Vibration Dampers

Damping – is the ability of a vibrating system or structure to dissipate energy. Mostly – mechanical energy is converted to heat energy

When the dissipation is by internal friction or hysterisis characteristics due to its molecular structure – **material damping**

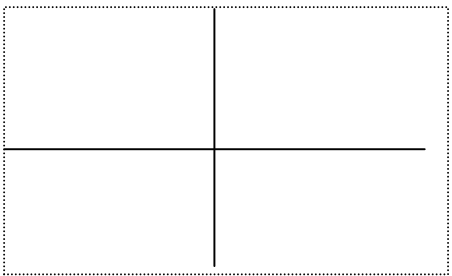
When it is generated by the friction, snapping, rubbing, slapping or impacting at the joints and interfaces of structural assemblies, - it is **structural damping**

Damping reduces dynamic load

Material damping

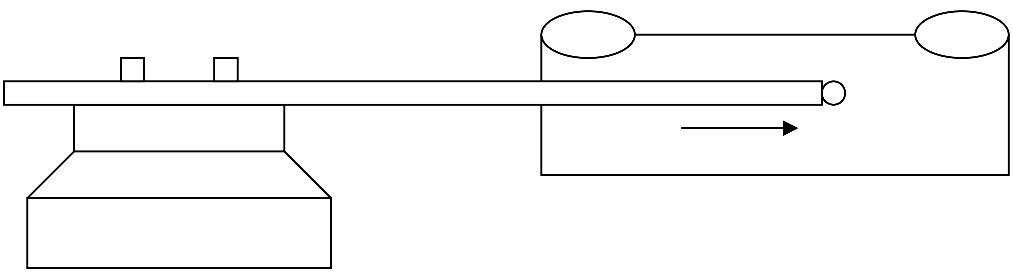
Depends on the internal energy lost as structure is deformed.

A beam stretching and compressing with time plot. The area enclosed by the loop represents the heat dissipated per cycle and is a measure of damping property. Area is higher when stress higher i.e. damping increases with stress level.



Displacement amplitude decreases with cycle.

Determination



More sinusoidal if less energy dissipated per cyle.

Logarithmic decay (rate of decay) .δ = 1/N In (X_0 /Xn). High δ values indicate high damping ie higher loss of energy.

$\tan \delta = [(\delta/\Pi) / (1 + \delta/ 2\Pi)^2] \quad = \delta / \Pi$

Structural damping

Energy lost at the mating interface of built up structures that experience relative motion during vibration

It is difficult to predict the structural damping because it varies widely (inter-batch, intrabatch) because of tolerances in surface finish and flatness, different interface pressures, different interface contamination(eg. Greese, dirt, oil etc)

Tests to be done on real structure than on test specimen

Test results = material damping + structural damping. At low stress, material damping is low

Inserts reduce overall rigidity- natural frequency reduced – dynamic displacement increases

Viscoelastic dampers

VE material capable of dissipating large amounts of energy when deformed substantially improve the damping of beams and panels

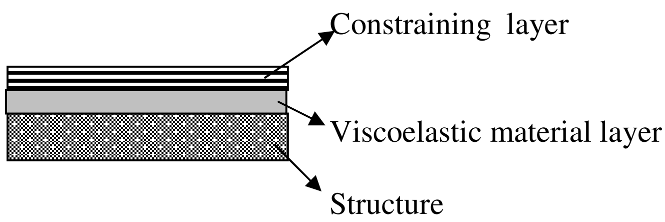
Fillers sometimes improve damping. NR + black has better strength and damping than NR gum

VE material improves damping characteristics of vibrating beams and panels. It can be applied as tape or paint

VEM is subjected to extension or shear. VEM dissipates energy on deformation such that kinetic energy available for vibrating system is low and hence displacement is low

Extensional is not very effective even when added at both the sides of the panel

Shear damping is better. By Adding a relatively rigid constraining layer on the top of the VEM



