } T < t$$

x(t) represents the position of the mass relative to the end of the spring k and dashpot c. Using the computer algorithms, we monitor which is the acceleration experienced by the hard drive usually in units of G's (1G = 9.8 m/s2). We also monitor the maximum displacement experienced by the hard drive which we call sway space. The variable c is traditionally viscous damping provided by a dashpot and k represent the spring stiffness. In an elastomeric spring used for shock protection, c and k combine to form a complex stiffness k*. The damping in the material called loss factorh represents the relationship between the real and imaginary components of that complex stiffness. The computer algorithms utilized cannot account for complex stiffness, so viscous damping is used. The variable used to represent viscous damping in the algorithms is _ which is called the critical damping ratio. We equate _ to loss factor h with the following expression:

This relationship is accurate for low levels of damping. Out of necessity, we must use it for high levels of damping because only the differential equations of motion dealing with viscous damping are readily solvable.

The equations of motion for the 1DOF system is shown below:

$$\zeta = \frac{c}{2\sqrt{km}} = \frac{\eta}{2}$$

$$\ddot{x} + 2\zeta\omega_n\dot{x} + \omega_n x = F\sin\left(\frac{\pi t}{T}\right) \text{ for } 0 \leq t \leq T$$

$$\ddot{x} + 2\zeta\omega_n\dot{x} + \omega_n x = 0 \text{ for } T < t$$

$$\text{where } \omega_n = \sqrt{\frac{k}{m}}$$

The time domain response of the above two equations can be solved utilizing the Laplace transformation. The solution is a bit lengthy and is outside the intent of this paper. Once solved, the resulting equations can be used in a computer algorithm, the time domain response can be plotted, and maximum displacement, velocity or G level can be determined. When enough simulations of the HDD response have been conducted and the maxima determined, the graphs found in this report can be generated.

A typical acceleration time response for this system is shown below using a system natural frequency of 400 Hz. To illustrate the effect of damping on the time response, two curves are shown in Figure 2. The dashed curve has light damping and the solid curve has high damping.

