Providing Solutions in
Pressure-Sensitive Films

FLEXCON

WHITE PAPER

Benefits of Engineered Pressure-Sensitive Adhesives for Vibration Damping

FLEXcon has been an active participant in the design and manufacturing of pressure-sensitive adhesive (PSA) containing composites for more than 50 years. These products range from material used for bumper stickers to the highly engineered PSAs used for sound and vibration damping or for bonding to low surface energy materials such as silicone rubber. The emphasis in this technical paper will be on the engineered PSAs.

Our engineered PSAs cover a wide variety of application requirements. They include adhesives that:

- meet aerospace, medical, and security requirements
- are designed to form a bond in sub-zero cold, or to maintain adhesion at temperatures in excess of 500°F (260°C)
- bond to low surface energy substrates
- resist "out gassing"
- respond to low frequency AC
- greatly resist dielectric breakdown
- act as a thermal insulator, or facilitate heat transfer
- are designed to lift a fingerprint, or can leave a fingerprint on the substrate if removed
- can be cleanly (no residue) removed
- can survive the strict requirements for LOCA (loss of coolant accident)
- can bond sound damping materials to the inner skin of aircraft, or can be the noise reducing component itself.

This paper will focus on vibration damping. Papers on other adhesive-related topics are available.

Vibration Damping

FLEXcon has been supplying engineered adhesives for use as the viscoelastic layer in constrained layer damping for more than 15 years.

Viscoelastic Material

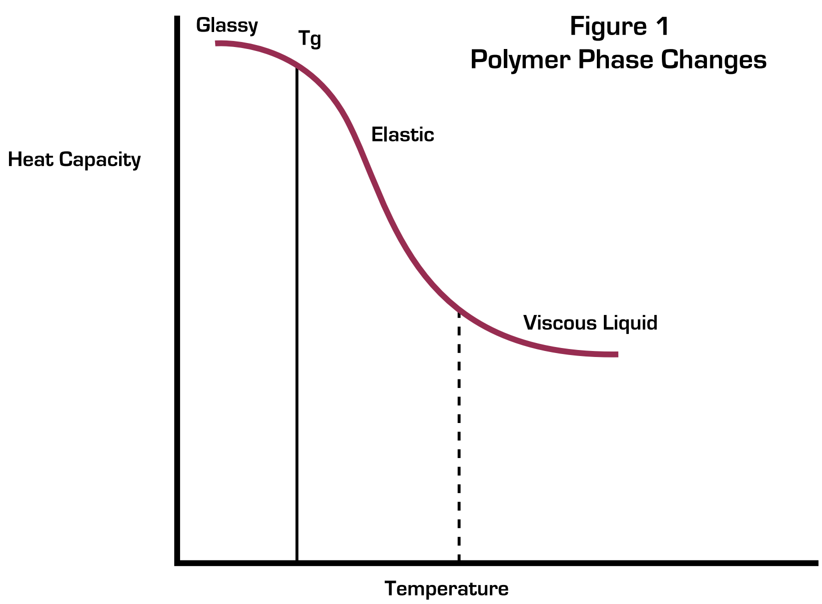
We are familiar with materials that change their state or phase with changes in temperature. Water, for example, at moderate temperatures is a "liquid." When the temperature cools to 32°F (0°C), water freezes into "ice." When the temperature is increased to 212°F (100°C), it boils into a "gas" (vapor).

Polymeric materials also undergo significant changes in their state with changes in temperature. While measurable, the changes in state may not be as clearly obvious as melting ice or boiling water. In fact, the term "melting point," or "melt flow," while used in processing some polymers, is not necessarily an accurate expression of the polymer's property, especially when pressure is involved or the polymer is cross-linked (thermoset).

In general, polymers have a more complicated relationship to temperature. For example, unlike water, they are also sensitive to the rate of temperature change. Given these facts, just what do polymers do? What are their changes in state with respect to temperature changes? And how does all of this relate to "vibration damping"?

To start, let's define polymer transition states.

