ME756A

Principles of Vibration Control

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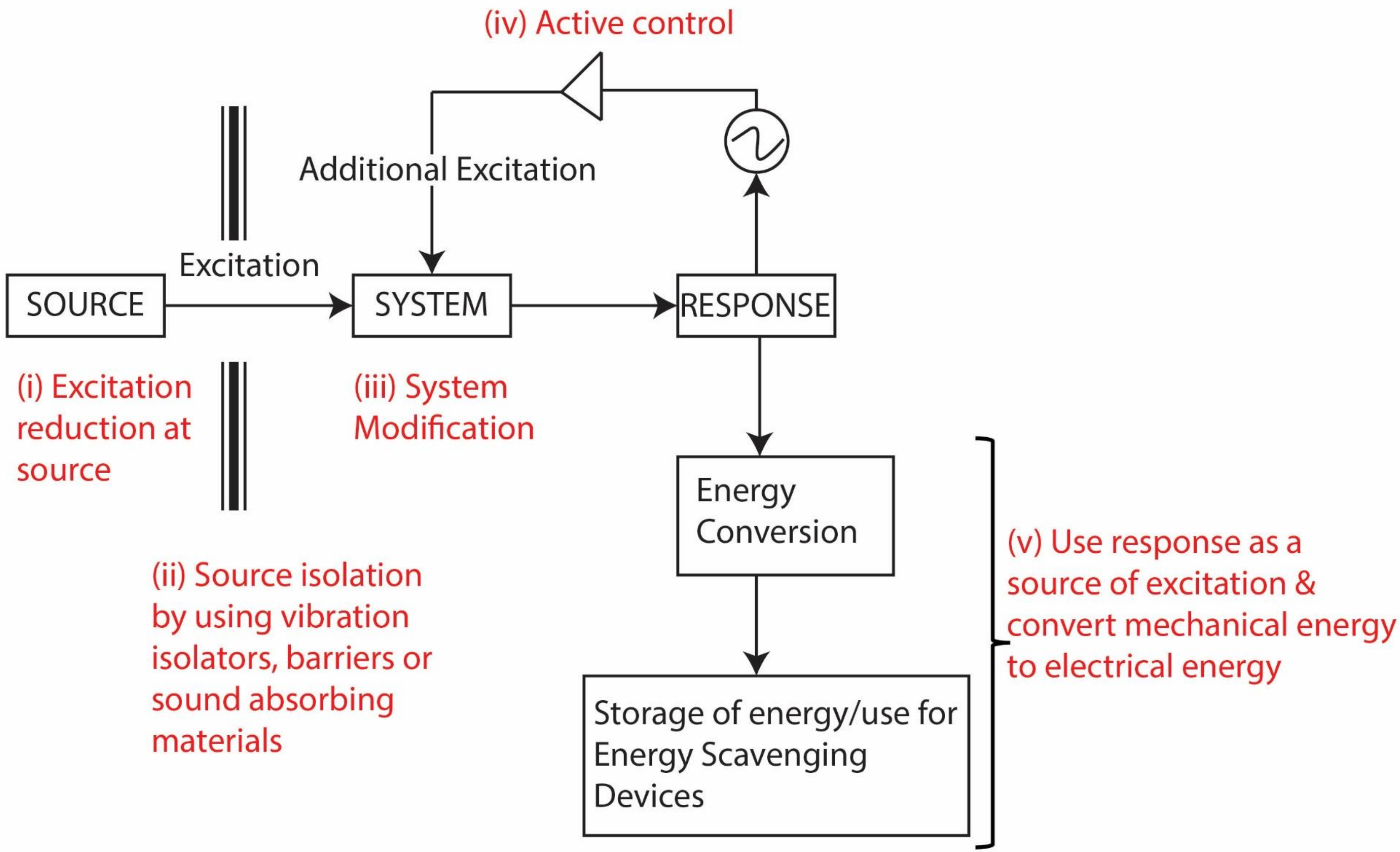
Contents

- ✓ Various Vibration Control Strategies
  - Reduction of excitation at the source
  - Isolation of the Source
  - System Redesign
  - Remedial Measures

Vibration Control Strategies



(i) *Reduction of excitation at the source*

Examples:

- Balancing of unbalanced inertia forces – rotors, engines.
- Changing the flow characteristics for flow induced vibrations.
- Reduce parameter variation for parametric excitation.
- Reducing friction, avoiding vortex shedding to reduce self-excitation.

