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Mechanical vibration and shock — Mechanical mounting of accelerometers

Vibrations et chocs mécaniques — Fixation mécanique des accéléromètres

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Foreword

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring.*

This third edition cancels and replaces the second edition (ISO 5348:1998), which has been technically revised.

The main changes compared to the previous edition are as follows:

— the theory of mass and stiffness influence on the frequency response obtained has been expanded;

— the frequency responses have been replaced by actual measurements and have been made more comparable;

— the influence of electrical loops has been added.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The method most commonly used for determining the vibratory motion of a structure or body is the use of an electromechanical vibration transducer, also called a transducer or a vibration sensor. These vibration transducers can be divided into the two broad classes: non-contacting and contacting transducers.

Non-contacting transducers are relative measuring transducers recording a motion in relation to a fixed space coordinate system. Typical examples are eddy-current probes, optical sensors and laser vibrometers. These transducers have no direct mechanical contact with the structure and are therefore not dealt with in this document.

Contacting transducers are mounted onto the structure by mechanical coupling. This includes, for example, piezoelectric, capacitive and piezoresistive accelerometers as well as seismic velocity transducers. These absolute measuring transducers record the motion by seismic forces from the space coordinate system onto which they are mounted. If such a transducer is mounted onto a structure, the properties of the mounting can significantly influence the frequency response of the structure as well as the vibration transducer. Very large measurement deviations can occur in case of lack of care in the mounting property, particularly at high frequencies.

Under certain circumstances the mass, geometry and mounting stiffness of the transducer can directly influence the measured vibration amplitude of the structure. This effect occurs for example if the masses of the transducer and the structure are in the same order of magnitude.

This document is concerned with the contacting type of seismic accelerometers and seismic velocity transducers which are currently in wide use. The concern with using such transducers is that the mechanical coupling between the accelerometer and the test structure can significantly alter the response of the accelerometer, the structure or both. This document attempts to isolate parameters of concern in the selection of a method to mount the accelerometer onto the structure.

In a basic sense, many aspects of velocity transducer mounting are similar to those of accelerometers, but they are not identical. Please refer to 6.2.1.

This document does not cover geophones.

Mechanical vibration and shock — Mechanical mounting of accelerometers

1 Scope

This document specifies the important technical properties of the different methods for mounting vibration transducers and describes recommended practices. It also shows examples of how accelerometer mounting can influence frequency response and gives examples of how other influences can affect the fidelity of the representation of actual motion in the structure being observed.

This document applies to the contacting type of accelerometer which is currently in wide use. It is applicable to both uniaxial and multi-axial transducers. This document also applies to velocity transducers.

This document enables the user to estimate the limitations of a mounting and consequent potential measurement deviations.

NOTE Transducer mounting issues are not the only problem that can affect the validity of acceleration measurement. Other such problems include, amongst others: transverse movements, alignment of the transducer, base bending, cable movement, temperature changes, electric and magnetic fields, cable whip and mounting torque.

Issues other than mounting and their possible effects are outside the scope of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2041, *Mechanical vibration, shock and condition monitoring — Vocabulary*

ISO 8042, *Shock and vibration measurements — Characteristics to be specified for seismic pick-ups*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

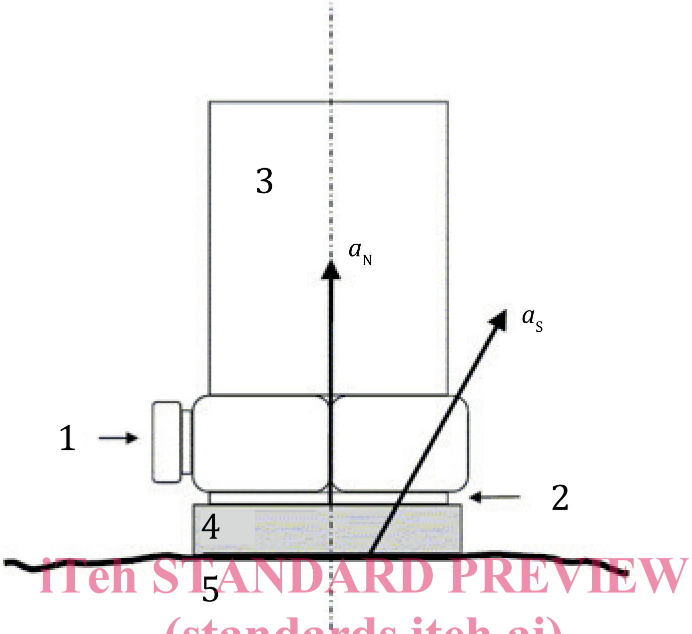
— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Basics

