Vibrations and vibration isolation

Introduction

There is an increasing demand to reduce noise emitted by plant and machinery. The use of vibration isolators is an important part of reducing noise and vibration from industrial and marine plant and from mechanical equipment located in offices, residential apartments, studios, theatres, auditoriums, schools and universities, hospitals and research laboratories and other critical low noise spaces.

Machinery vibration from rigidly mounted equipment can be transferred to the supporting structure and travel large distances to be emitted as noise elsewhere in a building or structure.

The aim of vibration isolation is to reduce the transfer of vibration to the supporting structure and a correctly designed vibration isolation system can reduce vibrations by more than 95%.

Equipment which is resiliently mounted will have at least one natural frequency – the frequency or frequencies at which it will naturally oscillate. When the disturbing frequency and the natural frequency coincide, vibrations are amplified. The best vibration isolation, therefore, is achieved when the disturbing frequency is significantly higher than the natural frequency.

Most machinery can be effectively isolated provided the vibration isolation system is selected in accordance with the simple design procedures detailed on pages 3 and 9.

Types of rubber

Rubber is manufactured in a wide range of different types, each with specific properties.

VIKAS’ vibration absorbers are normally manufactured in one of the rubber types listed below. Other types of rubber are available on request:

<table>
<thead>
<tr>
<th>Rubber properties</th>
<th>Natural rubber</th>
<th>Neoprene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal adhesiveness</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Compression</td>
<td>Good</td>
<td>Acceptable</td>
</tr>
<tr>
<td>Internal absorption</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>Max. Operational Temp</td>
<td>70°C</td>
<td>100°C</td>
</tr>
<tr>
<td>Oil Resistance</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Ozone Resistance</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Sunlight Resistance</td>
<td>Poor</td>
<td>Very Good</td>
</tr>
<tr>
<td>Heat Resistance</td>
<td>Acceptable</td>
<td>Good</td>
</tr>
</tbody>
</table>

Material Properties

Resilience

To make the best use of rubber’s properties, VIKAS produce vibration absorbers with different levels of resilience:

<table>
<thead>
<tr>
<th>Type</th>
<th>(White) resilience</th>
<th>I.R.H.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft</td>
<td>45 ± 5</td>
<td>I.R.H.D.</td>
</tr>
<tr>
<td>Medium</td>
<td>55 ± 5</td>
<td>I.R.H.D.</td>
</tr>
<tr>
<td>Hard</td>
<td>65 ± 5</td>
<td>I.R.H.D.</td>
</tr>
</tbody>
</table>

As the rubber cannot be compressed, a spring effect can only be achieved if the rubber under pressure is able to expand.

The rubber’s degree of deflection is determined by its size, shape and resilience. The resilience indicates the rubber’s resistance to changes in its form when under pressure. Rubber can tolerate a great pressure load with a deflection capacity of around 20% of its unloaded height.

Sideways pressure or “shear” can normally take between 10 and 15% of the pressure load. One should ensure, however, that the rubber is not exposed to tensile load as the rubber’s lifetime will then be significantly reduced.
Design procedures

Requirements
The following description of the design procedure is a useful and detailed tool, but should not be viewed as complete. It should, however, be sufficient for the vast majority of design challenges when:

- The vibration mountings are significantly softer than the sub-floor and the machine's feet.
- The force of the vibration goes approximately through the centre of gravity.
- The distance between the vibration mountings is greater than the vertical distance between the level of the vibration mounting and the centre of gravity.
- The design does not directly aim for a degree of isolation that is lower than 70%.

Very low rotating speed requires a very high degree of deflection to achieve a high degree of isolation. However, as a high deflection can lead to positional instability, a common solution is to choose a vibration mounting that is so hard that the resonancy frequency becomes higher than the disturbing frequency.

This gives zero isolation in terms of the fundamental frequency but shock and high frequency vibrations are significantly absorbed – and these are often the most disconcerting.

Supporting medium or base frame
Insofar as the machinery is made up of several units, they should all be mounted on the same supporting medium or base frame. The vibration mountings are then mounted between the frame and the sub-floor. If the various individual units employ different RPM's, the isolation must be selected to correspond to the lowest RPM.

A heavy supporting medium or base, which markedly increases the overall weight of the machine, appears to be stabilising when positioned. If, however, the force of the vibration is great and/or the RPM is low, then it is recommended that an extra mass is added in the following order of size, (where m stands for the machine's mass in kg):

<table>
<thead>
<tr>
<th>RPM</th>
<th>Weight of extra required mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 800</td>
<td>1.5 - 2.0 x m</td>
</tr>
<tr>
<td>800 - 1200</td>
<td>1.0 - 1.5 x m</td>
</tr>
<tr>
<td>&gt; 1200</td>
<td>0.0 - 1.0 x m</td>
</tr>
</tbody>
</table>

Sub-floor
An apparently correct vibration isolation can entirely fail, if the sub-floor lacks sufficient mass or stiffness. The following table indicates the relevant values for how great a machine mass can be placed on a concrete layer of a given thickness. If the layer rests directly on the earth, it is permissible to double the mass.

