DYNAMIC DATA PREDICT RESPONSE OF ELASTOMERIC ISOLATORS

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DYNAMIC DATA PREDICT RESPONSE OF ELASTOMERIC ISOLATORS IN VARIOUS APPLICATIONS

Traditionally, when engineers have employed isolators in their product designs, they have predicted a system's natural frequency using static (non-vibratory) isolator spring rate (stiffness). This is a single-value number, representing the slope of the linear region of an isolator's load-versus-deflection curve. Stiffness can be used to estimate both the natural frequency and isolation effectiveness of a lightly damped isolation system made of neoprene, natural rubber or similar materials. (See Figure 1.)

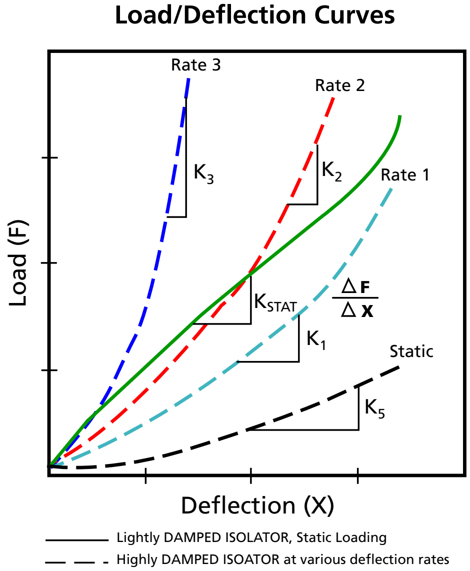

Figure 1

Design engineers using E-A-R isolation mounts, however, can utilize characterization data to take advantage of the company's damped polymers' unique properties. To help customers select the right components for a range of applications, E-A-R's Applications Engineering Group developed a method to accurately present dynamic performance characteristics of highly damped E-A-R vibration isolators in an easy-to-use graph-and-table format in the catalog *Standard Parts Catalog & Engineering Design Guide.*

The method uses load-versus-dynamic stiffness graphs obtained from laboratory vibration shaker test data and allows E-A-R to determine dynamic stiffness as a function of isolator load and temperature. This information is used in engineering calculations to estimate the effectiveness of a specific isolation system.

Highly damped E-A-R isolators don't conform to the simple, single-stiffness behavior common for lightly damped rubber mounts. Instead, they produce rate-dependent load-deflection curves, resulting in variable spring rates that depend on the dynamic conditions to which the isolators are subjected. This largely accounts for their outstanding shock response.

Dynamic stiffness, measured under realistic vibratory loading, can be several times larger than static stiffness, and when used in frequency, produces results similar to experimentally obtained values on real systems. Dynamic stiffness can be obtained via frequency response function (FRF) measurement of transmissibility on a laboratory-controlled test isolation system. Once the natural frequency of the system is identifies, dynamic stiffness can be calculated with the equation

$F_n=3.13\sqrt{\frac{K'}{W}}$ (where W is weight in lb) and solve for K′ (where K′ is stiffness in lb/in).

By varying the isolator load experimentally, it is possible to determine the change in dynamic stiffness throughout the recommended load range.

Isolators of similar geometry and materials exhibit similar trends in dynamic stiffness-versus-load data. Stiffness values for different isolator models with similar geometry can be fitted to a single curve by *normalizing* (dividing all the data by the mid-range values) and plotting the results on a graph using normalized axes.

Each curve transposed onto the normalized axes then requires a set of X (load) and Y (stiffness) de-normalizing constants. E-A-R provides these in a data table for each isolator family.

All elastomeric materials vary in characteristics like modulus, over temperature. To account for such variation, E-A-R also provides a set of temperature correction factors for each material. All this information can be found in the catalog *Standard Parts Catalog & Engineering Design Guide.*

HOW TO USE THE DATA

Using static stiffness values to determine the natural frequency of a highly damped isolation system can lead to overestimation of the system's effectiveness. Figure 2 shows static load-versus-deflection, obtained from an Instron Physical Tester, for a standard E-A-R G-411-1 grommet. This equates to a static stiffness of the grommet of 121 lb/in under a 2-pound load at room temperature (refer to the slope drawn on Figure 2).

These values of stiffness and load yield a natural frequency of

$$F_n = 3.13 \text{ X } \sqrt{\frac{121}{2}} \approx 24 \text{ Hz}$$

and a system *cross-over frequency* of

$$F_x = 3.13 \text{ X } \sqrt{2} \text{ X } F_n = \sqrt{2 \text{ X } 24} \approx 34 \text{ Hz}$$

Above this frequency value, isolation occurs.

If the frequency to be isolated were 250 Hz, the estimated isolation efficiency for the system is calculated using Figure 3.

