

Understanding Damping Techniques for Noise and Vibration Control

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Introduction

Effective control of noise and vibration, whatever the application, usually requires several techniques, each of which contributes to a quieter environment. For most applications, noise and vibration can be controlled using four methods: (1) absorption (2) use of barriers and enclosures (3) structural damping and (4) vibration isolation.

Although there is a certain degree of overlap in these classes, each method may yield a significant reduction in vibration and noise by proper analysis of the problem and application of the technique. The principles behind the use of absorption materials and heavy mass barrier layers are generally understood, so this paper will focus on the third and fourth methods, which deal with reducing structural vibration.

Structural Damping

Structural damping reduces both impact-generated and steady-state noises at their source. It dissipates vibrational energy in the structure before it can build up and radiate as sound. Damping, however, suppresses

only resonant motion. Forced, nonresonant vibration is rarely attenuated by damping, although application of damping materials sometimes has that effect because it increases the stiffness and mass of a system.

A damping treatment consists of any material (or combination of materials) applied to a component to increase its ability to dissipate mechanical energy. It is most often useful when applied to a structure that is forced to vibrate at or near its natural (resonant) frequencies, is acted on by forces made up of many frequency components, is subject to impacts or other transient forces, or transmits vibration to noise-radiating surfaces.

Although all materials exhibit a certain amount of damping, many (steel, aluminum, magnesium and glass) have so little internal damping that their resonant behavior makes them effective sound radiators. By bringing structures of these materials into intimate contact with a highly damped, dynamically stiff material, it is possible to control these resonances.

Of the common damping materials in use, many are viscoelastic; that is, they are capable of storing strain energy when deformed, while dissipating a portion of this energy through hysteresis. Several types are available in sheet form. Some are adhesive in nature and others are enamel-like for use at high temperatures.

Free-layer or extensional damping is one of the simplest forms of material application. (See Figure 1.) The material is simply attached with a strong bonding agent to the surface of a structure. Alternatively, the material may be troweled onto the surface, or the

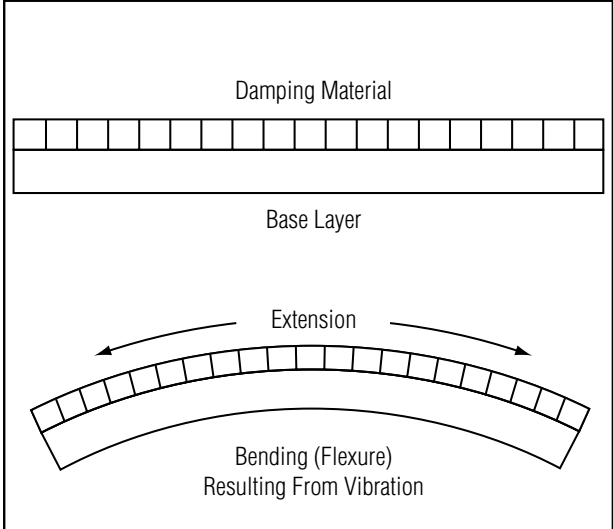


Figure 1

A free-layer damping system is the simplest form of damping material application. Energy is dissipated as result of extension and compression of the material under flexural stress from the base structure.

structure may be dipped into a vat of heat-liquefied material that hardens upon cooling. Energy is dissipated as a result of extension and compression of the damping material under flexural stress from the base structure. Damping increases with damping layer thickness. Changing the composition of a damping material may also alter its effectiveness.