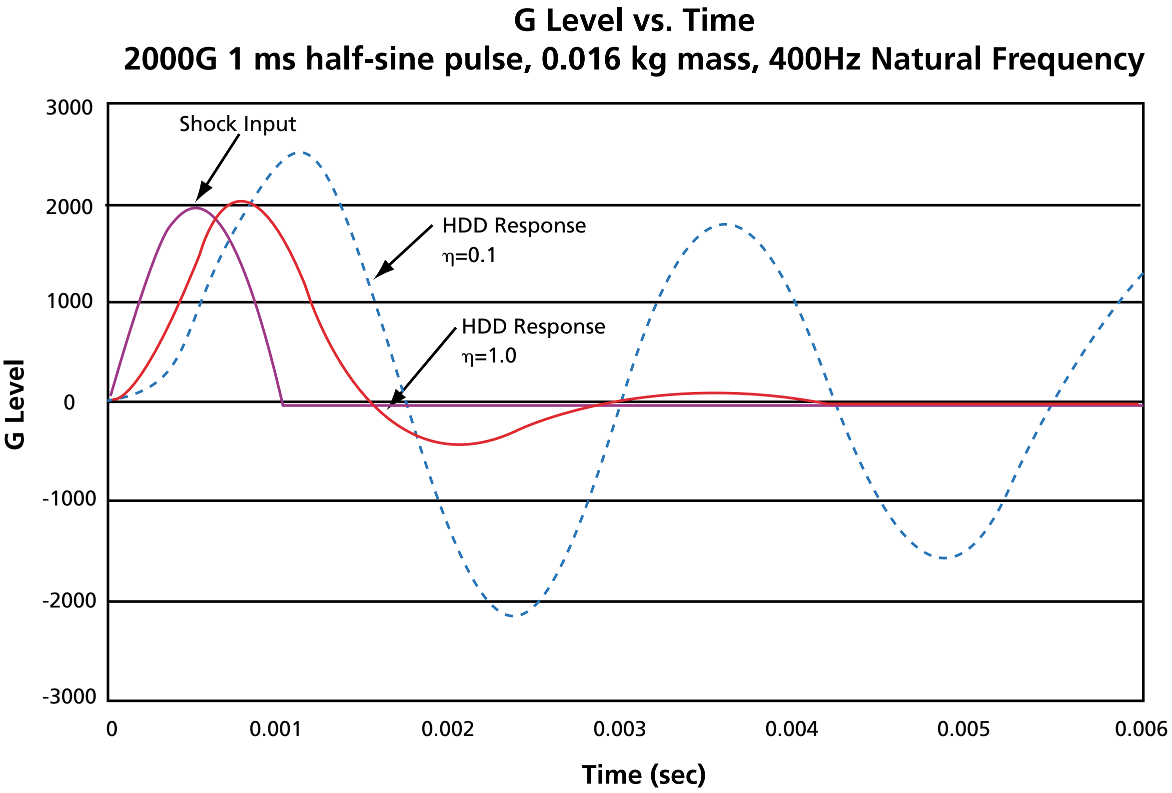

Figure 2: Time domain response, 1DOF System subjected to half sine pulse

Figures 3 through 8 on the following pages depict the shock response spectrums for three different half-sine shock pulse durations: 0.0005 seconds, 0.001 seconds and 0.002 seconds. For each pulse duration, the peak transmitted G level and deflection are plotted versus system natural frequency. Since the mass is always the same, system natural frequency really represents changing stiffness.

