Sorbothane®

ENGINEERING DESIGN GUIDE

Your Guide To Shock & Vibration Solutions

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Sorbothane®
SHOCK & VIBRATION SOLUTIONS

This design guide has been developed to assist engineers in a practical, hands-on approach to designing with Sorbothane®. This guide is advisory only. It is the responsibility of the user to verify the results. This guide does not take into account buckling or casting limitations of the material.

The data used in this manual is supported by empirical work. Sorbothane, Inc. offers additional technical support. You may contact support@sorbothane.com if you have questions. A Windows-based program "Design Guide" which parallels this calculation method can be downloaded from the Sorbothane web site (www.sorbothane.com).

Sorbothane is a polyether-based polyurethane. It is formulated for enhanced visco-elastic properties. Sorbothane is consistently effective over a wide temperature range (-29 to + 71 degrees Celsius).

Because Sorbothane is a non-Newtonian material stress is not proportional to strain and mechanical energy is "lost" by conversion to heat. The response of Sorbothane to a load is highly dependent on the rate of force application (frequency dependent responses).

Sorbothane is highly damped which makes it particularly desirable for difficult applications which require operation near or at resonant frequencies.

Sorbothane is available as custom-molded parts, select standard shapes and in sheet stock in a variety of thickness and sizes. Parts can be specified in durometers ranging from 30 to 80 on the Shore 00 scale.

The most effective static deflection for Sorbothane with a shape factor between 0.3 and 1.0 is in the range of 10-20%.

GLOSSARY OF TERMS

Vibration: A periodic motion around a position of equilibrium.

Random Vibration: Vibration whose magnitude is not specified for any given instant of time.

Shape Factor: The loaded area over the unloaded area of a vibration mount.

Static Deflection: The amount that a given mass compresses.

Percent Deflection: The fraction of static deflection to thickness.

Frequency: The number of times the motion repeats itself per unit of time measured in Hertz (Hz).

Natural Frequency: The frequency of free vibration of a system.

Resonant Frequency: A frequency at which resonance exists.

Resonance: The frequency match between the natural frequency of the system and the external forced vibration frequency.

Damping: The dissipation of energy in an oscillating system.

Transmissibility: The ratio of the response amplitude of a system in steady state forced vibration to the excitation amplitude.

Isolation: A reduction in the capacity of a system to respond to an excitation.

SHAPE FACTOR

$$\text{Shape Factor (SF)} = \frac{\text{Loaded Area}}{\text{Unloaded Area}}$$

$$\text{Rectangular Prism (SF)} = \frac{\text{Length x Width}}{\text{2 x Thickness x (Length + Width)}}$$

$$\text{Square Prism (SF)} = \frac{\text{Length}}{\text{4 x Thickness}}$$

$$\text{Disk (SF)} = \frac{\text{Diameter}}{\text{4 x Thickness}}$$

$$\text{Ring (SF)} = \frac{\text{Outside Diameter}}{\text{4 x Thickness}} - \frac{\text{Inside Diameter}}{\text{4 x Thickness}}$$

$$\text{Spherical Cap (SF)} = \frac{\text{2 x Radius - Thickness}}{\text{2 x Radius}}$$

STATIC DEFLECTION

(Iterate until Assumed Percent Deflection agrees with calculated deflection within 3%)

$$\text{Compressive Modulus} = \frac{\text{Cs}}{\text{Assumed Percent Deflection} / 100}$$

See Figure 1 on Pg. 4 for Cs

$$\text{Corrected Compressive Modulus} = \text{(Compressive Modulus) x } [1 + 2 \text{ x SF}^2]$$

$$\text{Static deflection } (\delta_{ST}) = \frac{\text{Load per Isolator x Thickness}}{\text{Corrected Compressive Modulus x Loaded Area}}$$

$$\text{Percent Deflection } (\%\delta) = \frac{\delta_{ST}}{\text{Thickness}} \text{ x } 100$$

Continued on pages 3 & 4

CALCULATING VIBRATION RESPONSE FOR SORBOTHANE®

• SYSTEM NATURAL FREQUENCY

(Iterate until assumed natural frequency agrees with calculated natural frequency within 3 Hertz.)