An example of the effectiveness of an extensional damping treatment is

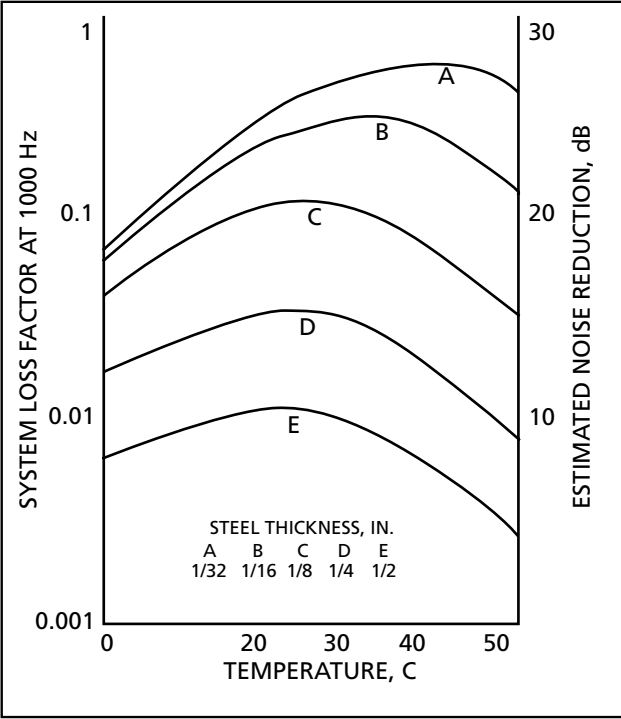


Figure 2

The relationship between system loss factor, estimated noise reduction and temperature for several free-layer damping systems is shown by these curves. The damping material type and thickness (3/16-inch) are the same in each case.

shown in Figure 2. The curves represent five extensionally damped systems. In each case, the damping sheet is $\frac{3}{16}$ -inch thick, whereas the steel base layers are from $\frac{1}{32}$ - to $\frac{1}{2}$ -inch thick. From such data, it is possible to obtain the overall system loss factors (measure of energy dissipated per radian of vibration at resonance) and the resulting estimated “large” panel impact noise reduction—the reduction in noise level that results from damping a panel that is being struck many times per second. *Large*, in

this case, means that the panel dimensions are equal to or greater than the bending wavelengths of the vibration being radiated as sound. The effect of temperature is clearly seen. The peak noise reduction for the $\frac{1}{2}$ -inch steel plate occurs at a lower temperature than for the $\frac{1}{32}$ -inch plate.

Constrained-layer damping (CLD) systems are usually used for very stiff structures. (See Figure 3.) A “sandwich” is formed by laminating the base layer to the damping layer and adding a third constraining layer. When the system flexes during vibration, shear strains develop in the damping layer. Energy is lost through shear deformation, rather than extension, of the material.

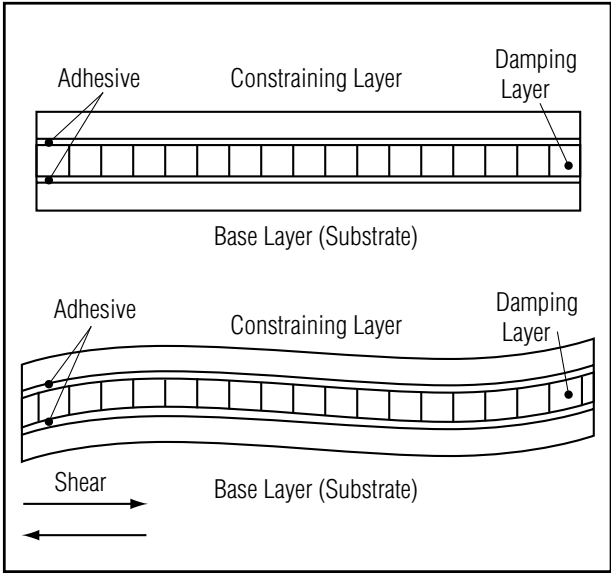


Figure 3

A constrained-layer damping system is usually recommended for stiff, structural applications. Energy is dissipated as a result of shear deformation of the damping layer.