Vibration reduction at the source – an example

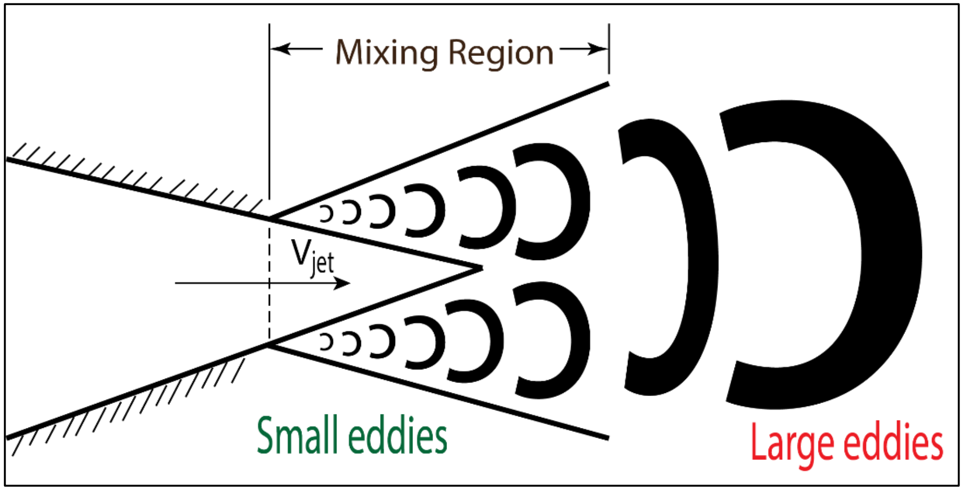
Consider Acoustic fatigue of Aircraft Structures. The fuselage & other structures of the aircraft are subjected to intense pressure fluctuations by the excitation forces generated in the Jet engines.

Due to the broad-band nature of this excitation, it is nearly impossible to avoid acoustic by simply redesigning the aircraft structure.

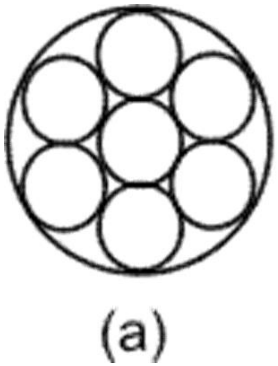
Jet Noise – 1% of Jet Energy

Analysis of Jet Flow

- ✓ High shear rate in the mixing region
- ✓ Large eddies – low frequency, away from jet exit
- ✓ Small eddies – high frequency
- ✓ Atmospheric attenuation of noise – high at higher frequencies
- ✓ Large eddies for larger jet diameter



Analysis of Jet Flow



Multiple jets of smaller diameter

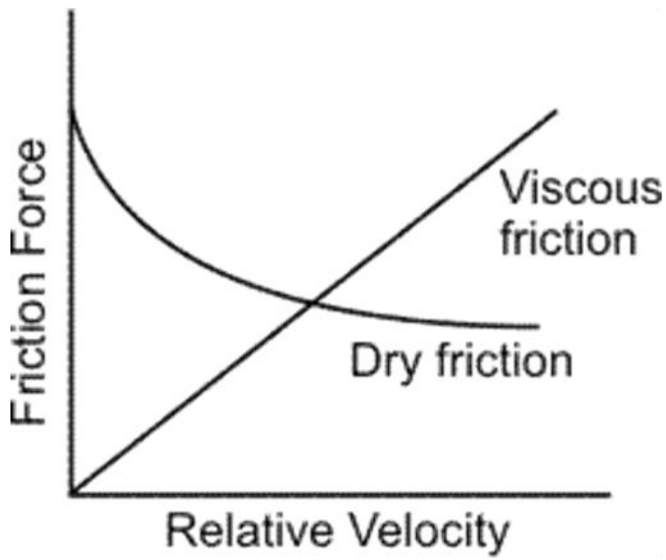
Serrated jet exit – gradual mixing of flow

