Use of Textile Composites in Vibration Damping Applications

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Damping is the phenomenon through which mechanical energy is dissipated by conversion into internal thermal energy in dynamic systems. Knowledge of the level of damping in a dynamic system is important in the utilization, analysis, and testing of the system. Knowledge of damping in constituent devices, components, and support structures is important in the design and operation of complex mechanical systems. The nature and the level of component damping should be known in order to develop a dynamic model of the system and its peripherals. Knowledge of damping in a system is also important in imposing dynamic environmental limitations on the system (that is, the maximum dynamic excitation the system can withstand) under in-service conditions. Furthermore, knowledge of a system's damping can be useful in order to make design modifications in a system that has failed the acceptance test.

What is Damping?

Damping is the phenomenon by which mechanical energy is dissipated in dynamic systems. Damping is any effect that tends to reduce the amplitude of oscillations in any oscillatory system. Vibratory response can lead to cracked structures, defocused optics, or other types of degraded performance. The damping in a vibratory system has been intrinsic. Damping came from things like bolted joints or airfriction.

Vibratory energy is transmitted from the aircraft skin panels into the substructure-the stringers, frames, and bulkheads. Thus, internal equipment also gets hit with structure-borne vibratory energy at mounting brackets as well as acoustic energy on their surfaces. This can lead to equipment degradation or failure.

Knowledge of a system's damping is useful in order to make design modifications in a system that has failed the acceptance test.

Types of Damping

There are mainly three types of damping:-

- Internal damping (for material)
- Structural damping (at joint & interfaces)
- Fluid damping (through fluid- structure interactions)

Internal damping: Internal damping is one, where energy dissipation takes place in a macro continuous media.

Structural damping: In structural Damping energy dissipation in the total structure. In addition to damping due to materials, it also includes energy dissipation effects of joints, fasteners, and interfaces.

Fluid Damping: When a mechanical system or its components move in a fluid, fluid damping arises from the mechanical energy dissipation resulting from drag forces and associated dynamic interactions.

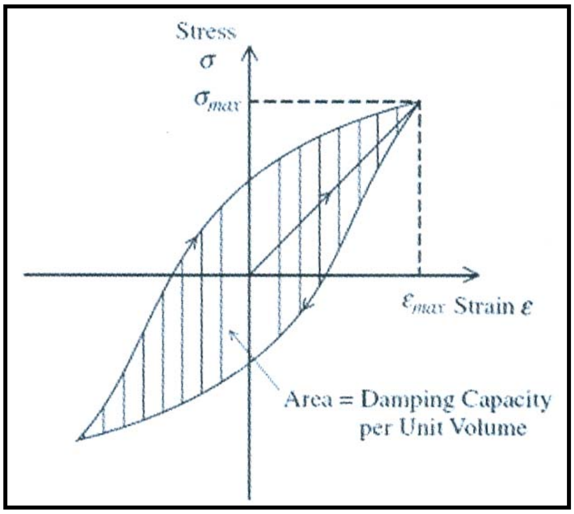

Figure 1: A representative hysteris curve for mechanical damping

The area of the hysteresis loop [Fig.1] gives the energy dissipation per unit volume of the material, per stress cycle. This is termed the perunit-volume damping capacity, and is denoted by d:

Active dampening and passive dampening

Active damping: Active damping refers to energy dissipation from the system by external means, such as controlled actuator, etc [Fig.2].