System loss factors and estimated noise reductions for several CLD steel systems are shown in Figure 4. For a given base layer thickness, the values obtained are significantly higher than those in Figure 2, although the damping material properties and thickness are identical. Further, varying layer thickness ratios permits optimizing system loss factors for various temperatures without changing the material’s composition, Figure 5.

The constraint method is not critical as long as there is adequate surface-to-surface pressure. The layers may be bolted or riveted instead of glued into a sandwich and still provide optimum performance. Adhesives, if used, must have a high shear stiffness. Shear strains in the adhesive will reduce the strains in the damping layer, reducing its effectiveness.

Another advantage of CLD systems is that they can be used in harsh environments. The damping layer is totally

covered by the top constraining layer, so it typically is not subject to abrasion or deterioration.

Structural damping, whether extensional or constrained-layer, provides an at-the-source solution to noise control problems. Further, it is not always necessary to use 100 percent panel coverage to achieve significant noise reductions. For example, 50 percent coverage will provide a noise reduction that is

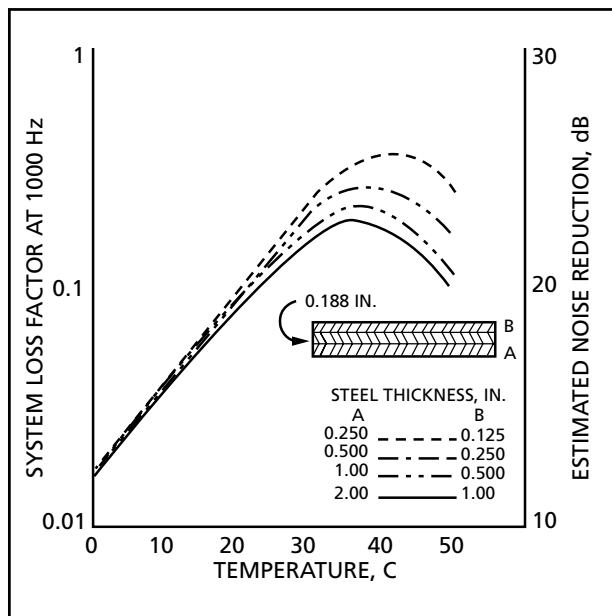


Figure 4

The relationship between system loss factor, estimated noise reduction and temperature for several constrained-layer damping systems is shown by these curves. The damping material type and thickness ($3/16$ -inch) are the same in each case.

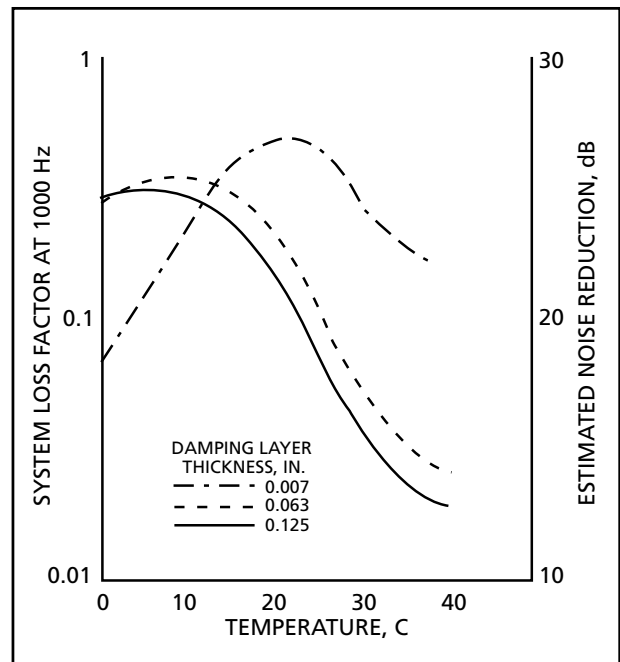


Figure 5

The relationship between system loss factor, estimated noise reduction and temperature for varying damping layer thicknesses in several constrained-layer systems is shown by these curves. In each case, constraining layer and base layer are $1/4$ -inch-thick steel. The damping material is the same in all cases.

typically only 3 decibels (dB) less than for 100 percent coverage; 25 percent coverage is only 6 dB less. When properly used, damping can be as cost effective as it is acoustically effective.

