Design for Vibration Suppression

Chapter 5

Design Requirements

- Depend on design problem
  - Human comfort
  - Human task performance
  - Machine task performance
    - Precision manufacturing processes
    - Scientific measurement applications

TABLE 5.1 RANGES OF FREQUENCY AND DISPLACEMENT OF VIBRATION

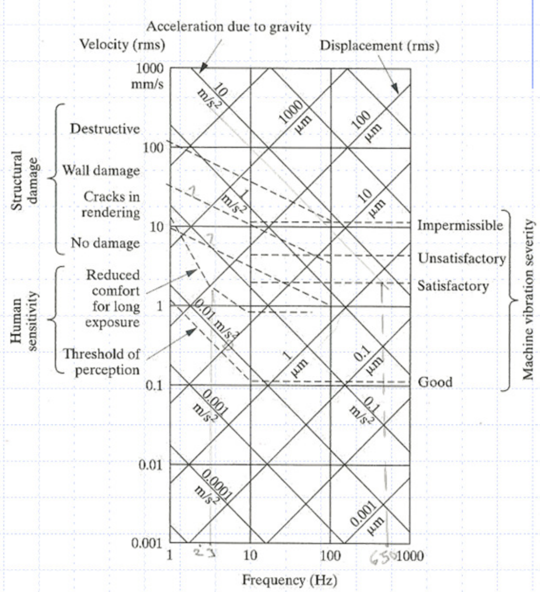
	Frequency (Hz)	Displacement amplitude (mm)
Atomic vibration	10^{12}	10^{-7}
Threshold of human perception	1–8	10^{-2}
Machinery and building vibration	10–100	10^{-2}–1
Swaying of tall buildings	1–5	10–1000

Design Requirements

- Detailed requirements provided in:
  - International Standards (e.g., ISO 2372)
  - Military Specifications
- Requirements usually given in terms of root-mean-square (RMS) not amplitude
  - Works for non-harmonic vibration
  - $$x_{\text{rms}} = \left[\lim_{T \to \infty} \frac{1}{T} \int_0^T x^2(t)\,dt \right]^{1/2}$$

Design Requirements

- To convert harmonic amplitude (A) to RMS use:
  -
  -
  -



Things we can control

- Depends on problem, but may include:
  -
  -
  -

Things we can control

-
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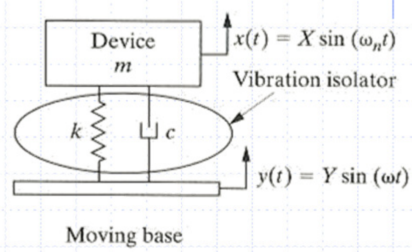
Vibration Isolation

- Case I: Isolate Device from Moving Base
  - Choose values for k & c

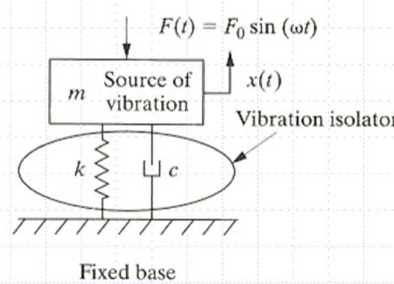


$$\frac{X}{Y} = \left[\frac{1 + (2\zeta r)^2}{(1 - r^2)^2 + (2\zeta r)^2}\right]^{1/2}$$

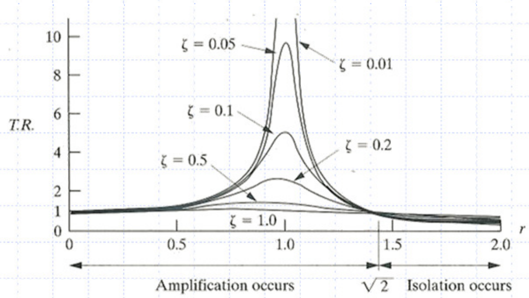
$$\frac{F_T}{kY} = r^2\left[\frac{1 + (2\zeta r)^2}{(1 - r^2)^2 + (2\zeta r)^2}\right]^{1/2}$$

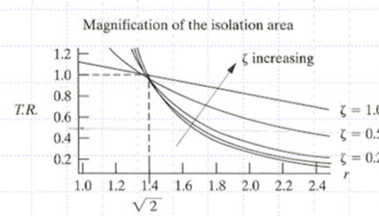
Vibration Isolation

- Case II: Isolate Base from Vibrating Mass
  - Choose values for k & c



$$\frac{F_T}{F_0} = \left[\frac{1 + (2\zeta r)^2}{(1 - r^2)^2 + (2\zeta r)^2}\right]^{1/2}$$





Vibration Isolation

- Commercially available vibration isolators
  - Come in many shapes, sizes, materials
  - Example from text:

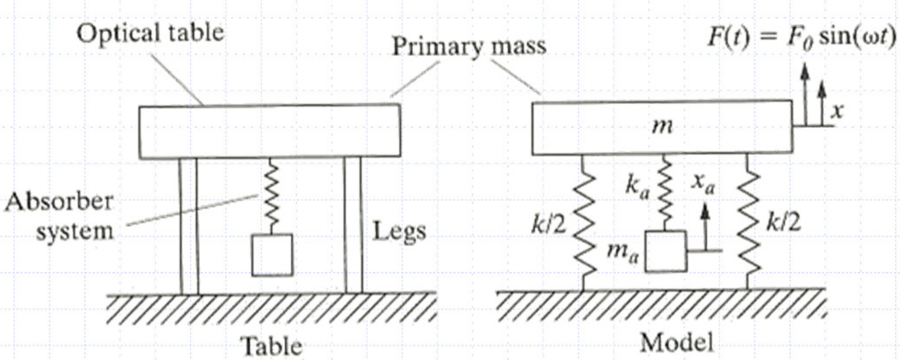
TABLE 5.3 CATALOG VALUES OF STIFFNESS AND DAMPING PROPERTIES OF VARIOUS OFF-THE-SHELF ISOLATORS

Part No.[a]	R-1	R-2	R-3	R-4	R-5	M-1	M-2	M-3	M-4	M-5
$k(10^3\ \mathrm{N/m})$	250	500	1000	1800	2500	75	150	250	500	750
$c(\mathrm{N \cdot s/m})$	2000	1800	1500	1000	500	110	115	140	160	200

[a] The "R" in the part number designates that the isolator is made of rubber, and the "M" designates metal. In general, metal isolators are more expensive than rubber isolators.

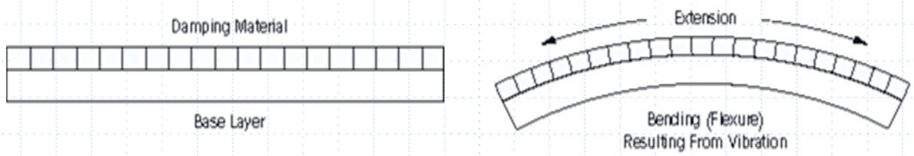
Vibration Absorption

- Attach floating mass to device via stiffness and damping

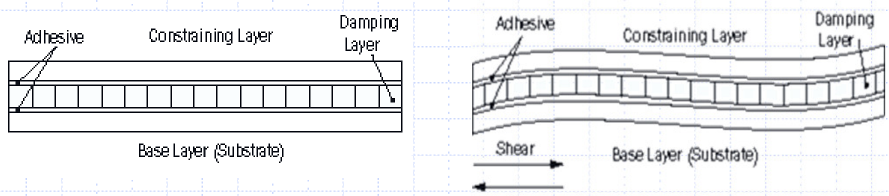


Viscoelastic Damping Treatment

- Applied to flexing structure (e.g., sheet metal)
- Two modes of use:
  - Free-layer damping



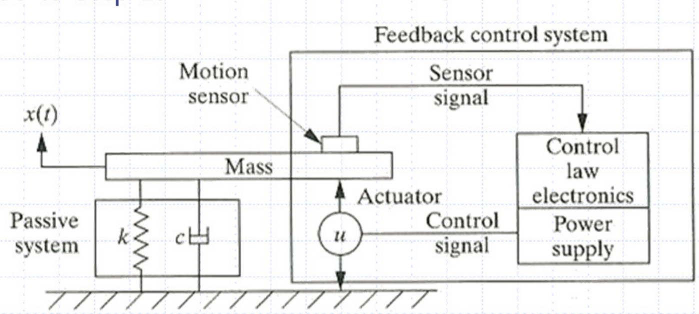
  - Constrained layer damping



Figures from EAR Specialty Composites (www.earsc.com)

Active Vibration Suppression

- Utilizes closed-loop control system:
  1. Sensors measure structure displacement, velocity or acceleration & pass signal to controller
  2. Controller computes what to do (based on a target displacement, velocity or acceleration) and sends signal to actuator
  3. Actuator applies force to structure
  4. Structure responds with new displacement, velocity & acceleration
  5. *Go to Step 1.*



Active Vibration Suppression

- Many commercial uses:
  - Noise canceling headphones
  - Tennis rackets
  - Downhill snow skis
  - Read/write head in optical and magnetic tape and disk drives
  - Digital camera imaging sensor
  - Aircraft wing and engine inlet flow control
  - Automobile floor/ceiling
  - Rotordynamic applications
  - Table for scientific measurement equipment
  - Platform stabilization for at-sea cargo transfer

Active Vibration Suppression

- Utilizes sensors, actuators and control system
- Many types of sensors available
  - Strain gauge
  - Laser
  - Piezoelectric
  - Inductance
- Many types of actuators possible
  - Piezoelectric
  - Electromagnetic
- Many types of control equations possible