Glassy Phase - The Glassy Phase is roughly equivalent to the solid phase in water. The polymer is at its hardest in this phase. It is unsuited for sound damping in the Glassy Phase, as the polymer is more likely to allow an unaltered pathway for noise through the vibrating structure.

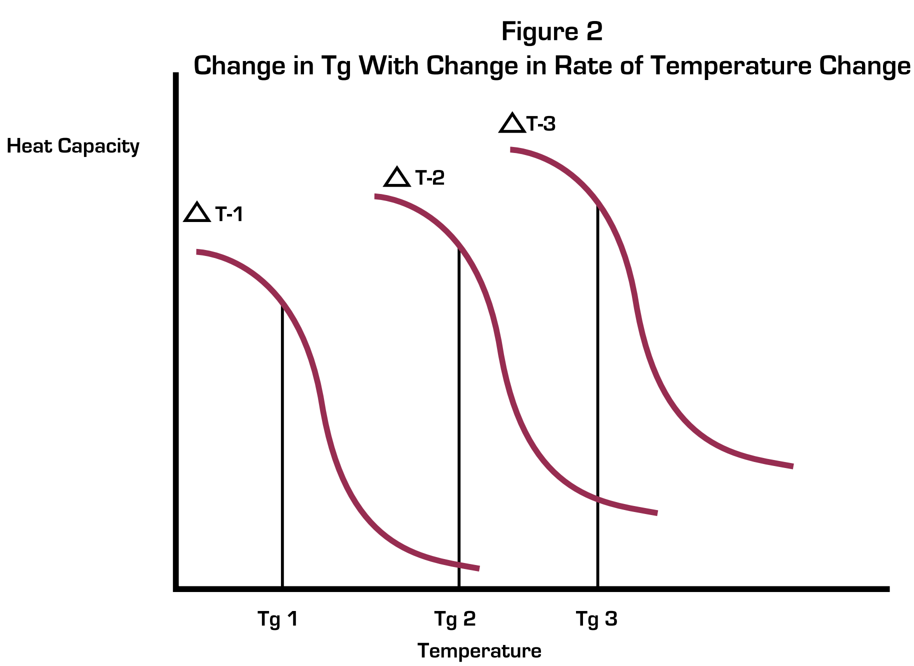


Elastic Phase - As a polymer is heated, it moves from its Glassy Phase to its Elastic Phase. The temperature at which this occurs is called "the glass transition temperature," designated Tg. It is this phase where vibration damping begins.

Viscous Phase - While still useful for damping, as temperature increases (at a constant frequency), the ability to recover begins to fade.

Polymers are more complex than simpler material, such as water, in how they behave with respect to changes in state with changes in temperature. Polymer response to changes in temperature can vary by the rate of change in temperature. Please note Figure 2, which depicts how changing the rate of temperature change affects the Tg.

Simply stated, the faster the rate of temperature change, the higher the Tg.



Further, if the change to a polymer is mechanical in nature (such as a vibration), the same principles apply, i.e., the faster the change (higher the frequency), the higher the apparent Tg. This phenomenon is familiar to everyone who has ever played with Silly Putty. Roll the Silly Putty into a cigar shape, then hold it by the ends, and slowly draw it out. It seems as though we could stretch it forever or at least until our arms are at full extension. However, when we pull the cigar quickly, in effect creating a "vibration," the Silly Putty snaps like a piece of chalk. The higher the vibrational frequency, the more "solid" the polymer is at any given temperature. Stated another way: to keep the same viscosity of a polymer as vibrational frequency is increased, the temperature must be increased.

