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AEROSPACE & INDUSTRY

DEFINITIONS

There are a number of terms which should be understood to facilitate discussions of vibration and shock theory as well as discussions related to the molded elastomer (rubber) materials commonly utilized in vibration and shock isolators. Some of these are quite basic and may be familiar to many. However, a common understanding should exist for maximum effectiveness.

Acceleration - Rate of change of velocity with time - usually along a specified axis, usually expressed in "g" or gravitational units. It may refer to linear or angular motion.

Aging - change in physical properties of elastomer with time. The material may become unusable due to excessive hardening, softening, cracking, crazing, or other surface degradations associated with long term exposure. These changes may be the result of the action of oxygen, ozone, light, heat, humidity, oils, water, and/or other solvents.

Amplification - The magnification of an input condition, resulting in a higher output amplitude.

Amplitude - The value of displacement, velocity, or acceleration relative to zero value.

All Attitude – Referring specifically to isolators, indicates that an isolator is capable of carrying static load in any direction or mounting orientation.

Axial-to-Radial Stiffness Ratio – Ratio of an isolator's stiffness in the axial direction to it's stiffness in the radial direction. If the isolator is not axi-symmetric it may have multiple stiffness ratios for the different loading directions.

Bloom - A discoloration or change in appearance of the surface of elastomer products (as sulfur bloom and wax bloom) caused by the migration of a liquid or solid to the surface.

Center-of-Gravity System - An equipment installation wherein the center of gravity of the equipment coincides with the elastic center of the isolation system.

Compression - When specified as a direction for loading - a deformation caused by squeezing the layers of an object in a direction perpendicular to the layers.

Critical Damping (Cc) – The theoretical value of the damping coefficient in a spring-mass-damper system which results in the return of the displaced mass to its equilibrium position without over oscillating and in the shortest possible time.

Critical Damping Factor (C/Cc) – The ratio of a system's damping coefficient (C) to its theoretical critical damping (Cc). Typical values for elastomers are commonly used in isolators are 0.05 to 0.33.

Damping - The "mechanism" in an isolation system which dissipates energy, typically by converting kinetic energy to heat. Damping controls resonant amplification (maximum transmissibility) and roll-off (isolation efficiency) in vibratory systems. Damping in vibration and shock isolators is often quantified using metrics such as Maximum Transmissibility (Tmax), Damping Factor (C/Cc), Loss Factor, Loss Angle, Loss Tangent, or Tan Delta. **DAMPING IS NOT THE SAME AS ISOLATION.**

Decibel (db) - A logarithmic ratio of an amplitude value relative to a reference value of the same units. Often used to relate quantities that differ by orders of magnitude.

Decoupling – The process of forcing modes of vibration to be independent of each other via strategic positioning and orientation of isolators and selection of their stiffness characteristics. Decoupling is achieved by positioning the elastic center of the isolators coincident with the CG location of the isolated mass. In a decoupled mounting system, excitation in one direction (degree-of-freedom) results in response only in that direction. Mounting systems can be designed to be fully decoupled, i.e. all modes independent of each other, or partially decoupled where only some of the system modes are independent of each other.

Deflection - The displacement or movement of a component or isolator due to the application of a force. In vibratory systems, deflection may be due to static or dynamic forces or a combination of the two.

Degree-of-Freedom - Expression of the freedom a system has to move within the constraints of its application. Typical vibratory systems may move in six degrees of freedom - three translational and three rotational modes (motion along three mutually perpendicular axes and rotation about those three axes).

Disturbing frequency (fd) - The number of oscillations per unit time of an external disturbance applied to a vibrating system. fd = disturbing frequency.

Durometer (hardness) – An industry standard hardness measurement for elastomers. It is an indirect indicator of material stiffness or modulus. A durometer gauge measures the resistance to the penetration of an indenter point into the surface of a molded elastomer specimen. The value may be taken immediately or after a very short specified time. Elastomers used in vibration and shock isolators generally fall in the range of 35-75 durometer on the Shore A scale.

Dynamic Matching - The selection of isolators whose dynamic characteristics (stiffness and damping) are very close to each other for use as a set on a given piece of equipment. Such a selection process is recommended for isolators which are to be used on rotational motion sensitive equipment such as guidance systems, radars and optical units.

Dynamic deflection (Δd) - Deflection of the isolator under the dynamic loads/forces of the mounted equipment.

Dynamic Disturbance - The dynamic forces acting on the body in a system. These forces may be the results of sinusoidal vibration, random vibration or shock, for example.