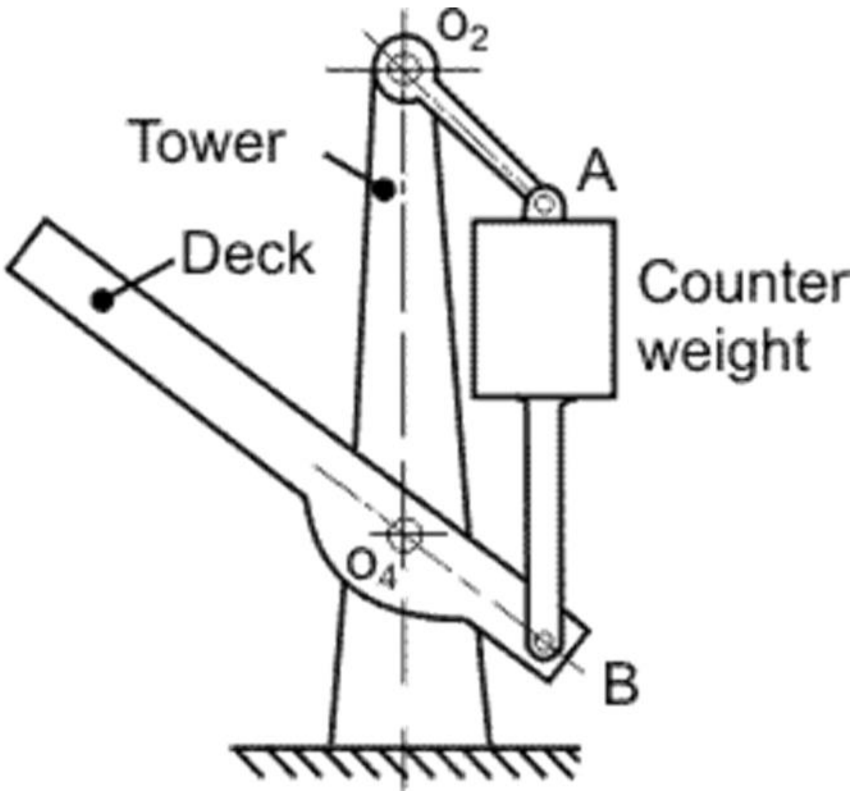
Preventive methodologies

Ref.: Principles of Vibration Control, A. K. Mallik

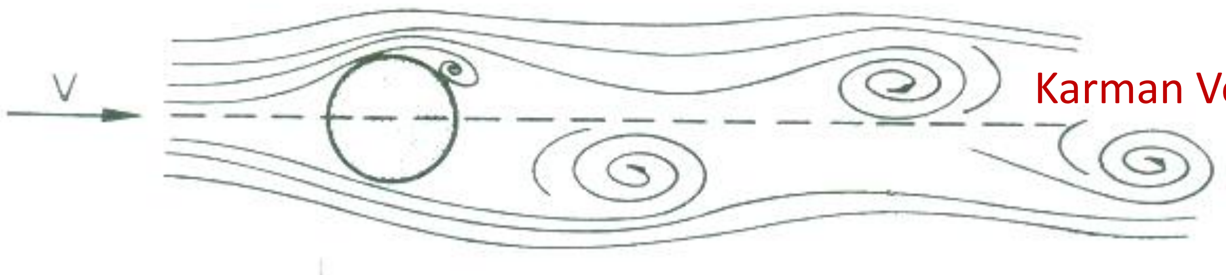
Self-excited vibration – friction driven, e.g., Chatter – due to negative slope of the friction force

Reduce friction





Flow Induced Vibrations



- ✓ **Vortex shedding frequency – f (Hz)**
- ✓ **Cylinder diameter – D (m)**
- ✓ **Free stream velocity of the fluid – V (m/s)**

Strouhal number = (*f D / V*)

