Mountings of transducers and its effects on environmental vibration measurements

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The last few years have seen a sharp increase in vibration measurements and surveys, thanks to the large infrastructure projects such as Crossrail and Thameslink, and increased awareness and concern of vibration effects on both human and non-human receptors. Previous Instrumentation Corner articles have provided insights on how to choose vibration transducers. This short article aims to provide some general knowledge on mounting of transducers and its effects on measurements.

Placement of transducers and how the transducers would be best mounted will be determined by the purpose of the vibration measurements. In general, "Transducers should be mounted so as to reflect faithfully the motion of the object or surface being measured. There should be no loss-of-contact or resonance to affect the measurement over the relevant frequency range." (BS 6472-1: 2008). "The aim should be to reproduce faithfully the motion of the element or substrate without introducing additional response." (BS ISO 4866:2010).

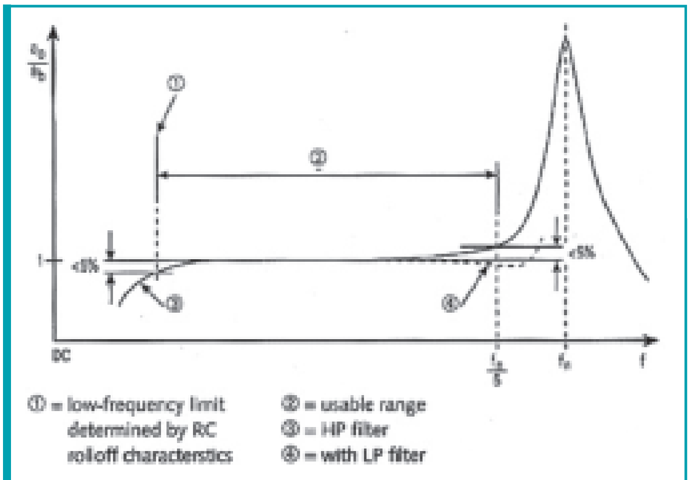


Figure 1 Typical accelerometer frequency response curve (Source: Kistler Instrument)

Accelerometers fundamentals

The majority of the accelerometers can be modelled as a simple mass-spring system. The fundamental frequency of the system is determined by its mass and the stiffness. The frequency response of the system below the fundamental frequency is virtually flat, which defines the usable range of the accelerometer as shown in the Figure 1.

Anything that modifies these characteristics during the mounting of the accelerometer will shift its natural frequency. Unfortunately, this shift in resonance always reduces the usable range of the accelerometer. The accelerometer is not broken, or any less worthy than when it was designed, it is just that the dynamic characteristics were altered during the mounting process. Figure 2 shows typical frequency responses for various mounting options.

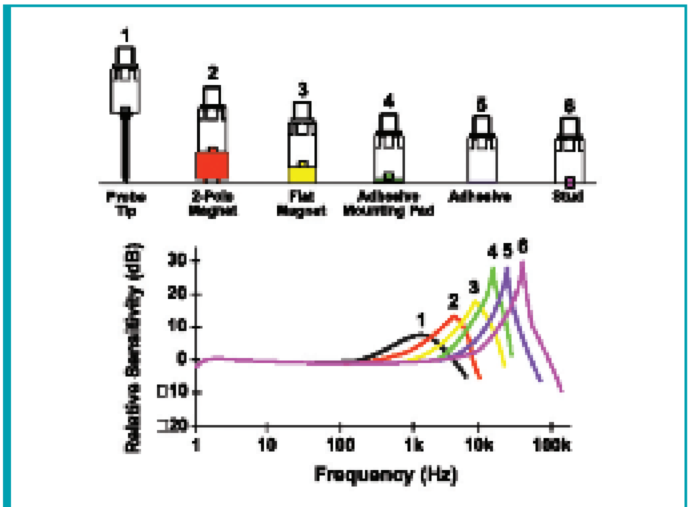


Figure 2 Typical frequency response curves for different mountings (Source SIRF Rt)

Mounting of vibration transducers to structural elements

The mounting of vibration transducers to vibrating elements or substrates should comply with ISO 5348:1998. Care should be taken with triaxial assemblies to avoid rocking or bending. In order to achieve these ideal conditions, it is necessary to ensure that:

- the accelerometer and its mounting are as rigid and firm as possible and the mounting surfaces shall be as clean and flat as possible
- the mounting introduces minimum distorting motions of its own, simple symmetrical mountings are best
- the mass of the accelerometer and mounting are small in comparison with that of the dynamic mass of the structure under test.

Poor coupling can cause friction and slippage of the transducer, resulting in distortion, alteration of the amplitude and phase of the signal, and often yielding higher measured vibration levels. The table on page 26 compares some typical mounting techniques for piezoelectric accelerometers with regard to different criteria as in ISO 5348.