A vibration transducer is mounted on the surface of a structure in motion, as illustrated in the simplified diagram shown in Figure 1. Under ideal conditions, the vibration transducer supplies an electric signal at its output which is proportional to the magnitude of the mechanical acceleration input vector, a_N. The vector a_N is normally directed to the transducer base and measures the projection of the structure vibration acceleration vector, a_S, in the direction of the transducer nominal sensitive vectorial axis, a_N (measurement direction).

The vibration in the direction of the acceleration vector, a_S, on the structure is transferred into the measurement direction of the transducer via the mechanical mounting fixture. Frequency-dependent changes of the nominal vibration amplitude, a_N, of the transducer can occur due to the dynamic properties of the mounting fixture with its mechanical stiffness, damping and the transducer mass. The mechanical mounting therefore changes the usable frequency range of the transducer with regards to amplitude and phase for a given accuracy (see 6.2.1). This document is only applicable to the mounting of accelerometers which are mounted on the surface of the structure in motion, as shown in the simplified diagram in Figure 1.



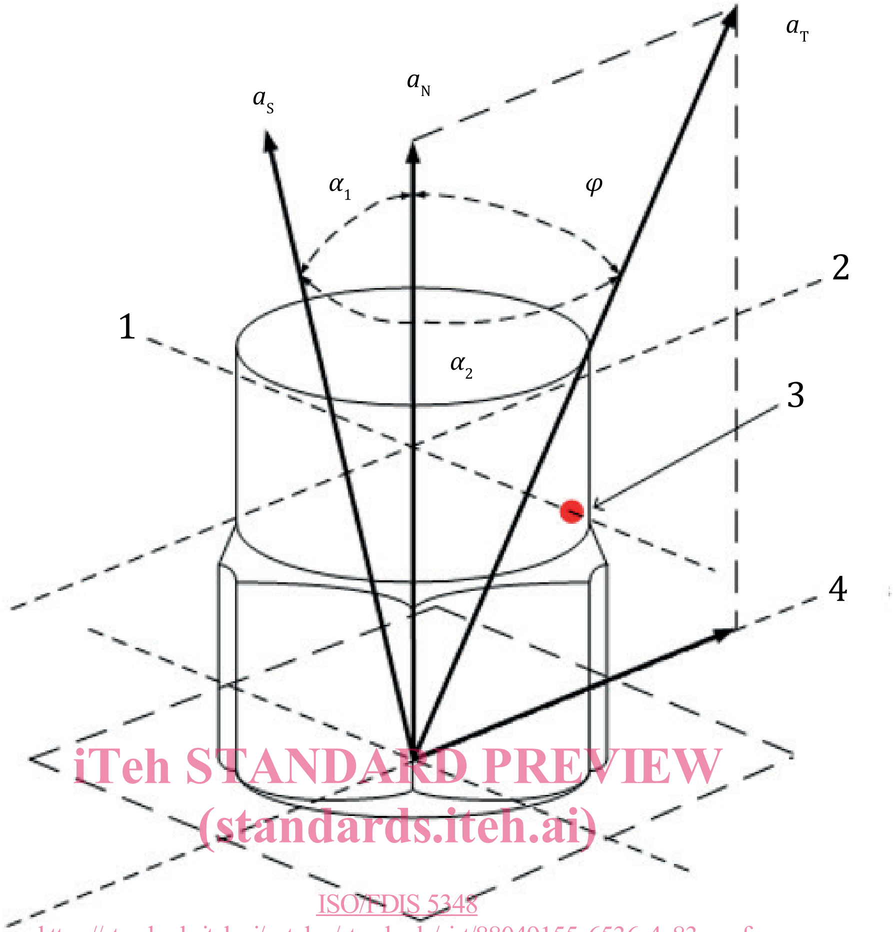
Key

$\boldsymbol{a}_N$ nominal vibration acceleration vector
$\boldsymbol{a}_S$ structure vibration acceleration vector
1 electrical connector
2 transducer base
3 transducer
4 mounting fixture
5 structure