Approximately 0.2 for a cylinder

For other bluff bodies 0.12 – 0.17

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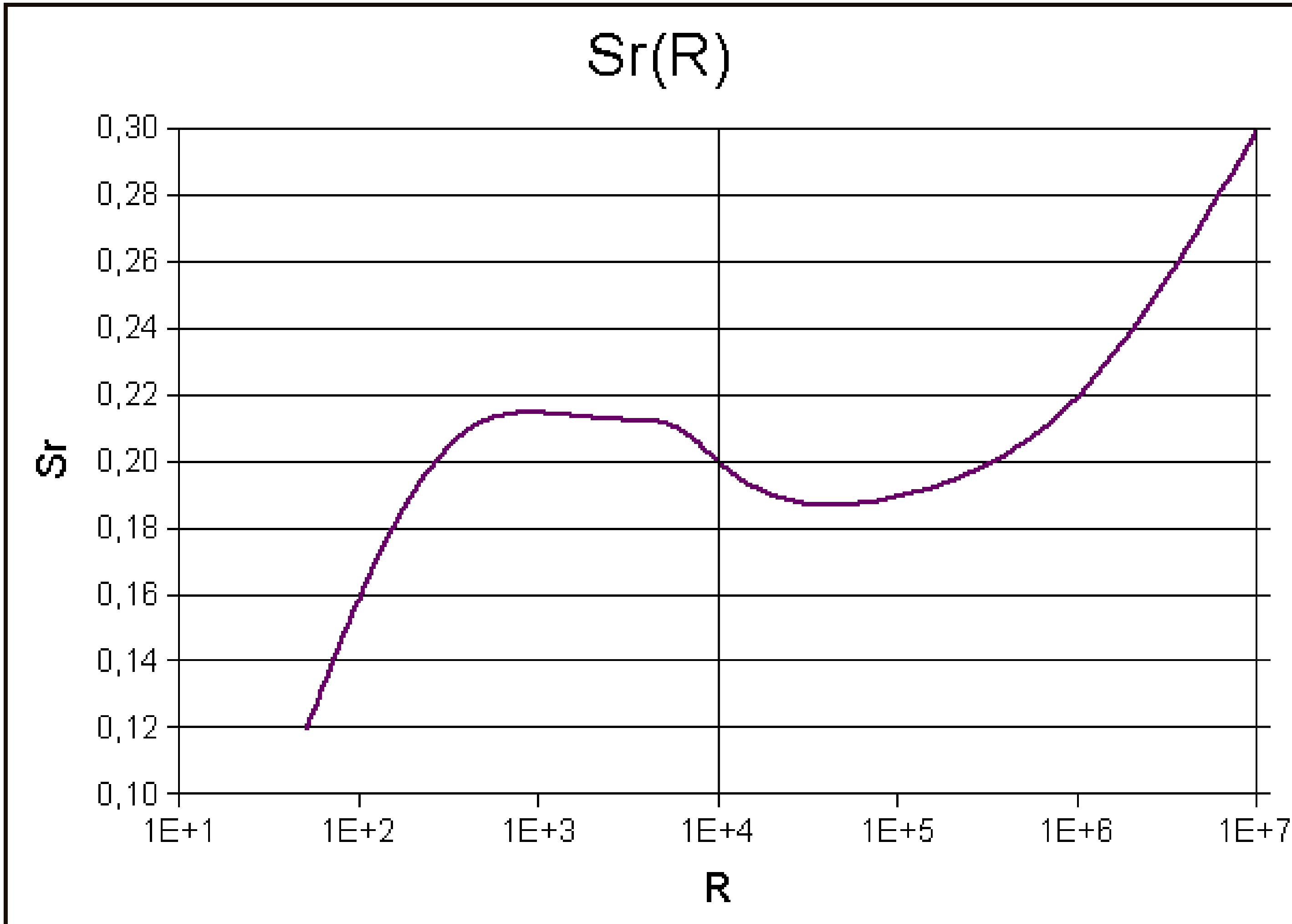
Ref.: Principles of Vibration Control, A. K. Mallik

Strouhal Number Variation with Reynolds Number for a Long Cylinder



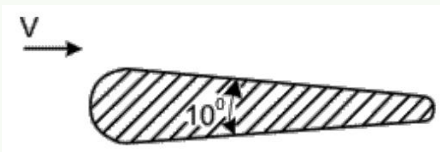
Source provides the energy to maintain Vibration.

Sources of Vibration could be of several types:

- **Transient – for e.g. shock loading.**
- **Forced Excitation – source (continuous) independent of response.**
- **Self-excited – Source generated by the response. Example: Vortex induced vibration.**
- **Parametric Excitation – System parameters (m, c, k) change with respect to time.**

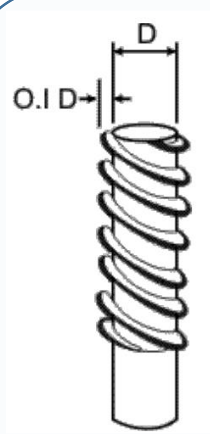
Controlling Vortex Induced Vibrations

To control the vortex-induced vibration, various methods have been suggested -



Streamline marine pier

This method is effective only if the flow angle relative to the structure is essentially constant.