Vibration Isolation

This method reduces the transmission of vibrational energy from one system to another. Common vibration isolators are steel springs, rubber pads or bellows. These devices are available in many shapes and are capable of isolating masses weighing from a few pounds to thousands of pounds.

An automobile suspension is a good example of damped isolation. Shock absorbers dissipate energy by pumping a fluid through orifices that offer a predetermined resistance to high-velocity flow. Many isolation systems use elastomeric materials to provide both the spring force and damping. Some rubbers are capable of achieving useful damping at certain frequencies, although at low frequencies most exhibit loss factors less than 0.2, or roughly 10 percent of critical damping. At resonance, when a system dissipates the same amount of energy per radian as it stores, it is said to be critically damped. Loss factor is equal to the percentage of critical damping divided by 50.

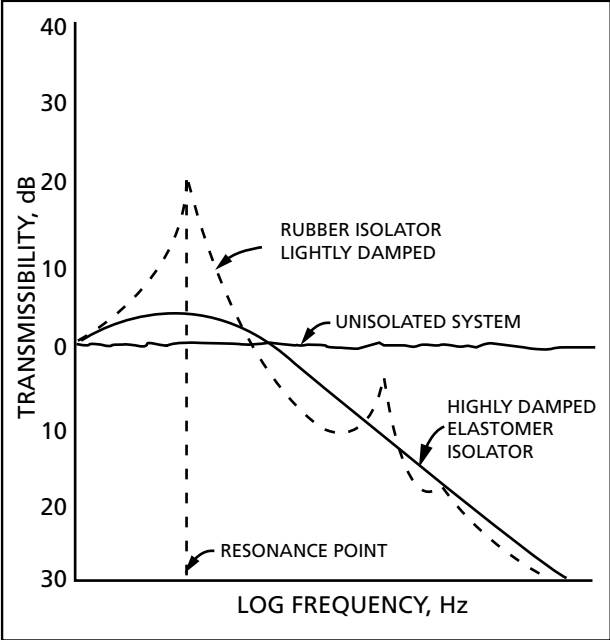


Figure 6

Transmissibility curves compare the vibration isolation performance of two materials. Data indicate that the highly damped elastomer is the better choice for a machine isolation mount. Note that the amplification of the elastomer isolator is only 3.5 dB at the resonance point compared to 23 dB for the rubber isolator.

One way to compare the behavior of various isolators is to measure their transmissibility. Typical transmissibility curves, as shown in Figure 6, compare the vibrational acceleration response of materials used in isolation applications. As the damping in a material increases, the system amplification response can be minimized at or near the natural frequency. This can be especially beneficial

in applications such as stepper motors, which must run through a variety of frequencies, or those applications that frequently go through a start up or slowdown as part of the operation cycle. In applications with little or no damping, amplification can reach as high as 23 dB, which would be a magnification factor of 14.2.

Uncontrolled resonant motion in a device's isolation mounts can have results ranging from acceptable to catastrophic, depending on the operational properties of the components involved. Undamped mounts have internal resonances that conduct considerable high-frequency vibrational energy from a device to its support structure. The large forces developed at and near resonance can easily damage internal components or even tear a device from its mounting.

Conclusion

The bottom line in noise and vibration control, as in virtually all other engineering efforts, is cost-effectiveness, which translates into achieving work-

able, inexpensive solutions to complex problems. Maximum advantages of reducing noise and vibration at the source can be realized by careful planning, thoughtful design, and proper choice of materials and structures specifically engineered for the task.

This technological state of the art in damping materials and systems is such that it is possible to design products that operate more quietly, with less vibration and greater precision, without being necessarily more expensive or difficult to build.



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