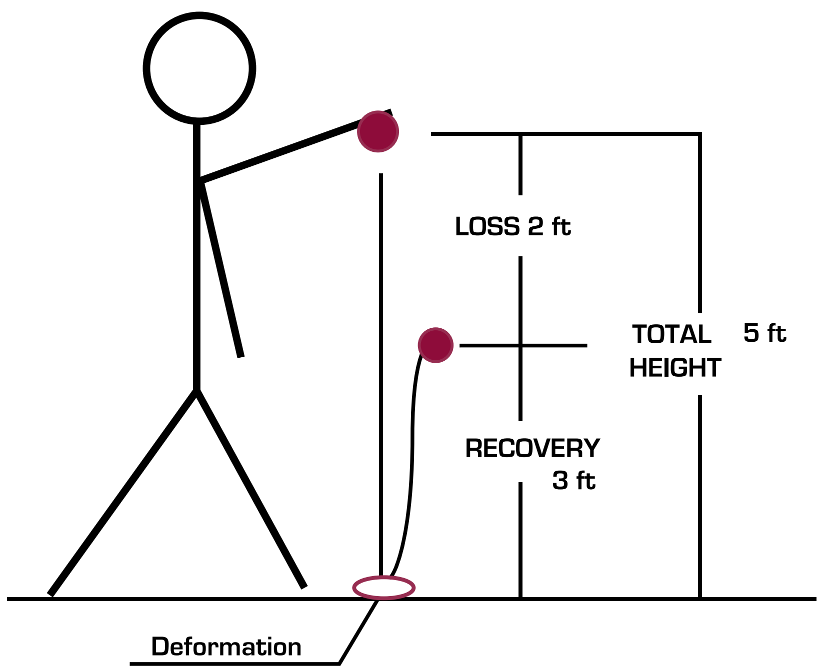
For the purposes of vibration damping, the measurement of the Tg is measured dynamically, i.e., at changing frequencies and temperatures.

Loss Factor and Storage Modulus

The most useful metrics in evaluating a polymer's damping potential are its loss factor and storage modulus. A simple way to demonstrate these two components of vibration damping is shown in Figure 3. In this rendering of a ball being dropped from a height, the ball deforms, then bounces back easily. The bounce-back (recovery) is a measure of how much of the impact energy the ball could store and release to bounce back. This is the "storage modulus."

The difference between the starting height and the recovery height is the "loss factor" or a measure of how much of the energy was lost to the surrounding environment as heat. The ratio of these two quantities is a useful measure of damping ability. Called the tan d (tan delta), it is defined as the ratio of the loss factor to storage modulus.

Figure 3
Loss Factor & Storage Modulus



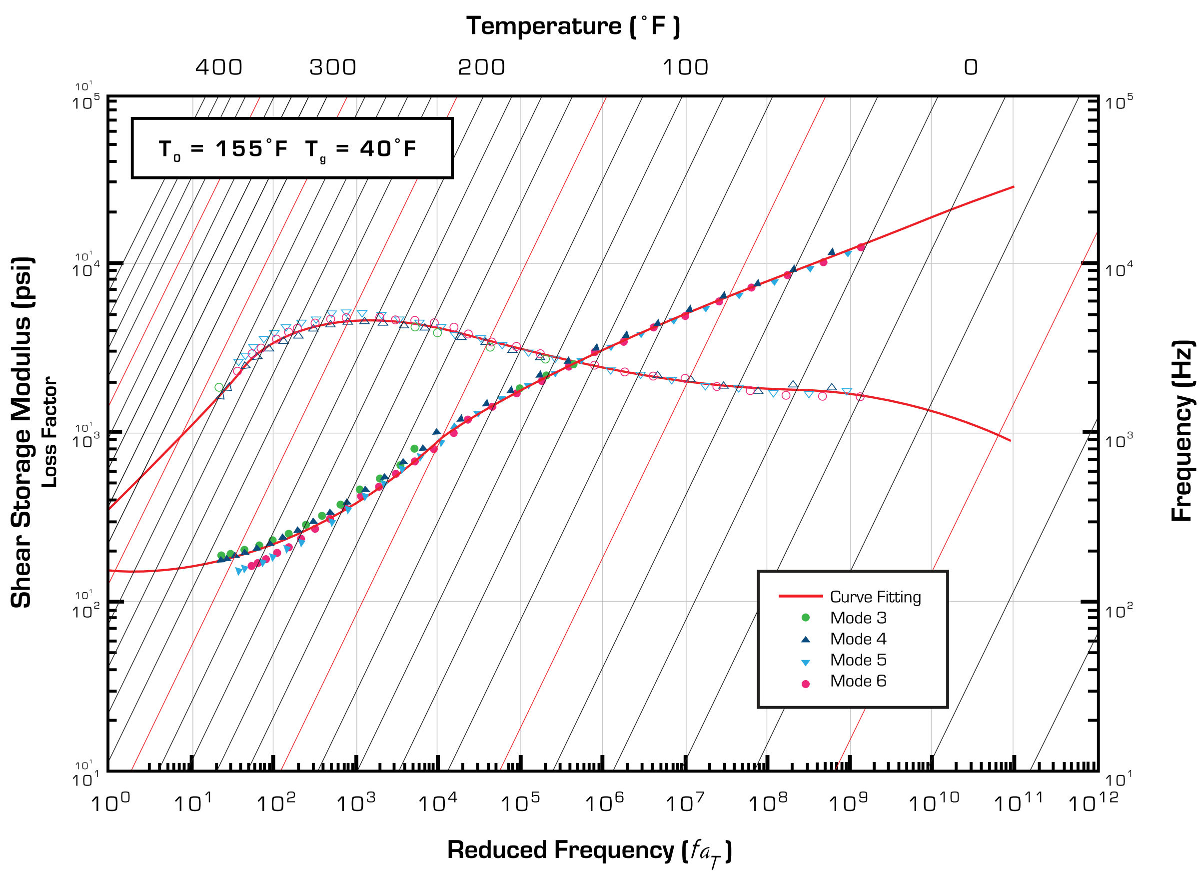
Some of the energy converted into heat (loss)
Some of the energy stored and released for recovery (storage modulus)