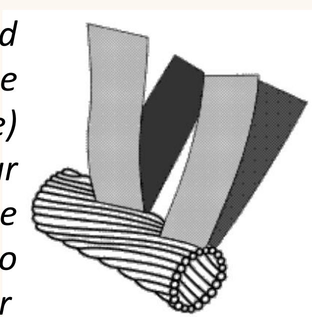


Helical spoiler

The helical spoiler found to be successful in breaking the regular vortex pattern in the wake of a tall cylindrical stack (chimney).

A marine cable requires a larger vortex-interfering device. This is because the density of water is much higher than that of air. If woven into a cable at close intervals, the plastic ribbons effectively prevent the vortex shedding.

It has been suggested that the ribbons be one diameter (of the cable) wide, extending four diameters behind the cable and spaced no more than one diameter apart.



Spoilers in underwater cables

Ref.: Principles of Vibration Control, A. K. Mallik

✓ Vibration Control Strategies

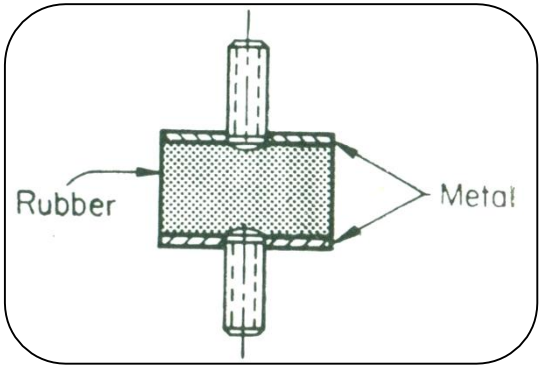
- Reduction of excitation at the source (completed)
- **Isolation of the Source**
- System Redesign
- Remedial Measures

(ii) Isolation of the source

- Modifying the path between source and the system to protect the system providing suspension.

Example - Insertion of resilient elements between source & system:

✓ Springs
✓ Dampers
✓ Viscoelastic materials,
✓ Pneumatic Suspension

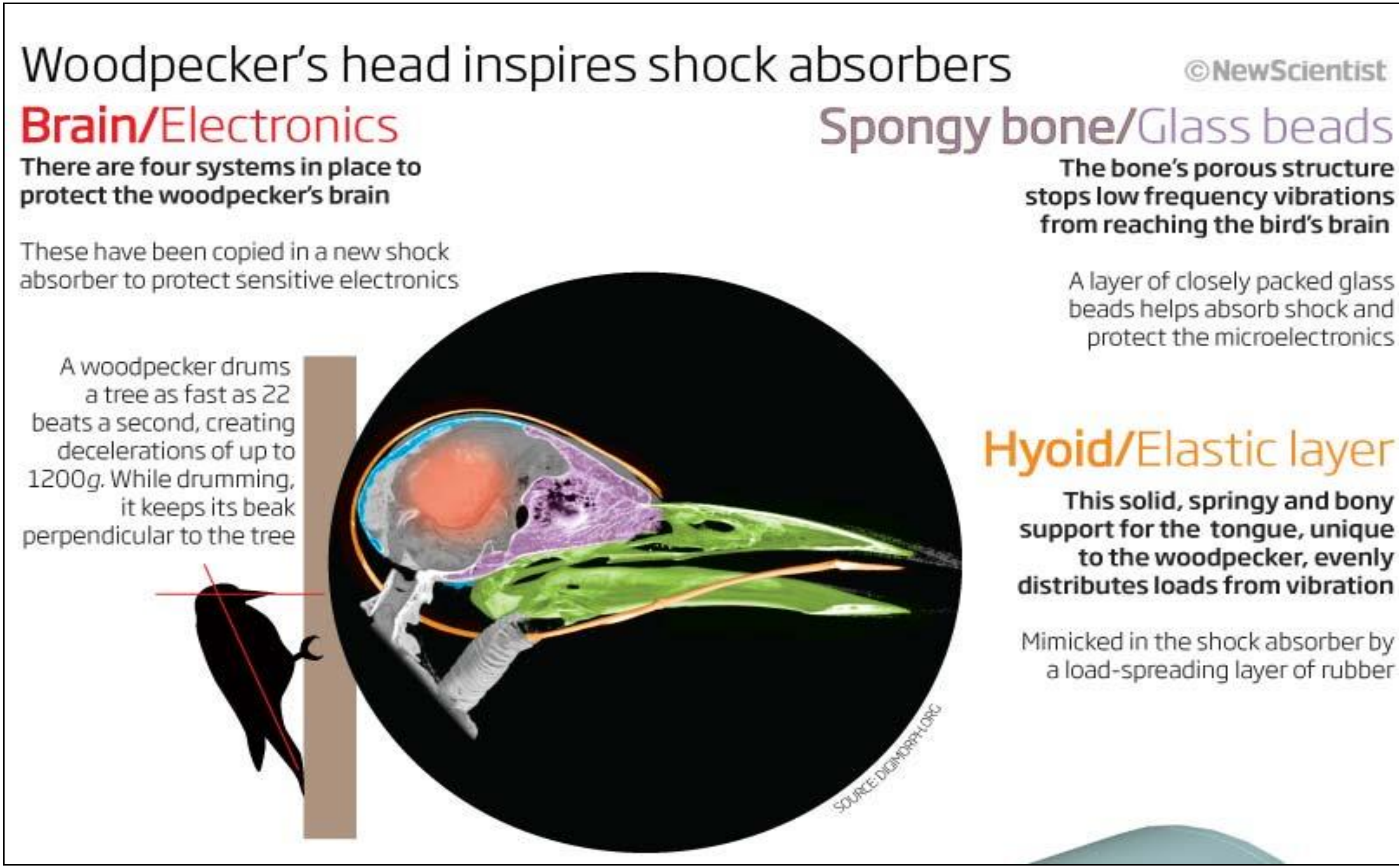


Typical Anti-vibration mount

- Often vibration isolators are developed using a combination of springs and dampers.

For example,
Viscoelastic materials are bonded to metal fasteners and used as anti-vibration mounts or isolators.

Ref.: Principles of Vibration Control, A. K. Mallik



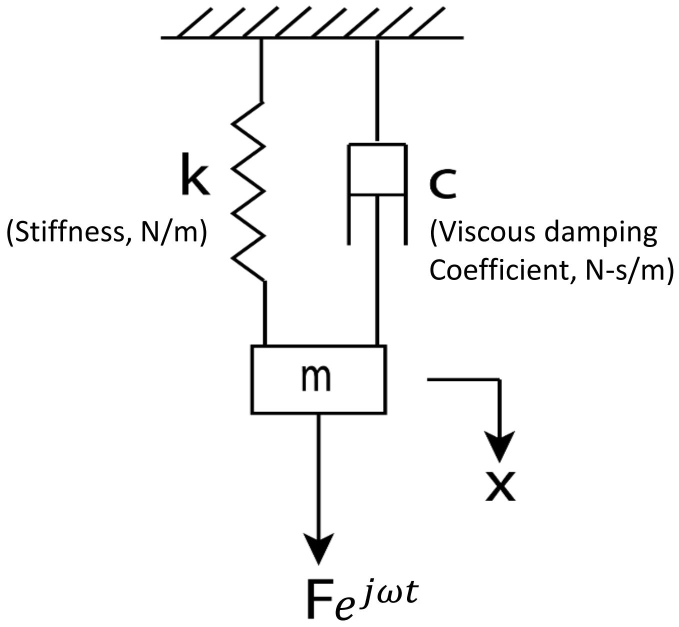
Reference: http://iopscience.iop.org/article/10.1088/1748-3182/6/1/016003