Dynamic Young's Modulus (E_{dyn}) = Dynamic Shear Modulus (G_{dyn}) x 3 *See Figure 2 on Pg. 4 for G_{dyn}*

$$\text{Dynamic Spring Rate } (K_{dyn}) = \frac{E_{dyn} \times (1 + 2 \times SF^2) \times \text{Loaded Area}}{\text{Thickness}}$$

$$\text{System Natural Frequency } (f_n) = \frac{\sqrt{K_{dyn} \times \text{gravity} / \text{Load per Isolator}}}{2\pi}$$

• TRANSMISSIBILITY

$$\text{Frequency Ratio } (r) = \frac{\text{Excitation Frequency } (f_{exc})}{f_n}$$

$$\text{Dynamic Shear Ratio } (Gr_{dyn}) = \frac{Gd_{dyn} @ f_n}{Gd_{dyn} @ f_{exc}}$$ *See Figure 2 on Pg. 4 for G_{dyn}*

$$\text{Transmissibility } (T) = \sqrt{\frac{1 + (\text{Tan Delta})^2}{(1 - r^2 \times Gr_{dyn})^2 + (\text{Tan Delta})^2}}$$ *See Figure 3 on Pg. 4 for Tan delta @ f_{exc}*

Percent Isolation = (1 - T) x 100

$$\text{Transmissibility at Resonance } (Q) = \sqrt{\frac{1 + (\text{Tan Delta} @ f_{exc})^2}{(\text{Tan Delta} @ f_{exc})^2}}$$

figure 1.

COMPRESSIVE STRESS VS. DUROMETER

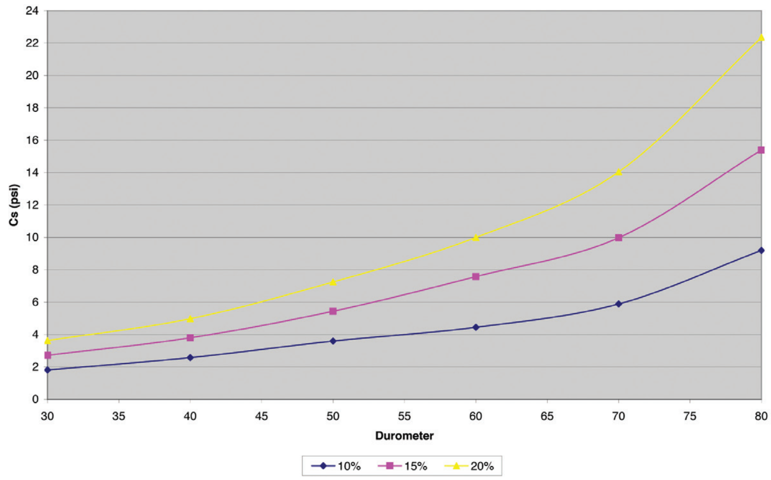


figure 2.