One method of graphically showing how temperature and frequency interact is to run Tg determinations at a given temperature over a range of vibrations. We then go to another temperature region and again evaluate the Tg as a function of changing frequency. Please note that, from the polymer's point of view, it would make no difference if the test were conducted at a constant frequency, then a varied temperature, then the cycle was repeated again at another constant frequency, varying the temperature again, and so forth. Thus, we see the limits on the use of viscoelastic liquid for vibration damping at a given frequency. If the temperature of the polymer is too low, it may be in its Glassy state. If the temperature of the polymer is too high, it may be in the very fluid part of the Viscous state and have too low a storage modulus to recover.

Reduced Frequency Nomograms

Polymer chemists have long used the concept of the "master curve" to graphically represent complex relationships in a concise, useful fashion. The master curve of the relationship between temperature and frequency as they relate to Tg changes and vibration damping is called the "Reduced Frequency Nomogram." See Figure 4 for the reduced frequency nomogram for the FLEXcon SA6000 Series tacky silicone adhesive. Here we note that a reference point was chosen to begin construction of the nomogram. While it is possible to start the nomogram at any point, it is most useful to select a point around a key element, such as the "loss factor" approaching a value of 1 (101).

Figure 4
Reduced Frequency Nomogram for FLEXcon SA 6000 Series



Reading the nomogram, we see that the FLEXcon SA6000 series adhesive seems to maintain good damping properties over a temperature range of -180°F to -280°F. Furthermore, the frequency range is indicated as roughly 500-15000 cycles/sec (Hz). This turns out to be in a good range for certain disc brakes on cars. Indeed, FLEXcon silicone adhesives have been used in this application for a number of years.

FLEXcon's tacky silicone adhesives in the SA6000 Series provide the pressure-sensitive characteristics of traditional PS adhesives, but with the added benefit of continued performance in extremely low or high temperature applications where acrylic adhesives could not endure.