Figure 1 — Mounting of an accelerometer

Often, the transducer vibration acceleration vector with the largest sensitivity is not parallel to the accelerometer nominal axis, as a_N is perpendicular to its coupling mounting area, as shown in Figure 1. This forms a cross axis sensitivity of the transducer; see ISO 16063-31. Cross axis sensitivity is maximal in one direction and ideally zero in a direction perpendicular to this in the mounting area. In some transducers on the market, a red dot marks the minimal cross axis sensitive direction. Mounting the transducer in this direction minimizes the cross axis sensitive effects of the transducer during a measurement, if large lateral acceleration magnitudes occur by proper alignment of the transducer.

Figure 2 illustrates the complex vectorial relationship between the structure vibration vector, a_S, the accelerometer nominal axis vector, a_N, the transducer vibration acceleration vector with largest sensitivity, a_T, and the angles φ, α_1 and α_2 in between them. The elimination of these alignment deviations usually requires a coordinate transformation. In this consideration, the projection of the structure vibration acceleration vector, $a_S = (a^S{}_X, a^S{}_Y, a^S{}_Z)$, to the transducer vibration acceleration vector with largest sensitivity, $a_T = (a^T{}_X, a^T{}_Y, a^T{}_Z)$, forms the output signal, u, of the transducer. But it is the magnitude in the direction of the accelerometer nominal axis vector, $a_N = (a^N{}_X, a^N{}_Y, a^N{}_Z)$, which is of interest.



Key

a_N	accelerometer nominal axis perpendicular to its coupling mounting area ($a^N{}_X$, $a^N{}_Y$, $a^N{}_Z$)
a_S	structure vibration acceleration vector ($a^S{}_X$, $a^S{}_Y$, $a^S{}_Z$)
a_T	transducer vibration acceleration vector with largest sensitivity ($a^T{}_X$, $a^T{}_Y$, $a^T{}_Z$)
φ	angle between a_N and a_T
α_1	angle between a_N and a_S
α_2	angle between a_S and a_T
1	axis of minimum cross sensitivity
2	axis of maximum cross sensitivity
3	red dot, assigning minimal cross axis sensitivity axis
4	cross sensitivity vector

NOTE For exact measurement of the structure vibration, the vectors a_S and a_N are ideally identical in amount and direction; see 6.1.1.

Figure 2 — Acceleration vector considerations for mounting the accelerometer

5 Characteristics to be specified by manufacturers of accelerometers

The technical characteristics of vibration transducers shall be specified in accordance with ISO 8042 in the data sheet or manual. From a multitude of information items, only a few are relevant for the mounting of transducers:

a) frequency response under well-defined mounting conditions, range of operation and best possible mounting;

b) mounting surface of the transducer: dimensions of the mounting surface, mounting options, thread dimensions, thread depths, sectional view of the mounting surface, material of the mounting surface, surface finish roughness, surface flatness, hole perpendicularity and tap class;

c) applicable recommended mounting torque and, as an option, the maximum permitted mounting torque;

d) geometric dimensions of the vibration transducer, including:

— position of the centre of gravity of the vibration transducer as a whole,

— position of the centre of gravity of the seismic mass of the vibration transducer;

e) pertinent mechanical characterisitics of the accelerometer, i.e.:

— total mass of the vibration transducer,

— material of the base,

— maximal transverse sensitivity and frequency at which it was determined;

f) first resonance frequency of the vibration transducer under mounting conditions;

g) temperature limitations of the transducer and the fastening device.

6 Considerations for selecting a mounting method

6.1 General considerations

6.1.1 Procedures

An accelerometer achieves optimal performance only if the following general procedures are followed:

a) The accelerometer shall perform as closely as possible the same motion as the structure at the accelerometer attachment.

b) The motion of the structure is changed as little as possible by the addition of the accelerometer, for example, by mass loading and reinforcement in the mounting surface area.