Cross-over frequency ratio is

$$F \div F = 250 \div 34 \approx 7.4$$

From Figure 3, the percentage isolation efficiency is 99 percent. The equivalence in reduction on transmitted vibration is

$$dB = 20 \text{ X } \log(0.01) \approx -40 \text{ (decrease)}$$

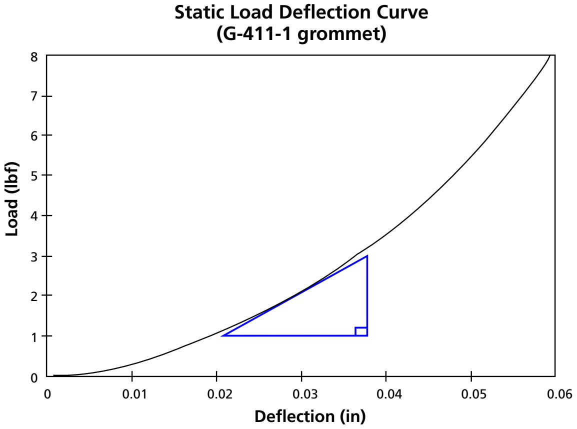

Figure 2

A shaker test in a laboratory will provide true dynamic results on an isolation system. Figure 4 exhibits a transmissibility graph (generated by FFT) of a 2-pound load on a G-411-1 grommet with input of random noise. The graph gives a natural frequency of the system of approximately 105Hz. Knowing the load, we back calculate for dynamic stiffness

$$K' = \frac{F_n}{3.13} \text{ X} W \approx 2230 \; lb\,/\,in$$

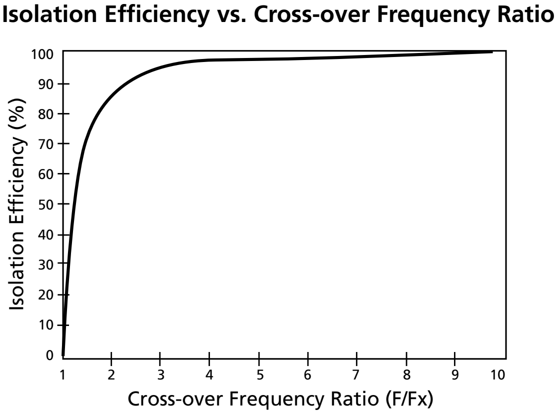

Figure 3

This is more than 18 times the static stiffness value. This dynamic stiffness value can also be calculated using the "Performance Graph" in the E-A-R's *Standard Parts Catalog & Engineering Design Guide.*

The graph in Figure 4 indicates a system cross-over frequency of approximately 160Hz. This will provide a cross-over frequency ratio of

$$F \div F_x = 250 \div 160 \approx 1.6$$

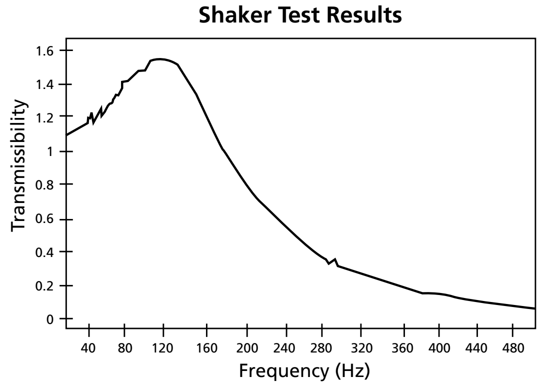

Figure 4

From Figure 3, the percentage isolation efficiency is 76 percent. The equivalence in reduction on transmitted vibration is

$dB = 20\ X \log(0.24) \approx -12$ (decrease)

Thus, using the dynamic data ensures a conservative estimate for design purposes.

Figure 5 illustrates the differences between static and dynamic stiffnesses being plotted against load.

The damping in E-A-R's materials dissipates mechanical energy through hysteretic loss within an isolator, converting it to low-grade heat. Damping also provides faster settling time after a shock input and helps reduce the amount of required sway space, for maximum shock protection.

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An undamped material such as natural rubber could yield an amplification of 14 times transmissibility (23dB)—potentially damaging to an electronic system that excites at or around the natural frequency. Figure 4 shows, however, that E-A-R's G-411-1 grommet exhibits amplification at resonance of about 1.5 transmissibility (3.5dB). The damping in E-A-R's isolator material minimizes the amplification at or near resonance frequency and can effectively avoid the problem.

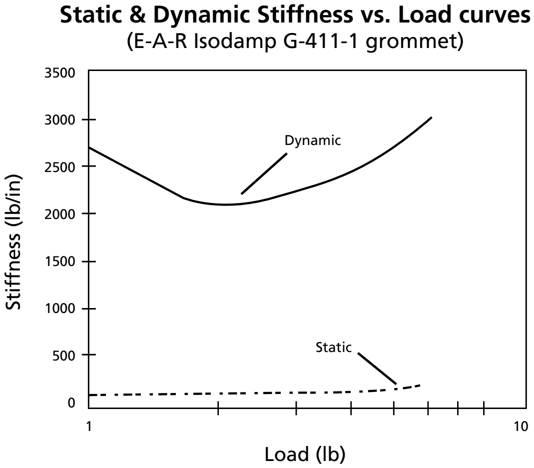

Figure 5

	Static Values	Dynamic Values
Stiffness (lb/in)	121	2230
Natural Frequency (Hz)	24	105
Cross-over Frequency (Hz)	34	160
Isolation Efficiency	99% or 40dB	76% or 12dB
	Undamped	Damped
Amplification @ Resonance Frequency	14 Times	1.5 Times