<table>
<thead>
<tr>
<th>Thickness of concrete layer (mm)</th>
<th>Max. permissible machine mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>1000</td>
</tr>
<tr>
<td>200</td>
<td>2000</td>
</tr>
<tr>
<td>300</td>
<td>5000</td>
</tr>
<tr>
<td>400</td>
<td>8000</td>
</tr>
<tr>
<td>600</td>
<td>10000</td>
</tr>
</tbody>
</table>

Shock disturbances
When selecting vibration isolator for mobile installations, the design also needs to take into account shock disturbances—that is to say, the vibration mountings, in addition to the mass of the machine and the force of the vibrations, need to be able to deal with any shock disturbances. It is recommended to reckon with an additional 50 to 100% to deal with shock. It is further recommended that a vibration mounting with Fail safe design I used, such as BRB, BSB, Marine mounts, MD, SCH and Cones.

Flexible connections
When a machine is mounted on vibration mountings, it has to be ensured that the vibrations are not transferred via stiff, inflexible connections. Pipe joints need to be fitted with flexible connecting links, (such as rubber tubing or compensators). Cables also need to be bendable and axle connectors should be fitted with flexible couplings.

Placing of the vibration mountings
Ideally the vibration mountings should be placed symmetrically around the centre of gravity and following the same layout.

Insofar as the load placed on the vibration mountings is unequal, isolators should be selected so that the deflection remains the same at all points.

In a purely practical sense, it can be difficult to position the vibration mountings on the same horizontal level as the centre of gravity. If that is the case, the distance between the vibration mountings needs to be greater than the horizontal distance between the vibration mountings and the centre of gravity.
Technical and Practical

Calculation of vibration isolation can be very complex and sometime require different advanced tools, which are normally not used during a simple selection of a mount. IAC Nordic has the in-house know how and also use tools and software to find solutions to jobs requiring vibration or shock insulation when a simple selection is not enough. So we have assisted several clients in fine tuning new products by doing what we call “vibration engineering” which covers:

• Development of special mounts
• Advanced calculations in 6 DOF
• Control by means of vibration measurements
• Turn key installation projects where we use our own trained fitters mostly with special focus on attenuation of structure borne noise in buildings.
• Improvement of existing systems

We undertake almost any case where vibration and shock engineering is involved and cooperate with leading partners, acoustical consultants and architects. Typically when a FE analyses is required or large scale measurements are needed, the consultant has a leading role, due to the complexity.

Below are shown some examples of special jobs, IAC are involved in. They involve vibration isolation of foundations from 20 tons to 500 tons and even advanced elements with viscous damping. These typical applications require high quality materials and high level of documentation.

Example 1: Noise attenuation in buildings by means of vibration isolation can be obtained by:
• Providing cast in-situ floating floor
• Passive isolation of building elements
• Mounting machines on inertia bases
• Isolating flight of stairs to dampen step noise.
We calculate all the different systems.

Example 2: A tuned mass damper in steel section of footbridge.
The special made damper combine a spring and viscous damping system.

The 2 pictures above show an AHU before and after the installation of 6 spring dampers the spring dampers are mounted to the outside of the frame and unit, which provide a very low build-in height. Hereby we avoid changing the piping and electrical installations. The project was delivered as a turn key solution, which included a calculation of the noise reduction in the offices below the unit.
Example 3: Model of large concrete foundation with a 2-stroke diesel engine.

The vibration isolation consists of 144 rubber pads type VIKA-FOAM25810 placed under the foundation.

Example 3 continued: The isolation of the concrete foundation was done by placing rubber pads so they cover the entire bottom of the hole in the ground for the foundation. Then the concrete was poured into the hole and the foundation was cast directly on the rubber pads.

Scope of delivery:
• Dynamic analyses
• Calculation of Eigen frequencies and visualization of mode shapes
• Transmissibility curves
• Delivery of rubber pads according to calculations

Examples from installations

During recent years, IAC has expanded the number of jobs in relation to designing anti vibration solutions for foundations and especially for large foundations.

Increased focus on the comfort of sound in buildings that are placed near to transport systems has meant an increasing activity in vibration isolation of buildings against the influences of external and internal noise. For this we often use our PUR products VIKAFOAM that are made in plate sizes of 500 x 2000 mm.