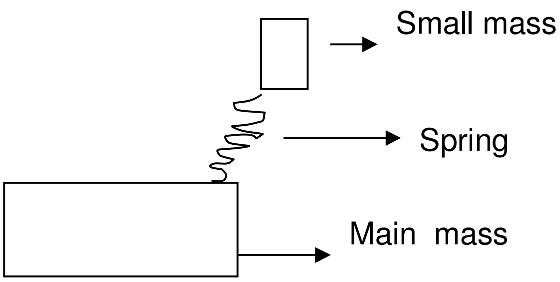
Dynamic dampers

Mechanical energy is converted to heat in a vibrating system

Damping – dynamic load is reduced , displacement is reduced and fatigue life is improved

Dynamic dampers are those which reduce dynamic load, displacement and improve fatigue life without converting mech. Energy to heat. They reduce the amplitude of systems vibrating at constant frequency

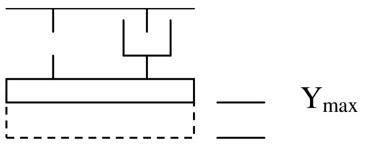
It consists of comparatively small mass with a spring, which would be tuned to have the damper vibrate at the same frequency as the disturbing force. The main mass will stop vibrating because the motion of the dynamic damper will always be equal and opposite to the motion of the disturbing force. The net force acting on the main mass would be in effect be reduced to zero.



Vibration damping relations

Amplitude Y_0 = constant

$Y = Y_0 \sin \omega t$



$$\frac{\text{Output amplitude}}{\text{Input amplitude}} = Y_{max} / Y_0 = Q$$

Q= transmissibility or amplification, magnification or quality of the system.

As f goes up still y_{max} reduces and becomes less than Y_0. (called isolation area or antivibration or antiresonance area)

For lightly damped systems

Natural frequency, fn $(1/2\Pi)(kg/w)^{1/2}$

K = spring constant
.g = gravity and w the weight.

.fn = $15.76\ (K/w)^{1/2}$ [k = dynamic spring rate n/mm, g = 9800 mm /s^2

For lightly damped systems ie Q > 10

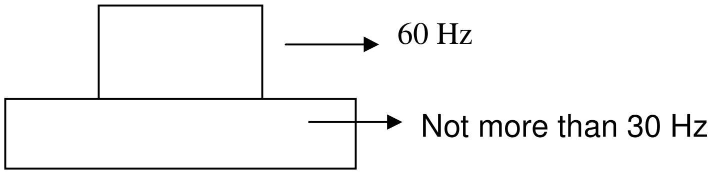
Vibration isolators

Vibration isolators typically have low natural frequency 5 – 30 Hz. Shock isolators will have higher natural frequency. Compromise has to be made to permit the isolators to work in both environment

Octave rule for damped systems

To reduce the coupling effects between resonances in adjacent structural elements natural frequency must be doubled for each additional degree of freedom, to prevent one resonance from magnifying another

Support structure should have a resonant frequency that is at least 2 times the natural frequency of the isolators mounted on the structure



If smaller elements are to be mounted on the main structure smaller elements must have natural frequency that is at least 2 x 60 = 120 Hz to avoid the coupling effects of the adjacent resonances

Controlling resonant peaks with damping

High resonance peak in structure gives rise to high displacement and it leads to fatigue failure.

The structure natural frequency can be low or high

Low fn Y_{max} is more, it is easier to give damping

High fn Y_{max} low, difficult to give damping

Damping for low frequency resonances (Fn < 100 Hz,)

- Viscoelastic strips can be cemented directly to the resonating structure to dissipate energy. Q can be reduced by 50 %
- In enclosed structures, damping can be increased by packing the enclosure with small rubber balls or blocks

- Snubber placed in the middle of PCB. A small clearance is provided between each adjacent snubber so the snubber impact against one another during vibration to dissipate energy.