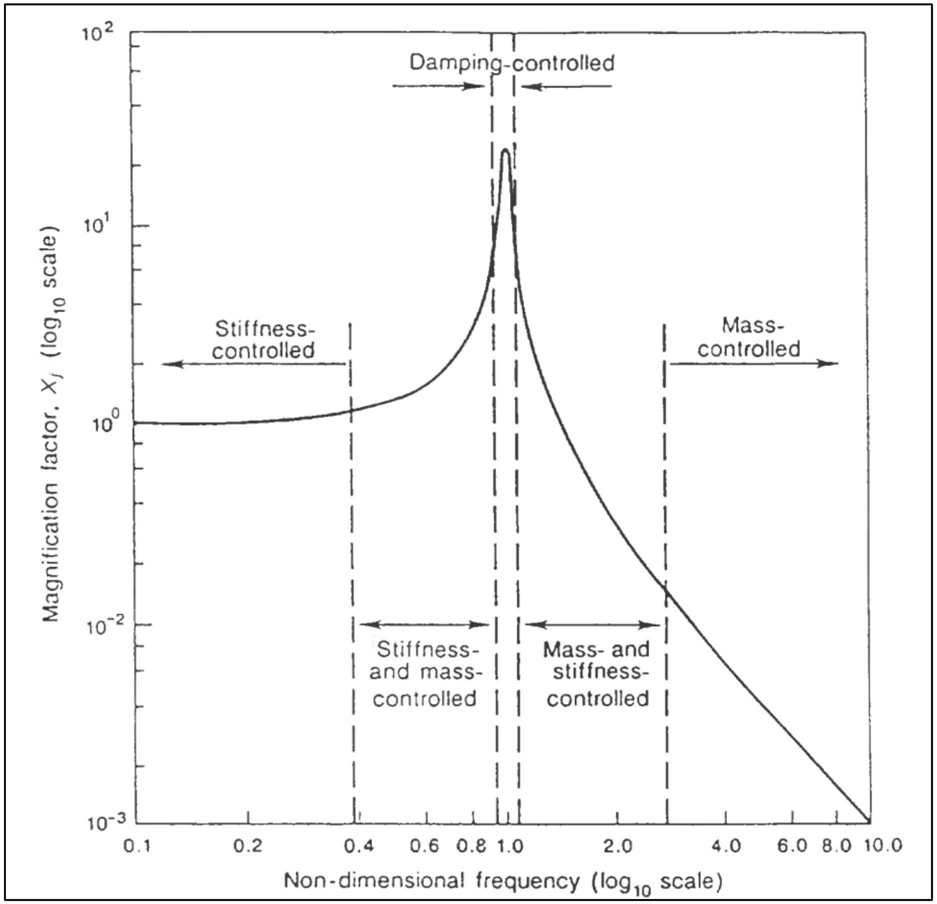
✓ Vibration Control Strategies

- Reduction of excitation at the source
- Isolation of the Source
- **System Redesign**
- Remedial Measures

(iii) System Modification/Re-design

Important methods - Detuning, decoupling, additive damping treatments (constrained and unconstrained), stiffeners & massive blocks (as foundation).





Ref.: Passive Vibration Control, Denys J. Mead

Redesign of a vibrating system involves modelling of materials generally:-

- Structural materials: metals and alloys
- Viscoelastic polymers: natural and synthetic rubbers (with additive)

For metals and alloys

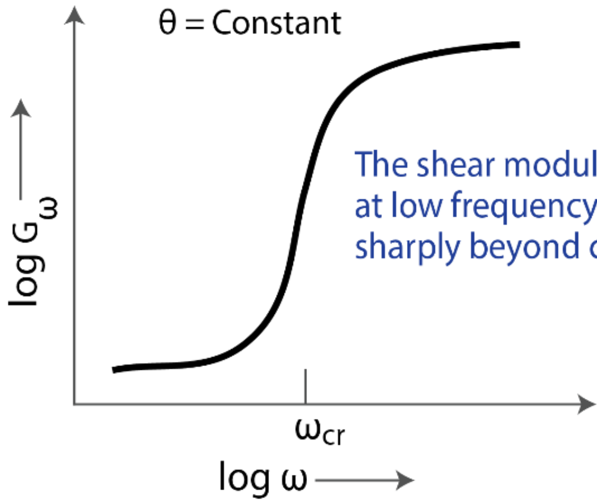
- **Stiffness** is a function of elastic moduli (E, G, K) and the geometric dimensions depending on the type of loading and deformation (bending, twisting etc.).
- **Damping and Loss Factor (fraction of total vibration energy lost in a cycle)** are generally constant.
- Inertia depends on Density and Geometry.