Dynamic Stiffness – The stiffness of a spring or isolator when measured with a load application rate or deflection rate that is fast enough to capture stiffness contribution effects from velocity dependent elements (e.g. material damping). Dynamic stiffness is typically determined by applying a sinusoidal displacement to an isolator, measuring the corresponding force, and calculating the dynamic stiffness as the ratio of peak dynamic force to peak dynamic deflection. The phase angle between the imposed displacement signal and measured force signal can also be measured as an indicator of the damping (see Loss Angle).

Elastic Center - A theoretical point in space at which a system of two or more non-coincident isolators can be represented by a single isolator of equivalent system stiffness. The elastic center of a system of isolators is analogous to the center-of-gravity of a system of masses, however it is not necessarily located at the geometric center of the system of isolators. Isolators which have different stiffness characteristics in different axes can be inclined or “focused” in order to project their elastic center to a point away from their geometric center. The position of the elastic center is a function of isolator locations, orientations and stiffness ratio(s).

Elastomer - A generic term used to include all types of "rubber" - natural or synthetic. Many vibration isolators are manufactured using some type of elastomer. The type typically depends on the environment in which the isolator is to be used.

Fail-safe – When used to describe an isolator, indicates that the isolator has some sort of captivation or mechanical interlocking feature that prevents separation in the event that the elastomer or reslient element fails.

Flash - Excess rubber on a molded product resulting from cavity overflow. It is common to most molding operations. Flash has two dimensions – extension and thickness. Extension is the projection from the part along the parting line of the mold. Thickness is measured perpendicular to the mold parting line. Flash needs to be removed or reduced where required.

Force-Deflection curve - The measured and recorded displacement of an isolator plotted versus applied force. Same as Load-Deflection curve.

Fragility - The amount of vibration or shock which a piece of equipment can experience without malfunctioning or breaking. In isolation systems, it is an indicator of the amount of dynamic excitation which the isolator can transmit to the isolated equipment. It is the highest vibration or shock level that can be withstood without equipment failure.

"g" level - An expression of the vibration or shock acceleration level being imposed on a piece of equipment as a dimensionless factor times the acceleration due to gravity

Iso-elastic - A word meaning that an isolator, or isolation system, exhibits the same stiffness characteristics in all directions.

Isolation - The protection of equipment from vibration and/or shock through the reduction of the input. The degree (or percentage) of isolation necessary is a function of the fragility of the equipment.

Linear (properties) - A description of the characteristics of an isolation system which indicates that behavior varies linearly with deflection, temperature, vibration level, etc. Linearity of isolators or isolation systems is often assumed in order to simplify analyses or calculations.

Load-Deflection curve - The measured and recorded displacement of an isolator plotted versus applied load (force). Often abbreviated as “LD curve”. Same as Force-Deflection curve.

Loss Angle – A measure of the amount of damping in an elastomer. Loss Angle is the phase angle between the applied displacement signal and measured force signal in a dynamic stiffness or dynamic modulus test. The greater the Loss Angle, the more damping in the elastomer. Loss Angles typically fall in the range of 5° - 30°.

Loss Factor - A measure of the amount of damping in an elastomer. It is equal to the tangent of the Loss Angle and is approximately equal to 2(C/Cc). Sometimes referred to as Tan Delta. The higher the Loss Factor, the more damping in the elastomer. Loss Factor is inversely proportional to Maximum Transmissibility (Tmax). The Loss Factor of elastomers can vary as a function of loading rate and environmental conditions, especially temperature.

Maximum Transmissibility (Tmax) – The maximum response or maximum amplification factor occurring in a spring-mass-damper system when the input frequency is equal to the natural frequency (resonance). It is often used as a measure of damping for elastomeric isolators. The lower the Tmax value, the more damping in the elastomer. Also referred to as Resonant Transmissibility. See also Transmissibility.

Modulus - A property of elastomers (analogous to the same property of metals) which is the ratio of stress to strain in the elastomer at some loading condition. Unlike the modulus of metals, the modulus of elastomers is non-linear over a range of loading and ambient conditions. This fact makes the understanding of elastomers and their properties important as related to the performance of elastomeric vibration and shock isolators.

Natural Frequency (fn) – The frequency at which a spring-mass system will exhibit a maximum response to a vibratory input. May also be referred to as Resonant Frequency. Natural Frequency is a function of stiffness and mass, and is usually expressed in units of "Hertz (Hz)" or "cycles per second". If the Natural Frequency (ies) of a system is (are) set up to be much lower than any disturbing frequencies the spring-mass system might experience, vibration isolation is achieved.