Shock Spectrum Results

Shock duration of 0.0005 seconds

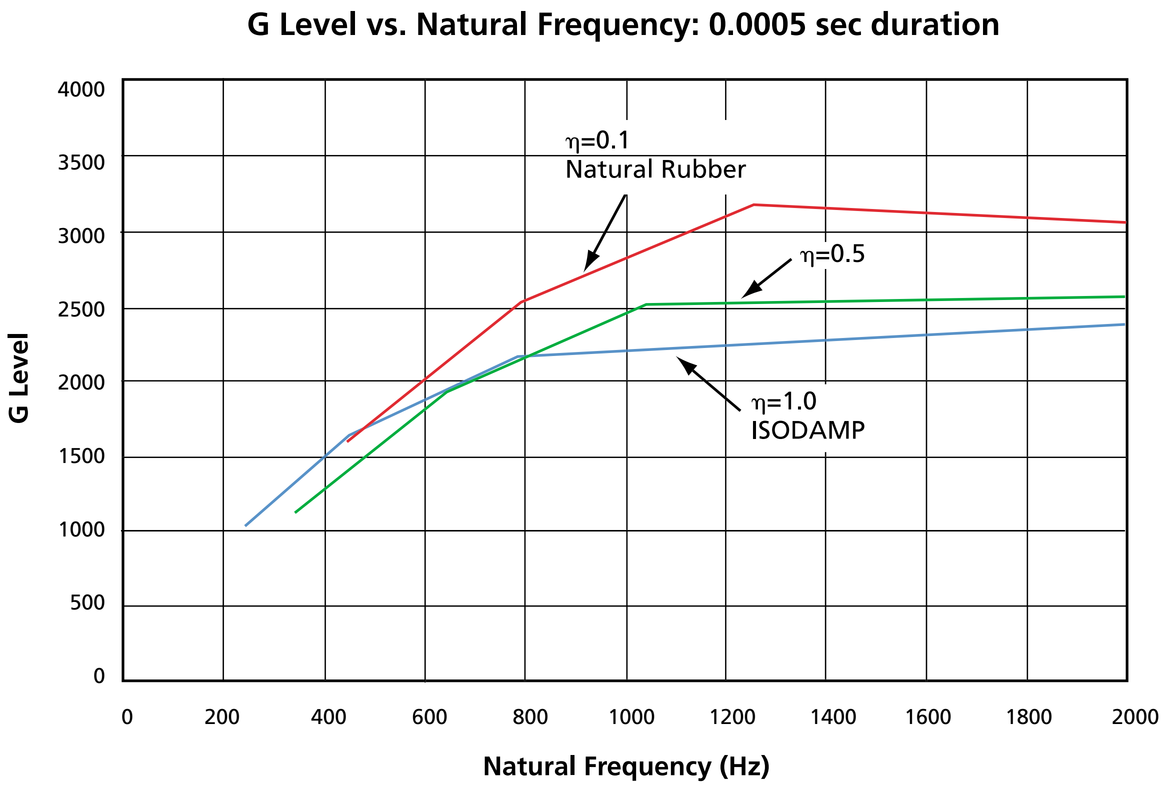

Figure 3

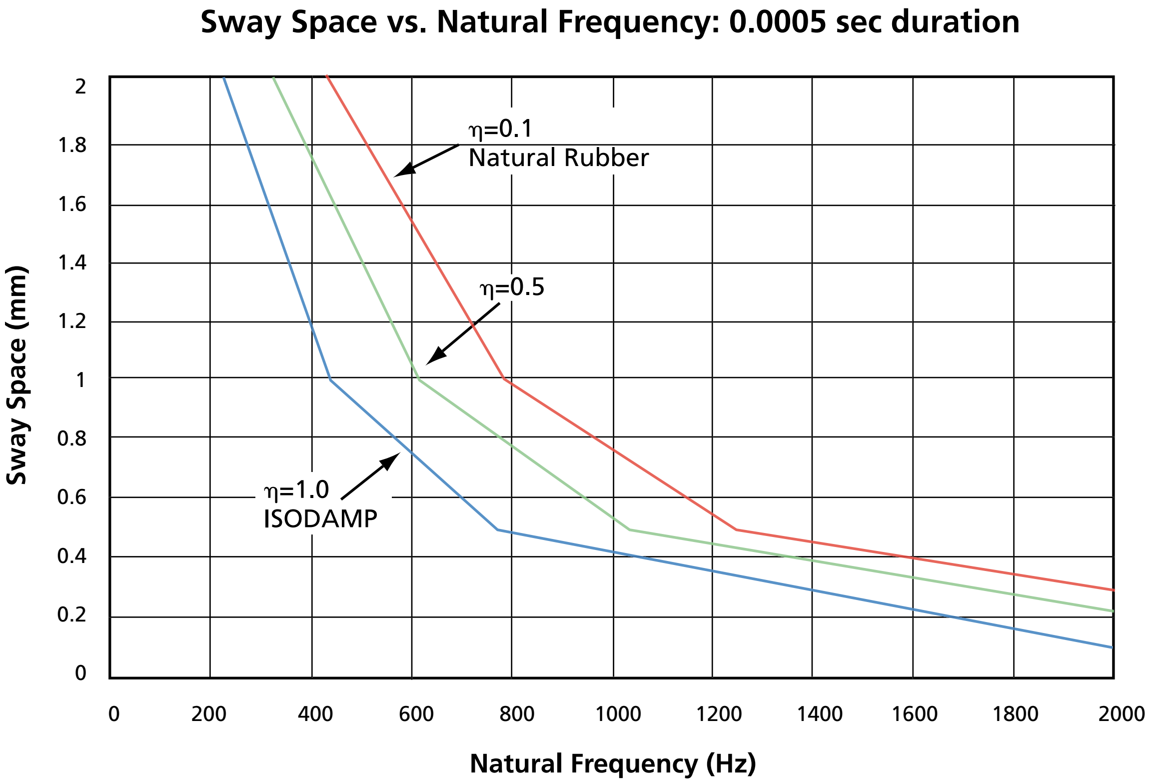

Figure 4

Shock duration of 0.001 seconds

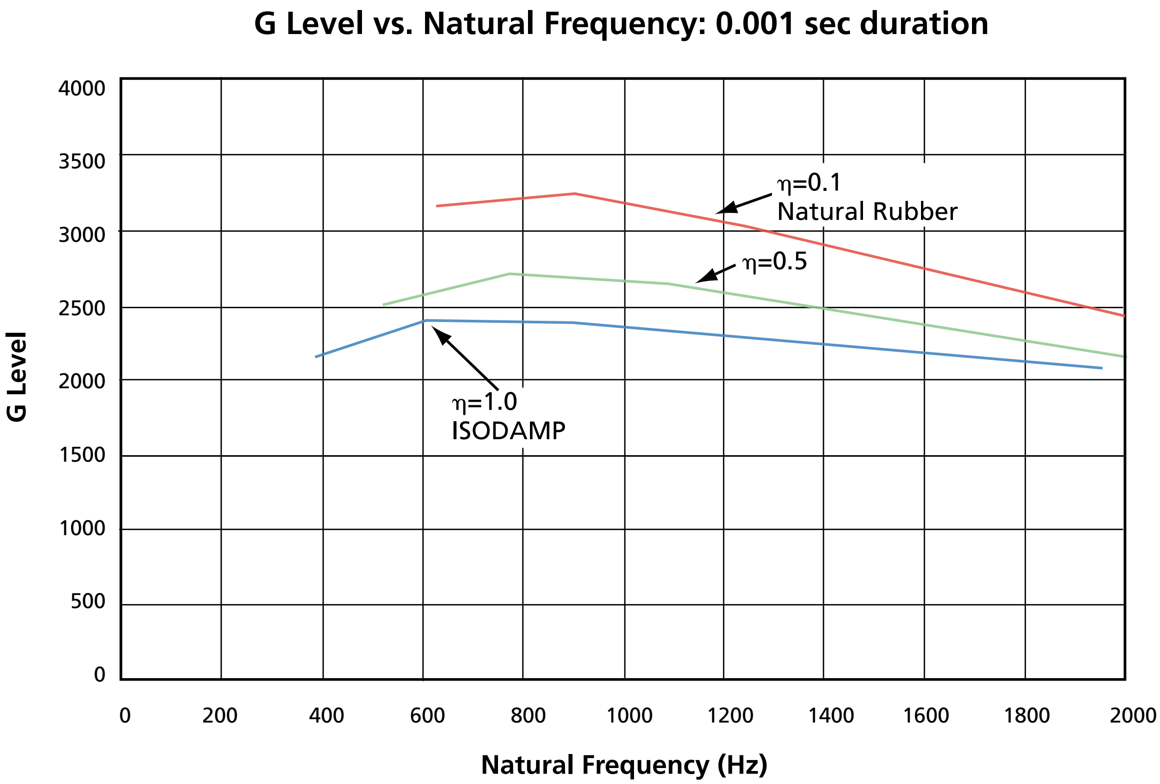

Figure 5

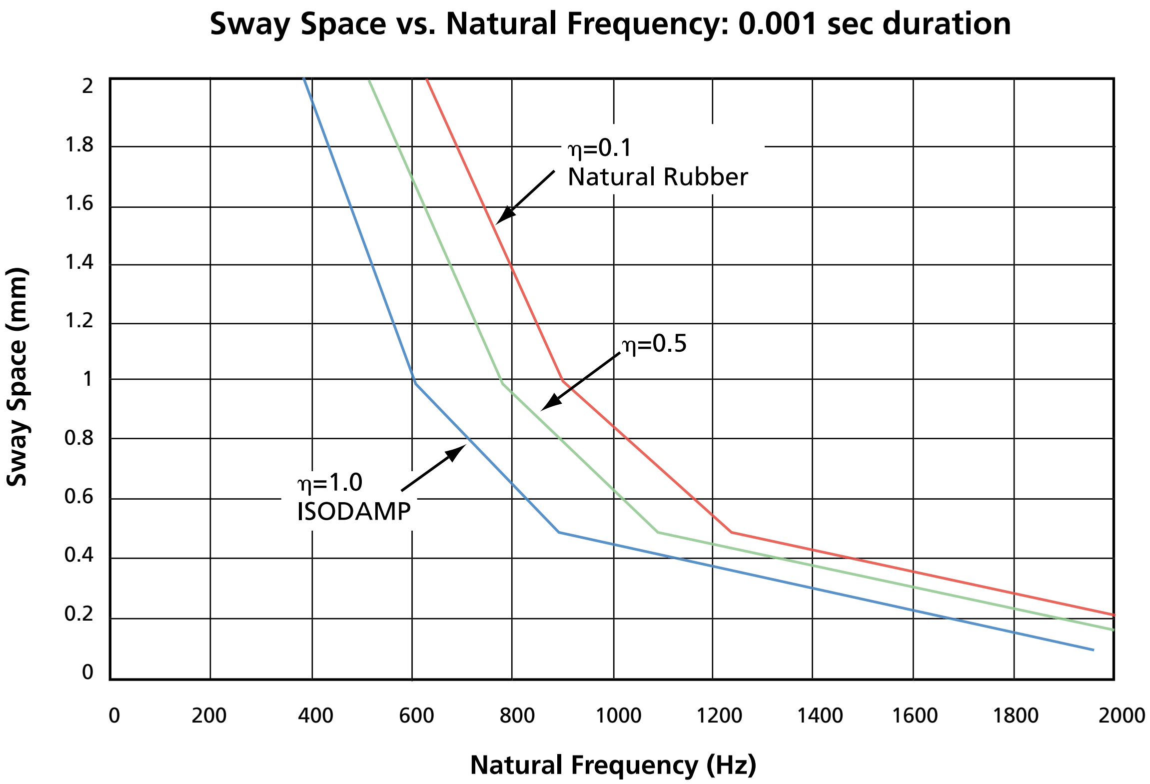

Figure 6

Shock duration of 0.002 seconds

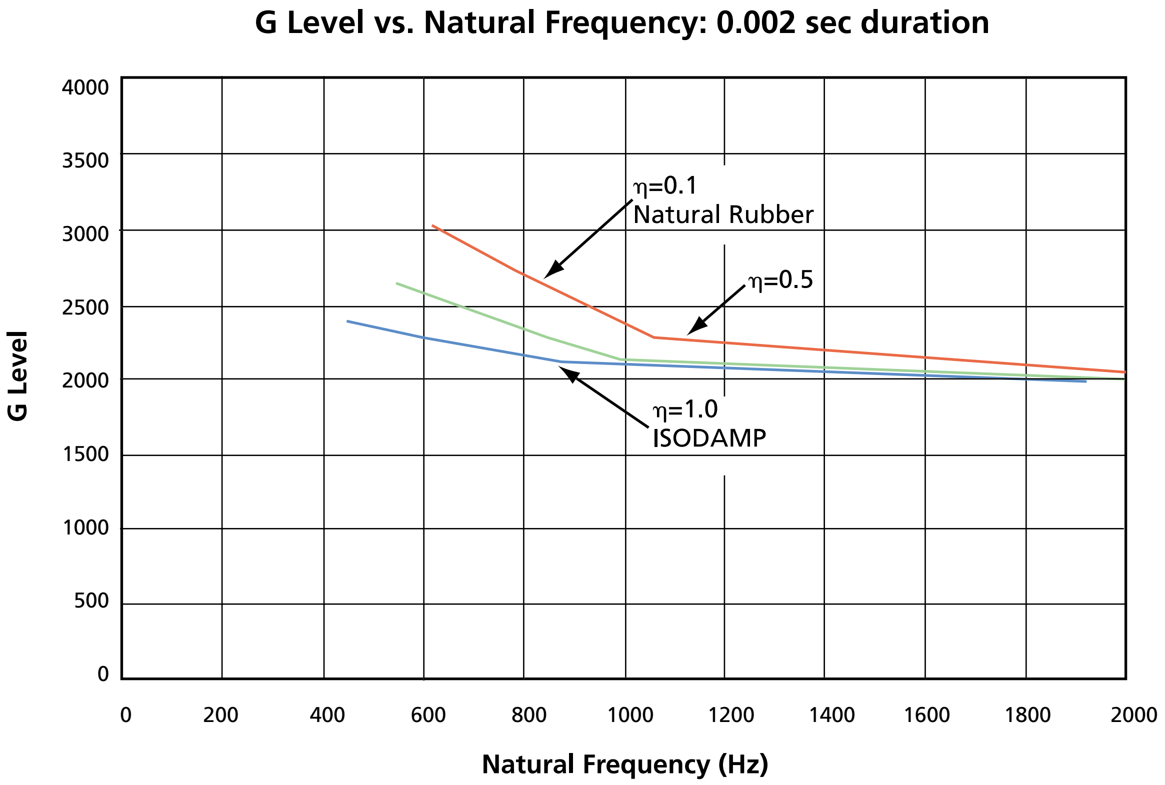

Figure 7

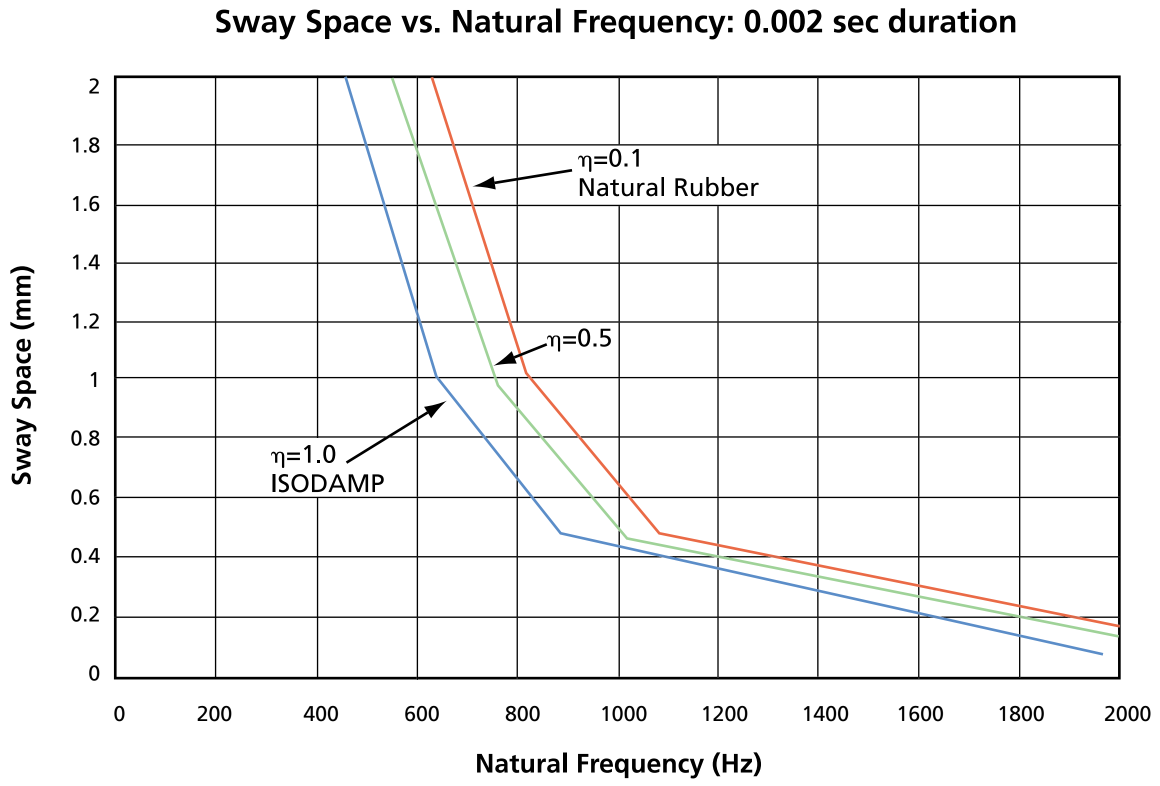

Figure 8