FREQUENCY VS. SHEAR MODULUS

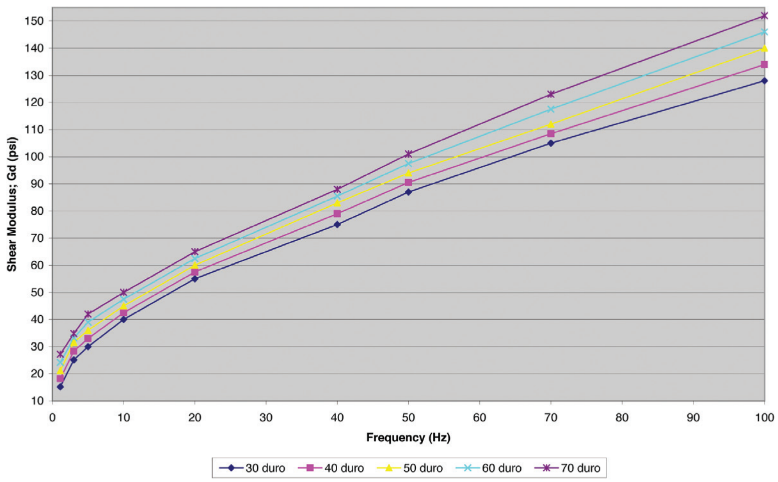
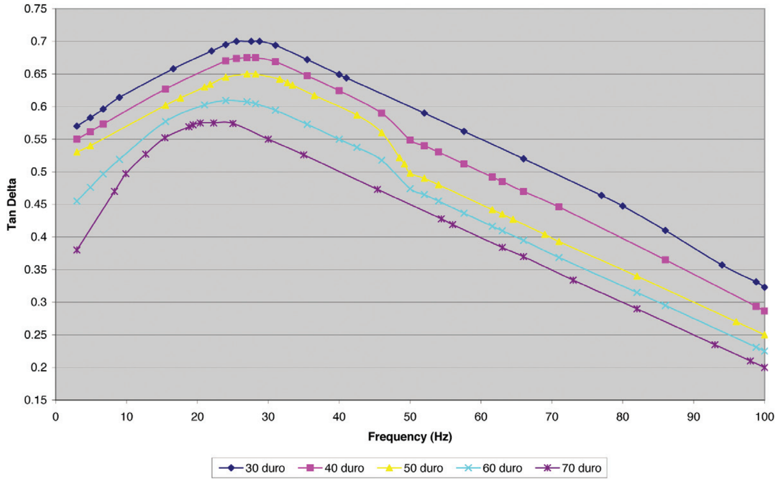


figure 3.

FREQUENCY VS. TAN DELTA



Required Starting Information:

1. **Weight (W) or Mass (m)**
2. **Velocity (V) or Drop Height (h)**

For these examples the work will be in English units of:

- Acceleration of gravity (g) = 386.4 inches/second^2
- Free fall drop height (h) in inches
- Dynamic deflection (δ) in inches
- Force (F) in pounds-force
- Kinetic Energy (KE) in pounds-force-inch
- Mass (m) in slugs
- Nominal spring rate* (k) in Pounds-force/inch
- Percent deflection (%δ) is unitless
- Velocity (V) in inches/second
- Part thickness (t) in line impact
- Static deflection (δ_{st}) in inches

Step 1.
Convert Weight in pounds-force to Mass:

$$m = \frac{W}{g}$$

Step 2.
Calculate the Kinetic Energy (KE) for the impact:

For horizontal impacts only the mass is considered.

$$KE = 1/2\ mV^2$$

For vertical downward free fall drop impacts.

$$KE = Wh$$

Step 3.
Calculate the Spring Rate for the trial part shape:

** Sorbothane has a non-linear spring rate. For purposes of simplification the rate is assumed linear based on its spring rate at 20% deflection.*

There are three accepted methods to develop the nominal Spring Rate.

1. Use the Sorbothane Design Guide Program. This program is available at www.sorbothane.com. It is a Windows-based program. This is valid for parts with shape factor of 1.2 or less. Load the selected shape to 20% deflection. The program will calculate the static deflection (δ_{st}).

$$k = \frac{W}{\delta_{st}}$$

2. Use static deflection equations on page 2 to manually calculate the same values.

3. Load the given shape to a 20% deflection. Measure the static deflection (δ_{st}) and record the load (W) at this deflection

$$k = \frac{W}{\delta_{st}}$$

Step 4.
Calculate the dynamic deflection:

The Spring Energy (SE) is expressed as

$$SE = 1/2\ k\delta_{st}$$

Equate the Spring Energy to the Kinetic Energy.

$$KE = SE$$

$$KE = \frac{1}{2} k\delta^2$$

Arrange terms and solve for dynamic deflection.

$$\delta_{dyn} = \sqrt{\frac{2 \times KE}{k}}$$

Step 5.
Calculate the dynamic percent deflection:

$$\delta_{dyn}\% = \frac{\delta_{dyn}}{t} \times 100$$

For Shape Factors less than 1.2 and percent dynamic deflections less than 40% the expected fatigue life is considered to be in excess of one million cycle (indefinite).