Natural Frequency can be physically observed as the frequency(ies) at which a spring mass system will naturally want to vibrate if disturbed by a transient input. Natural Frequency(ies) can also be calculated if the stiffness and mass properties of a spring-mass system are known. Spring-mass systems have a number of natural frequencies corresponding to the number of degrees-of-freedom in the system. Natural Frequencies also occur in structures with distributed mass and stiffness.

The relationship of the system natural frequencies to the frequencies of vibration or shock disturbances determines, in part, the amount of isolation (protection) which may be attained.

Octave - A doubling (or halving) of frequency. This word is used in various expressions dealing with vibration isolation.

Outgassing - the release of a gas that is present in elastomer. Most elastomers contain small amounts of oil and other ingredients that will become volatile under elevated temperatures and vacuum conditions. These materials can deposit on optics and electronics and cause reduced function. "Post curing" elastomers like fluorosilicone and silicone after molding removes or reduces many of the unwanted volatiles.

Power Spectral Density (PSD) - An expression of the level of random vibration being experienced by the equipment to be isolated. The units of PSD are g^2/Hz, and the typical symbol is "Sf.".

Random Vibration - Non-cyclic, non-sinusoidal vibration characterized by broad band frequency content and randomly varying amplitude. Typically, many applications of equipment in the field of Military Electronics are exposed to random vibration.

Resilience - The ability of a system to return to its initial position after being exposed to some external loading. More specifically, it is the ability of an isolator to completely return the energy imposed on it during vibration or shock. Typically, highly damped elastomers have low resilience while low-damped elastomers have high resilience.

Resilient Element – Typically refers to the flexible component or material in an isolator. e.g. elastomer, coil spring, metal mesh.

Resonance - A vibratory system is said to be operating in resonance when the frequency of the disturbance (vibration) is coincident with the system's natural frequency.

Resonant Dwell - A test in which isolated equipment is exposed to a long term sinusoidal vibration at its resonant frequency. This type of test can be used as an accelerated fatigue test for sinusoidal vibration conditions. In current practice, sinusoidal testing is being replaced by random vibration testing, and resonant dwell tests are becoming less common.

Resonant Transmissibilty – See Maximum Transmissibility (Tmax).

Returnability - The ability of a system, or isolator, to resume its original position after removal of all outside forces. This term is sometimes used interchangeably with resilience.

Roll-off Rate - The steepness of the transmissibility curve being recorded during a vibration test, after the system natural frequency has been passed. This term is also used to describe the slope of a random vibration curve.

Set - The amount of permanent deformation occurring in an isolator after removal of a static load or an imposed deflection. It may occur in shear or compression.

Shear - When specified as a direction for loading - a deformation caused by sliding layers of an object past each other in a direction parallel to the layers.

Shock Pulse - A transmission of kinetic energy to a system, occurring over a relatively short length of time compared to the natural period of this system. It is followed by decaying oscillatory motion of the system at its natural frequency. Shock pulses are usually described via plots of acceleration vs. period of time.

Snubbing Washer – A special washer, used in conjunction with an isolator, to provide a fail-safe captivation feature, to alter its force-deflection characteristics, to limit dynamic deflection, or any combination of these.

Spring Rate - See Stiffness.

Static deflection (Δs) - Deflection of an isolator under the static weight (dead weight) or static load of the mounted equipment or mass.

Static Stiffness – The stiffness of a spring or isolator when measured with a load application rate or deflection rate that is very slow, thus excluding any stiffness contributions that are velocity dependent.

Stiffness –Force required to produce a unit deflection of a spring or isolator. Typically determined by calculating the slope of a force-deflection curve. Steel coil springs typically have a very linear relationship between force and deflection. Elastomeric isolators may or may not be linear depending on the amount of deflection, the direction of loading, and the geometry of the elastomer. For isolators with non-linear force-deflection characteristics, the stiffness varies depending where along the force-deflection curve the slope is measured. Stiffness is usually expressed in pounds per inch of deflection (lbs/in) under load, or Newtons per millimeter (N/mm) in metric units. It is also commonly referred to as Spring Rate.

Sway Space – The amount of space an isolated unit has in which it can move without interfering with surrounding equipment or structure. This is sometimes called "free deflection" or “dynamic clearance”.

Tan Delta – A measure of the amount of damping in an elastomer. See Loss Factor.

Tension - When specified as a direction for loading - a deformation caused by pulling or separating the layers of an object in a direction perpendicular to the layers.

Transmissibility (T) - A dimensionless unit expressing the ratio of vibration response compared to the input. It may be measured as motion, force, velocity or acceleration. When transmissibility is greater than 1, amplification occurs; when less than 1, isolation is achieved.