The high damping response curves shown in the graphs indicate that for a given natural frequency (i.e. stiffness) you need less sway space and can get a lower G level than with a material with low damping. Note how much the system response changes when the shock duration changes. An optimal solution for one acceleration pulse is not necessarily optimum for another duration pulse (let alone another pulse shape such as a triangular pulse or versed sine pulse).

E-A-R Solutions Available

E-A-R Specialty Composites shock protection solutions typically involve the use of highly damped elastomers such as ISODAMP® or VersaDamp™ in the form of grommets, snubbers and sleeves and/or the use of our highly damped CONFOR® foam.

E-A-R Specialty Composites can create a variety of custom molded part designs for use with the 1-inch hard drive. Because of the proprietary nature of many of these designs, we will only show our new corner bumpers which are now standard parts (CB-100 and CB-101) available in our catalog and a schematic of a generic style isolator. There are many variations to this design where we could add ribs, cores and other features to change compliance.

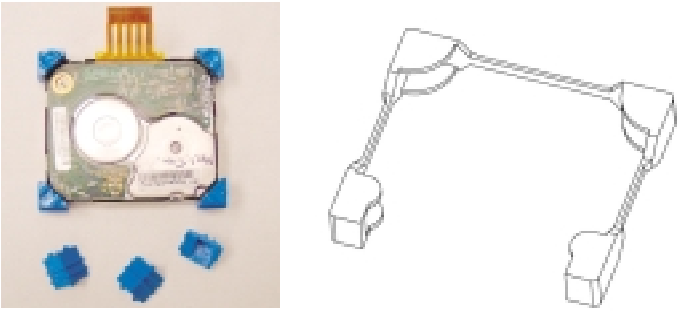

Figure 9: 1-inch HDD & isolators

There often is little available space for any isolation solution. When this happens, CONFOR® foam is a viable solution. CONFOR® foam is highly damped and can be cut as thin as 1.5 mm. CONFOR® foam can be compressed to 50 percent of its thickness without dramatically impacting its stiffness properties.

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