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Technical guide - Anti-Vibration Mounts

What they are:

Purpose:
Anti-vibration mounts (AV mounts) are designed to minimize the transfer of vibrations from machines to their base or structure. This helps protect both the machine and its surroundings by reducing noise, wear, and potential structural damage. The AV mount operates like a spring, storing energy when the machine vibrates and releasing it to counterbalance the vibrations.

How it works:

- The effectiveness of AV mounts depends on its Natural Frequency, which is the frequency at which it vibrates on its own, being different from the Forcing Frequency, this being the frequency of the machine's vibration.

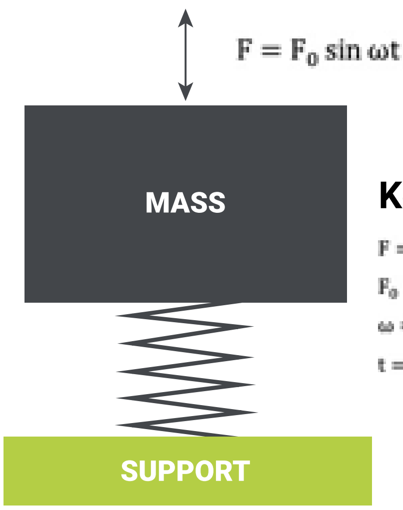
- The further apart these two frequencies are, the better the isolation. Rubber is often used for AV mounts because it's flexible, durable, and capable of returning up to 97% of the energy it absorbs, making it the ideal material for reducing vibrations.

- Spring Action: When a vibrating force (e.g., from an engine) pushes against it, the mount absorbs the force and springs back, releasing the energy slowly, rather than letting the full force pass through to the structure below.

Vibration Engineering:

How it works

- **Natural Frequency (f_n):** Every object has a Natural Frequency, the rate at which it vibrates whenever disturbed. The frequency depends on the object's Mass and Stiffness. The heavier the object and the stiffer the spring (or mount), the slower it will vibrate.



Key

F = Force change over time, N
F_0 = Maximum peak value of the Force, N
ω = Angular Frequency, rad/s
t = Time, s

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- **6 Degrees of Freedom:** An object can vibrate in six different directions:
  - **Translational:** Moving in three straight-line directions—longitudinal (forwards/backwards), lateral (side to side), and vertical (up/down).
  - **Rotational:** Rotating in three directions—roll (tilting sideways), pitch (tilting forwards or backwards), and yaw (rotating left/right).

These six types of motion are known as the Six Degrees of Freedom. By carefully positioning AV mounts, you can reduce or "decouple" these vibrations, keeping the equipment stable.

Coupled Frequencies: Sometimes, a vibration in one direction can cause vibrations in others (e.g., a bump causing both vertical and sideways vibrations). Placing the AV mounts along the main axis or near the centre of gravity helps minimise this "coupling."

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{M}}$$

Key

f_n = Natural Frequency, Hz

k = Stiffness, N/m

M = Mass, kg

Forcing Frequency:

- Definition: The forcing frequency is the frequency at which an external force makes an object oscillate. To isolate vibrations effectively, the AV mount's Natural Frequency must be much lower than the forcing frequency.

- Frequency Ratio: The relationship between the forcing frequency and the natural frequency is called the Frequency Ratio. The higher this ratio, the better the vibration isolation. In practice, the engine's running speed should be at least 2 to 3 times the natural frequency of the AV mount to achieve effective isolation.

- Calculating the Vibration Isolation

1. Natural Frequency

$$f_n(\mathrm{CPM}) = \frac{300}{\sqrt{\frac{MD}{10}}}$$

Key

MD = Mounting Deflection, mm

2. Isolation

$$\%\mathrm{Isolation} = \left[1 - \frac{1}{\left(\frac{RS}{f_n}\right)^2 - 1}\right] \times 100$$

Key

RS = Running Speed, RPM

Resonance:

What it is:

Resonance occurs when the natural frequency and forcing frequency are equal. In this situation, the object's vibrations are amplified, causing larger and more dangerous oscillations. At resonance, vibrations are not absorbed or dampened, leading to potentially catastrophic equipment damage. This is why avoiding resonance is critical in vibration isolation.

Harmonic Orders

- **Fundamental Frequency:** Machines usually have a primary frequency, also called the 1st order frequency, based on their rotational speed. For example, an engine running at 1500 RPM has a 1st order frequency of 1500 RPM or 25 Hz.