6.1.2 Conditions

In order to achieve the aforementioned ideal conditions, it shall be ensured that:

a) the accelerometer and its mounting are as rigid and firm as possible and the mounting surfaces are as clean and flat as possible;

b) distortions due to natural vibrations of the mounting are only very small (e.g. symmetrical mountings shall be aimed at);

c) the mass of the accelerometer and mounting are small in comparison with that of the dynamic mass of the structure (see ISO 2954).

6.2 Specific considerations

6.2.1 Frequency range of operation

The accelerometer shall be used well below its mounted fundamental resonance frequency to prevent amplitude distortions. In the case of undamped accelerometers (resonance magnification factor, *Q*, greater 30 dB) and mounting in accordance with manufacturer's recommendations, the following limit frequencies can be used for estimation of the amplitude deviations:

— the amplitude deviations of the transducer are mostly lower than 5 % for up to approximately 20 % of the resonance frequency of the transducer;

— the amplitude deviations are mostly lower than 10 % for up to approximately 30 % of the resonance frequency;

— the amplitude deviations are mostly lower than 3 dB for up to approximately 50 % of the resonance frequency.

NOTE 1 Special measurement methods exist, for example, in the rolling bearing condition monitoring that operates in the resonance range of the accelerometer.

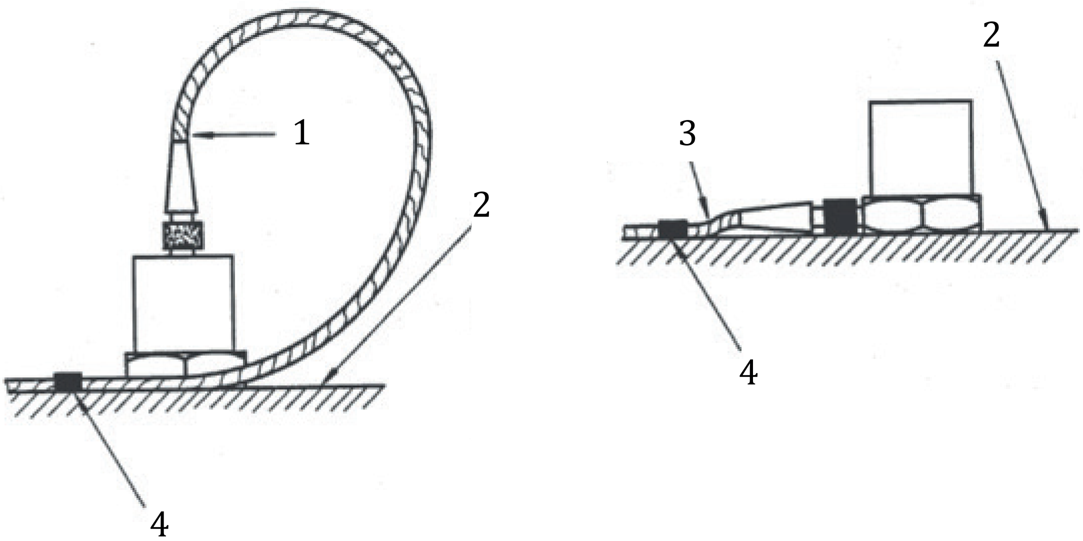
NOTE 2 For single-shock measurements, deviations of a few percent can be expected if the mounted fundamental resonance frequency is ten times greater than the inverse of the pulse duration.

NOTE 3 Electrodynamic vibration velocity transducers are mostly used above their resonance frequency.

6.2.2 Transducer cable

Relative movement of the cable to the transducer can lead to incorrect measurement signals, in particular in the case of stiff cables. Careful clamping and laying of the cables is required to avoid this problem (see Figure 3).

Loose, moving cables can introduce triboelectric effects for piezoelectric type transducers with charge output or impose dynamic response on the transducer not consistent with the motion of the tested surface.



a) Accelerometer with axial connector **b) Accelerometer with radial connector**