For Shape Factors less than 1.2 and percent dynamic deflections between 40% and 60% the expected fatigue life is considered to be in excess of 1,000 cycles.

If the results achieved fail to achieve the desired performance then revise shape and/or durometer and repeat calculations.

The percent static deflection (continuous load without impact) must not exceed 20%.

There is no accepted methodology for higher shape factors or higher percent dynamic deflections.

VIBRATION

Assumptions: Use 4 pads in each corner
4 inch by 4 inch by 2 thick pads
70 Durometer
15% compression

$$\text{Shape Factor} = \frac{4\text{ in}}{(4)(2\text{ in})} = \boxed{0.5}$$

$$\text{Compressive Modulus} = \frac{10\text{ psi}}{0.15} = \boxed{66.67\text{ psi}}$$

$$\text{Compressive Modulus Corrected for sf} = (66.67\text{ psi})(1+(2)(0.5^2)) = \boxed{100\text{ psi}}$$

$$\text{Static Deflection} = \frac{(250\text{ lbs})(2\text{ in})}{(100\text{ psi})(16\text{ in}^2)} = \boxed{0.3125\text{ in}}$$

$$\text{Percent Deflection} = \frac{0.3125\text{ in}}{2\text{ in}} \times 100 = \boxed{15.6\%}$$

Assume a Natural Frequency of 8 Hz

$$(E_{dyn}) = 48\text{ psi} \times 3 = \boxed{144\text{ psi}}$$

$$K' = \{(144\text{ psi})(1 + (2 \times 0.5^2)\} \times \frac{16\text{ in}^2}{2\text{ in}} = \boxed{1728\text{ in. lb}}$$

$$\text{Natural Frequency} = \frac{1}{2\pi} \times \sqrt{\frac{1728\text{ psi} \times 386\text{ in/sec}^2}{250\text{ lbs}}} = \boxed{8.22\text{ Hz}}$$

$$\text{Frequency Ratio} = \frac{50\text{ Hz}}{8.22\text{ Hz}} = \boxed{6.08\text{ Hz}}$$

$$\text{Transmissibility} = \sqrt{\frac{1 + 0.4^2}{(1-(6.08)^2\left(\frac{48\text{ psi}}{100\text{ psi}}\right))^2 + (0.4)^2}} = \boxed{0.06}$$

$$\text{Percent Isolation} = (1-0.06) \times 100 = \boxed{94\%}$$

SHOCK

A 4 oz component must pass a 3 ft drop test. A space limitation of the pad thickness is 3/16 inch. Four pads will be used to isolate the part but design criteria will be the worst case scenario of the total weight being applied to one pad.

Given Information: Drop Height – 36 in
Weight of Component – 0.25 lbs
Pad Dimension – 1.75 in x 0.625 in x 0.1875 in @ 70 durometer

Step 1. This is skipped because it is a drop test.

Step 2. Calculate the Kinetic Energy (KE) for the impact.

KE = 0.25 lbs x 36 in = 9 in – lbs

Step 3. Calculate the Spring Rate for the trial part.

Method 1: From Design Guide Report - Load per Isolator is 62 lbs and Static Deflection is 0.0375 in.

$$k = \frac{62\text{ lbs}}{0.0375\text{ in}} = 1653\text{ lbs/in}$$

Step 4. Calculate the Dynamic Deflection.

$$\delta = \sqrt{\frac{2 \times 9\text{ in – lbs}}{1653\text{ lbs/in}}} = 0.104\text{ in}$$

Step 5. Calculate the Dynamic Percent Deflection.

$$\%\,\delta = \frac{0.104\text{ in}}{0.1875\text{ in}} = 0.55 \rightarrow 55\%^*$$

**Fatigue life is considered to be in excess of 1,000 cycles*