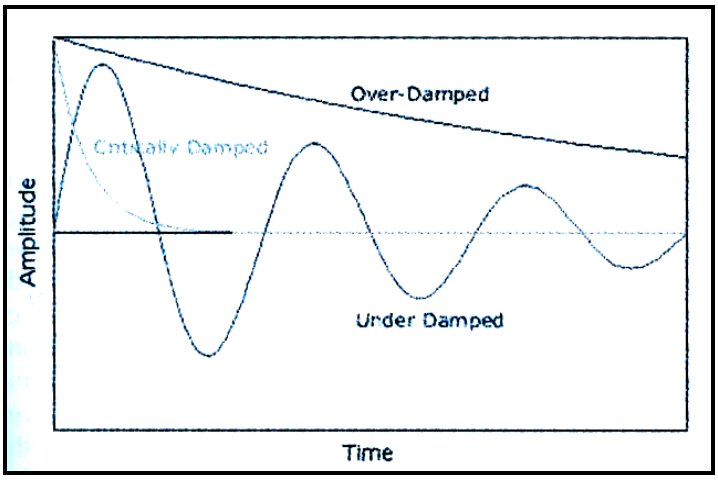

Figure 2: A comparison of under damped, critically damped and over damped materials

Passive damping: Passive damping refers to energy dissipation within the structure by add-on damping devices such as isolator, by structural joints and supports, or by structural member's internal damping.

Oscillation modes

Over Damped: If any system contained high losses, the mass could slowly return to its rest position without ever overshooting. This case is called over-damped.

Under-Damped: Very commonly it is seen that the mass tends to overshoot its starting position and then return, overshooting again. With each overshoot, some energy in the system is dissipated and the oscillations approach towards zero. This case is called under-damped.

Critically Damped: Between the over-damped and underdamped cases, there exists a certain level of damping at which the system will just fail to overshoot and will not make a single oscillation. This case is called critical damping.

Damping Parameters

Damping Ratio: It is defined as the ratio of the actual resistance in damped harmonic motion to that necessary to produce critical damping a disturbance. Damping ratio is denoted by the sign 'ζ'.

Damping Capacity: The damping capacity of a device can be defined as the energy dissipated in a complete cycle of motion. It is denoted by 'ΔU'.

Damping capacity per volume: Damping capacity per volume can be defined as the energy dissipated per cycle per unit material volume. It is denoted by 'd'.

Specific damping capacity: It is defined as the ratio of energy dissipated per cycle to the initial maximum energy. It is denoted by 'D'.

So, it can be written as $D = \Delta U/U_{max}$, where, U_{max} = Initial maximum energy.

Loss factor: It is defined as the specific damping capacity per unit angle of cycle. It is denoted by η. This loss factor can be written as $\eta = \Delta U / 2\pi U_{max}$

For low damping η= 2 x damping ratio

Measurement of Damping

Damping may be represented by various parameters, such as specific damping capacity, loss factor, Q-factor, and damping ratio.

There are two general ways by which Damping of a system can be measured, namely-

1) Using a time response record.
2) Using a frequency response record.

There are many techniques by which Damping in a system can be measured, of which two techniques are most commonly used. They are-

1) Logarithmic decrement method, which measures damping in Time domain.
2) Bandwidth method, which measures damping in frequency domain.

1) logarithmic decrement method

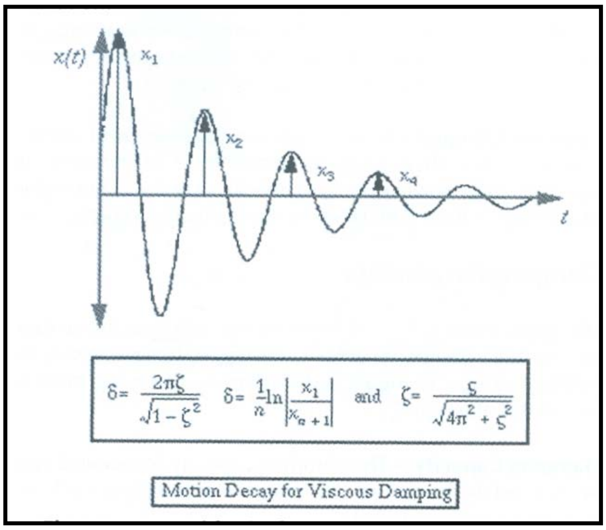

Figure 3: Logarithmic decrement for free vibrations

In this method, the free vibration displacement amplitude history of a system to an impulse is measured and recorded.