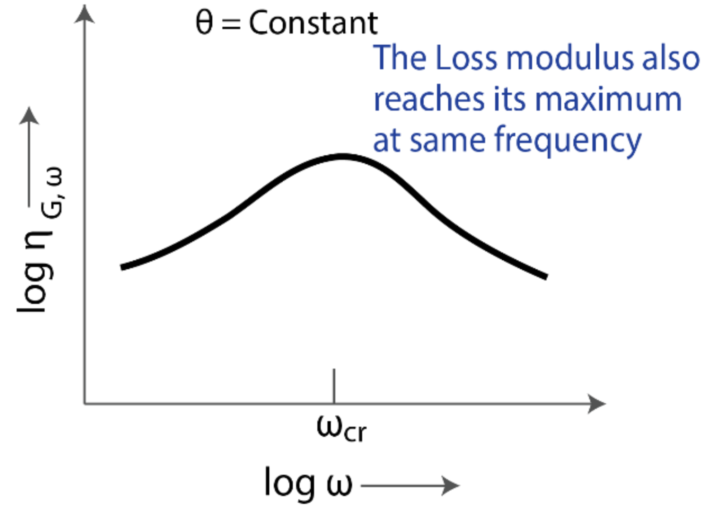
Material	Density (kg/m^3)	E (GPa)	Loss factor
Al	2.8×10^3	72.5	10^{-5}
Brass	8.5×10^3	104	10^{-4}
Steel	7.8×10^3	210	10^{-3}
Cast Iron	7.3×10^3	103	10^{-2}
Cu-Mn (40 - 60)	7.25×10^3	84	10^{-2}
Concrete	2.3×10^3	27	10^{-2}

Viscoelastic materials: Butyl rubber, Plasticized polyvinyl acetate, silicon rubber, polyurethane, Thiokol etc.

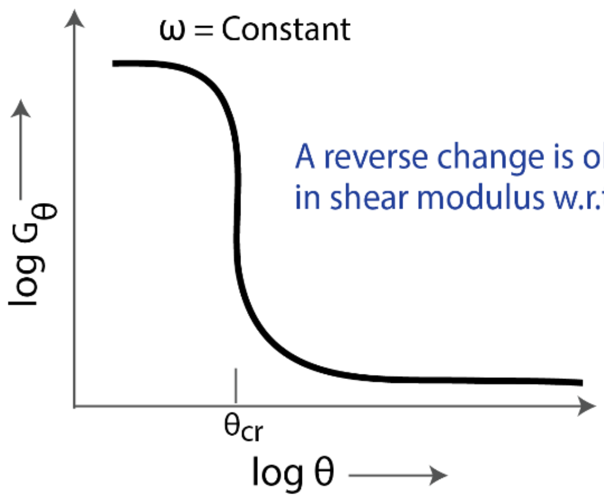
Stiffness and *Damping* properties for viscoelastic materials are frequency and temperature dependent due to transition from Glassy to Rubbery Phase.

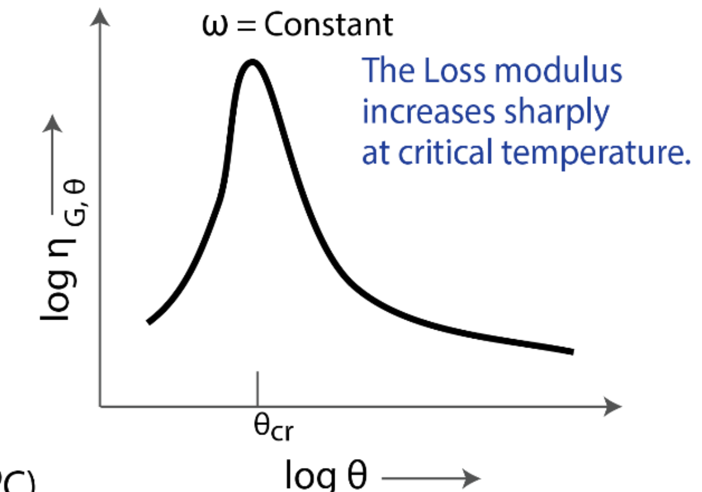
Viscoelastic material: Frequency & temperature dependence of Shear modulus and Loss factor





$$\textit{Loss factor}, \eta = \frac{\textit{Energy dissipated in a cycle}}{\textit{Max. potential energy of the system during that cycle}}$$





θ = Temperature (^{0}C)
ω = Frequency (rad/s)

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