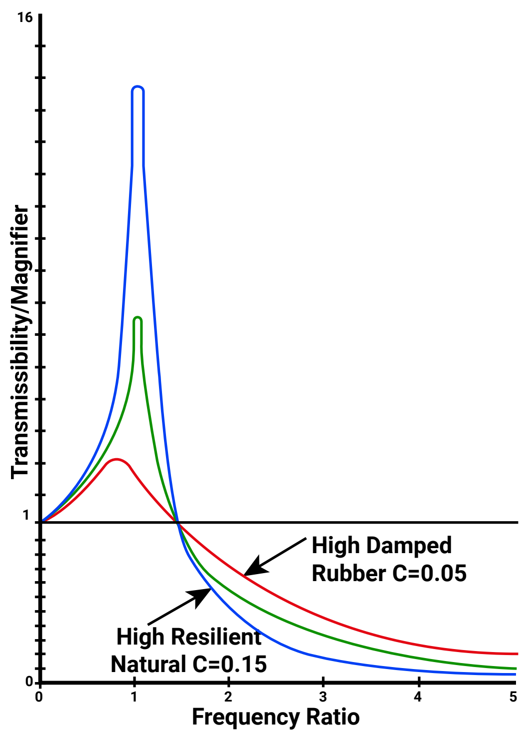
- **Higher-Order Harmonics:** Engines can also produce vibrations at multiples of the fundamental frequency. For example, a 4-stroke engine with four cylinders has a 2nd-order vibration at twice the RPM, so a 1500 RPM engine creates a 3000 RPM (or 50 Hz) second-order vibration. When calculating isolation, these harmonic orders are important because higher-order vibrations can still affect the system.

Isolator & Damper

- **Isolator:** An isolator, such as an AV mount, is designed to reduce the transmission of vibrations and shocks between a machine and its foundation.

- **Damper:** A damper dissipates energy. In rubber AV mounts, internal friction (called hysteresis) converts some of the vibration energy into heat, which helps control excessive movement but reduces isolation efficiency. Natural rubber is favoured for its low hysteresis, offering a good balance between damping and isolation.

- **Damping Use:** Some damping is beneficial, especially during resonance (e.g., during startup or shutdown). Additional external dampers (e.g., viscous dampers) can be used in heavy-duty systems, such as single-cylinder engines, to better control movement.



Rubber

Rubber is versatile and reliable and therefore commonly used in AV mounts due to its flexibility and ability to endure harsh conditions:

- **Vibration & Shock Absorption:** Rubber absorbs both vibrations and sudden shocks, making it ideal for isolators.
- **Temperature Resistance:** Rubber functions across extreme temperatures, from -40°C to 300°C.
- **Chemical Resistance:** Resistant to fuels, oils, acids, and other harmful substances, rubber can withstand harsh environments.
- **Flexibility:** Rubber can stretch up to 400% of its original length and return to its shape, even after repeated deformation.
- **Electrical Insulation:** Rubber is a natural insulator, making it useful for applications where electrical isolation is needed.

Rubber Hardness & Stiffness

- **Hardness:** Rubber's hardness is measured on the Shore A scale. Softer rubber (e.g., 30 Shore) is more flexible and better at absorbing vibrations, while harder rubber (e.g., 75 Shore) is stiffer but less effective at isolation.
- **Stiffness:** Stiffness is the force needed to deform the mount. Rubber is incompressible, so the mount's design (e.g., its shape and hardness) affects how well it isolates vibrations. Stiffer mounts are often used when more load-bearing capacity is needed, but they transmit more vibration.

Creep & Compression Set

- Creep: When rubber is under constant pressure, it deforms slightly over time. Most of this deformation occurs within the first 48 hours of loading. Heat can accelerate creep.
- Compression Set: When rubber is compressed for extended periods, it may not fully return to its original shape when the load is removed. This is called a compression set, and it's important to consider in long-term applications.

Dynamic Properties

Hysteresis: When rubber is repeatedly compressed (e.g., during vibration), it loses some energy as heat. This process is called Hysteresis, and it affects the rubbers dynamic stiffness. Natural rubber has low hysteresis, meaning it provides excellent isolation even under repeated use. The dynamic stiffness of rubber is typically 1.1 to 1.4 times higher than its static stiffness, but for some synthetic rubbers, this ratio can be as high as 8 times.

Rubber Fatigue

What it is:

- Rubber fatigue is the wear and tear of rubber caused by repeated stress, heat buildup, and environmental exposure (e.g., ozone and oxygen). Over time, this can cause cracks to form, especially the at stress points such as sharp corners or bonding areas.

- **Crack Growth:** In natural rubber, tiny crystals form at the crack tips, slowing further crack growth. In synthetic rubbers like SBR or EPDM, cracks grow over time without this self-reinforcing effect. That's why natural rubber is preferred in applications with high stress and repeated load cycling, such as springs and high-durability AV mounts.

Conclusion

Anti-vibration mounts are essential for reducing the transmission of vibrations from equipment to its foundation. Rubber, due to its resilience, flexibility, and resistance to harsh conditions, is ideal for these particular mounts. To achieve perfect isolation, the natural frequency of the mount must be carefully selected relative to the forcing frequency of the machine, taking into account the resonance, harmonic orders, and the specific rubber properties (like hardness and stiffness). Understanding how these factors work together ensures the mount provides long-term vibration isolation and protection for both machinery and structures.