As the mass of the transducer and monitoring unit (if any) compared with that of the structure element on which it is mounted can lead to significant changes in its modal behaviour, the mass of the measuring equipment should not be greater than 1 % of that of the structure. Vibration transducer requirements for human response to vibration are listed in Annex E of BS EN ISO 8041. Of interest for buildings is the recommended distance of less than 25mm, from the measurement surface to the transducer axis.

The transducer mounting can be secured to the frame of the structure by expansion bolts. Gypsum joints are preferred when taking measurements on lightweight concrete elements. When this is not possible, the transducer should be adhesive mounted with rigid glues such as cement glue or epoxy filler. Beeswax is also widely used. It is interesting to note that recent research suggested that "Blu-tack" (kept to a practicable minimum) performs very similarly to beeswax although not referred in standards.

Measurements on floors having compliant coverings tend to give distorted results and should be avoided. Transducers may be mounted using heavy steel plates with support legs that can be pushed through carpets so that they are attached firmly or special adaptors should be used.

Mounting of vibration transducers to the ground

BS ISO 4866:2010 provides some guidance on typical methods of mounting transducers to the ground, which include the P26

◄P25 buried transducer method; rigid plate and spike method.

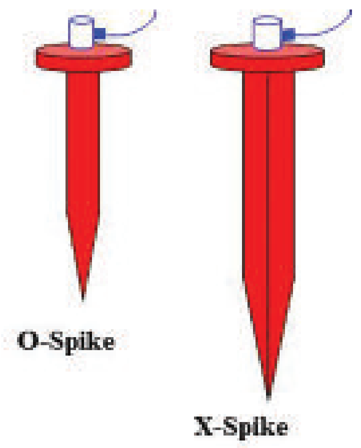
The buried transducer method is considered by a vast number of experts as the method that minimises ground coupling distortion. Where transducers have to be mounted in the ground, in order to minimise coupling distortion, they should be buried to a depth at least three times the main dimension of the transducer/mounting unit. In order to minimise the risk of disturbance and also ensure good coupling with the ground, the pit should be refilled with the excavation soil and then hand-tapped around the sensor. Where the material has large particle size, extreme care is required to avoid poor repeatability.

Alternatively, transducers can be fixed to a rigid surface plate with a mass ratio $(m/\rho r^3)$ not more than 2, where m is the mass of the transducer and rigid plate, ρ is the bulk density, in kilograms per cubic metre, of the soil, and r is the equivalent radius of the plate. The rigid surface plate may, for example, be a well-bedded paving slab.

The spike method consists of a small transducer mounting disc welded to a steel spike. The spike is to be driven fully into the ground vertically through a loose surface layer. There are different recommendations for the shape and size of the spike. BS ISO 4866 recommends a round spike (O-spike) while DIN 45669:2005 recommends a cross spike (X-spike). For good practice the O-spike should be:

- less than 400mm in length to avoid natural frequencies within the frequency range of interest;
- greater than 200mm in length to ensure adequate coupling between transducer and ground;
- greater than 10mm in diameter to ensure good contact and resist rotation; and
- no more than a few millimetres above the ground surface.

The resonant frequency of the spike is directly proportional to the length. This is attributed to an increasing surface area in contact with the ground. For a spike of 250mm in length, the resonant frequency is about 200Hz.



Concluding remarks

Careful planning and professional judgement are required when conducting vibration measurements to obtain reliable vibration levels. The decision on the mounting system alone can influence measurements by as much as 20 dB within a 100 Hz bandwidth. However, most environmental vibration measurements only deal with low frequencies up to 250 Hz where the coupling system performance yields relatively limited impact. For example BS 6472-1:2008 states that "This part of BS 6472 provides guidance on predicting human response to vibration in buildings over the frequency range 0.5 Hz to 80 Hz.", and BS 7385-2:1993 states that "however a more limited range of 4 Hz to 250 Hz is usually encountered in buildings." For further reading, refer to BS ISO 4866:2010, BS ISO 5348, BS EN ISO 8041:2005, DIN 45669 and the 2nd Edition of the ANC Red Book. ◘

	Resonance frequency	Temperature	Mass of transducer and stiffness of mounting	Resonance magnification factor Q	Importance of surface preparation
Stud	●	●	●	●	●
Methylcyano acrylate cement	●	●	●	●	◐
Beeswax	◐	○	◐	●	●
Double-sided tape	○	◐	○	○	●
Quick mount	◐	●	◐	◐	◐
Vacuum mounted	◐	●	●	◐	◐
Magnet	◐	●	○	○	●
Hand held	○	○ *)	○	○	○

*) Depends entirely on distance between hand and measured surface.

Key: ● high ◐ average ○ poor