Incorporating Viscoelastic Materials into a Damping Treatment

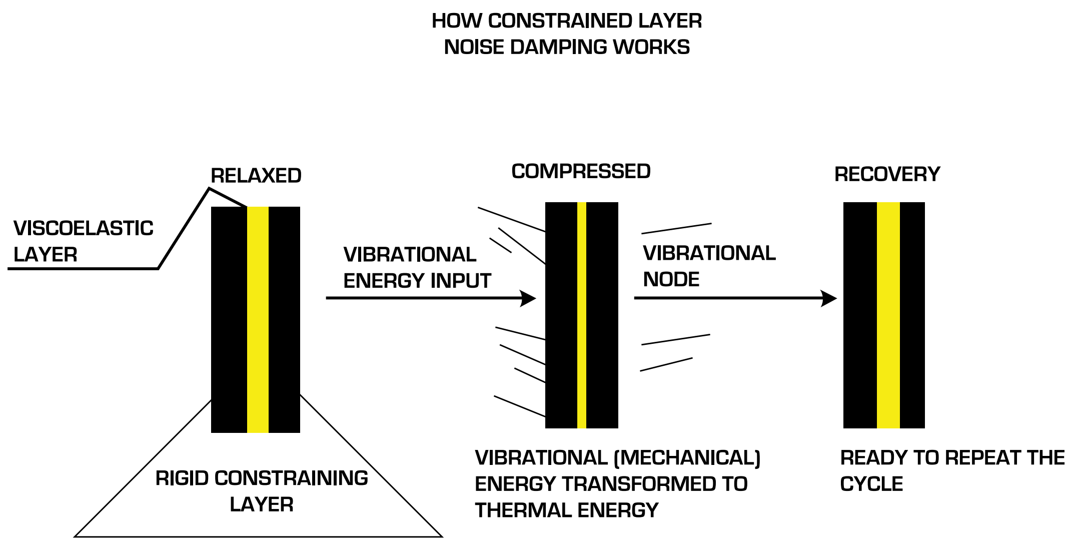


FIGURE 5

Measuring a polymer's properties and constructing its reduced frequency nomogram are important steps in defining a damping treatment for a noise (vibration) problem. But one more step is needed -- the construction of the actual device. By placing a viscoelastic layer between two more rigid layers, the composite forms a constrained layer damping system. The constrained layer damping system uses the displacement/recovery of the viscoelastic material. As can be seen from Figure 5, the vibrational input is transmitted through the rigid constraining layer to the viscoelastic layer. The deformation of this viscoelastic layer is the means by which vibrational energy is dissipated to thermal energy (loss factor). As the final stage in the cycle, the viscoelastic layer recovers, and is thus ready for the next vibration (storage modulus).

While there may not be a single viscoelastic material to cover all possible frequency/temperature combinations, FLEXcon has scores of adhesives that can cover many different vibration/temperature combinations.

FLEXcon can provide any of these adhesives in a format appropriate for the application – as a transfer tape, as a component of a single-coated protective product, or as part of a double-coated construction using an additional adhesive when it is necessary to bond two incompatible surfaces.

Conclusion

FLEXcon offers adhesive solutions and technical expertise that benefit many industries, from aerospace to automotive to appliance. By working closely with OEM Design Engineers and contributing FLEXcon's special PSA capabilities and expertise, we can jointly find solutions to the most difficult challenges in noise and vibration control.

For technical information on FLEXcon's products and capabilities, including adhesive solutions for sound/vibration damping, contact Shirley Monte, Business Development Manager, Performance Products Business Team, 508-826-4646, smonte@FLEXcon.com.

About the Author

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About FLEXcon

FLEXcon is an ISO 9001:2008 worldwide manufacturer of pressure-sensitive films and adhesives for applications including indoor and outdoor advertising, bonding/mounting, and product identification, safety, hazard, bar-coded, and primary labels. The company's Value-Better-Supreme (VBS) product offering is the most extensive standard product offering in the pressure-sensitive film industry. FLEXcon is also a leader in developing custom solutions to meet unique converting or application needs. FLEXcon's mission is to provide its customers the highest quality products with exceptional service. The company is headquartered in Spencer, Massachusetts, and has operations throughout North America and Europe, with distribution worldwide. For more information on FLEXcon, visit www.FLEXcon.com.

Let's Talk Solutions

Bring your challenges or next big idea to FLEXcon and we will work together to find a solution.
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