LDPU foam is good for damping

Damping for high frequency

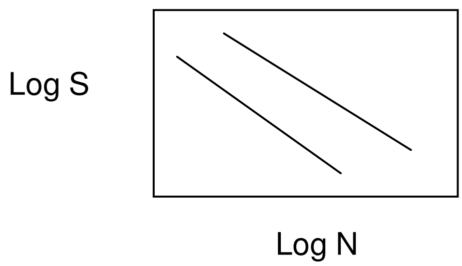
VE strips along do not work well because dynamic displacements are quite small. To amplify strain, the spacers are incorporated between the structure and VE material.

VEM is kept away from the neutral axis. The spacer must be rigid. To give shear strain to VE dampers, a constraining layer is given on the top. Spacer consists of beams, separated by small clearance.

This ensures

The spacer does not deform so that the VE is sheared
It gets clearance for vibration in opposite directions
It gives surface for mounting VEM.

Effect of damping on fatigue life



When damping is reduced, Q is increased, stress level goes up. So number of cycles reduces.

.t = N / fn. When S = 12, 960, N = 6 x 10 ^{3}

.t = 30.6 sec. = 0.51 min to fail. When 2 is doubled fatigue life reduced by a factor 133

It is a log- log plot where S to fail is plotted on the y axis and number of completely reversed stress cycles requied to produece that failure is plotted on x acis.

The approximate fatigue life of a structure in a sinusoidal vibration environment is

Time to fail t (seconds) = N / fn

Eg. for polycarbonate cantilever beam with a stress level of S= 6480 psi will fal at N= 8×10^5 cycles , f_n = 196 Hz.

.t = 8×10^5 / 196 = 4082 sec. = 1.13 hours

when damping is reduced, higher Q produces higher S ie. 12960 , N = 6×10^3 then t is 30.6 second ie. 0.51 min. i.e. doubling stress level reduces fatigue life by a factor of about 133.

Response of damped structures to shock

- Eg. box is dropped
- Hitting somewhere
- Humping of cars

Anytime a rapid transfer of energy occurs, where there is a significant change in the displacements or acceleration the condition is usually defined as shock

Fatigue is usually not an important consideration when the reversal of cycles does not exceed a value of about 1000.

Velocity shock

It is usually associated with a sudden change in velocity, as when a falling object strikes a hard floor. The survival of a structure in such a shock depends on the dynamic deformation that develops.

To reduce the dynamic load, the deformation should be large. It is better to let the deformation develop in a packaging crate or in a cushioning material instead of in a sensitive piece of equipment which may be damaged when it deforms.

Two types of protection

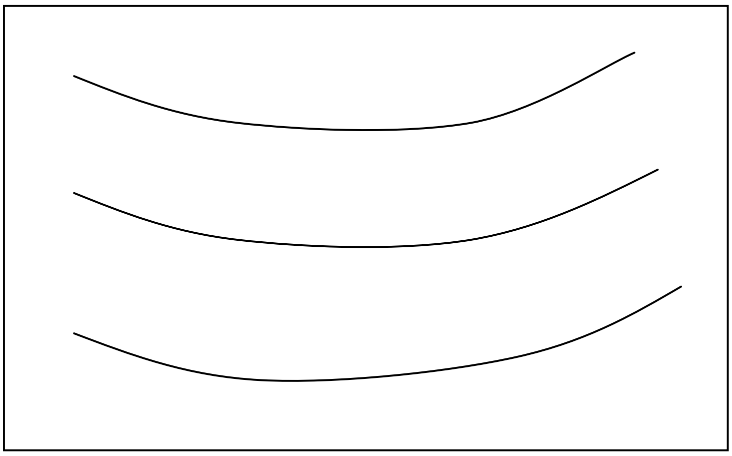
Linear

Consists of real steel springs or rubber springs that deform under load

Non linear

Consists of low density elastic materil packed around the device to isolate from shock. E.g. expanded PS, rubber coir, PUR, foamed PE. NR latex foam etc

For non linear material to be used sufficient test data in the form of peak acceleration G versus static stress at different thickness level are to be known.



Static stress W/A , weight / area

Peak acceleration

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