A typical free decay curve is shown as here. Logarithmic decrement [Fig.3] is the natural logarithmic value of the ratio of two adjacent peak values of displacement in free decay vibration.

Where, 8 = Logarithmic decrement per unit cycle S = Damping ratio.

2) Bandwidth method

To estimate damping ratio from frequency domain, we may use half-power bandwidth method. In this method, Frequency Response Function amplitude of the system is obtained first. Corresponding to each natural frequency, there is a peak in Frequency Response Function amplitude. (1/√2) times down from the peak there are two point corresponding to half power point, as shown in the figure below. The more the damping, the more the frequency range between this two point. Half-power bandwidth is defined as the ratio of the frequency range between the two half power points to the natural frequency at this mode.

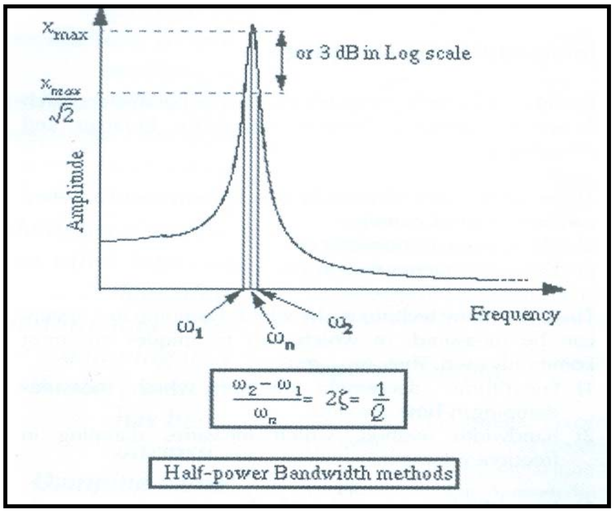

Figure 4: The Bandwidth method

Use of Textile Composites as aid in Damping

Damping materials play an important role in vibration damping and control systems. Vibration can be reduced through damping material by transferring the mechanical energy into heat. Recently researchers started to pay attention to the damping enhancement of the composites. Composite materials can be widely used as vibration damping due to its strength and stiffness. The weight of a composite material is much lower than metal. The durability and low cost of composites add to the attraction of using a structural material to enhance damping. In aero plane graphite, fiber glass composites are used to dampen noise & vibration. In addition to that it also has the advantage of light weight. In automotive engineering textile composites are widely used as floor, door panel coverings etc. In acoustic centre walls are covered with composite materials so as to reduce vibration and noise level. In aero space also composite materials are widely used. By the use of interfaces and visco-elasticity provided by appropriate components in a composite material, the damping capacity can be increased.

It is important to note that Stress, and hence the internal damping force, of a viscoelastic damping material depends on the frequency of variation of the strain (and consequently the frequency of motion). For some materials, it has been observed that the damping force does not significantly depend on the frequency of oscillation of strain (or frequency of harmonic motion). This type of internal damping is known as hysteretic damping.

The development of effective lightweight acoustic structures for the low-frequency range is a special challenge in many technical fields, e. g., the design of vehicles. Use of multilayered components with a high stiffness and a low constructive weight often leads to deterioration of the vibroacoustic property profile. The low frequencies result in a heavy structure-fluid coupling already for the first eigen frequencies of the lightweight components and therefore produce a high modal sound radiation. However, the classical sound reducing methods, such as the use of absorption concept, cannot be used in the low-frequency range in view of the usually limited constructional space. Thus, only secondary measures, e.g., elastic bearings and additional sound insulating foils, are possible for improving the acoustic behavior of structural parts. But these conventional methods inevitably lead to an unwanted increase in weight and costs"'. Textile-reinforced anisotropic composites allow one to synergetically adapt the direction dependent material damping and the modal spectrum to external dynamic loads. The resulting innovative possibilities for designing textile lightweight structures with optimized vibro-acoustic and damping properties are hardly realized technically as yet. Preliminary research by the group has shown that the nature of fibre in reinforced composites and the interface play an important role in influencing damping properties.

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