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Acoustics and vibration — Laboratory measurement of vibro-acoustic transfer properties of resilient elements —

Part 3:
Indirect method for determination of the dynamic stiffness of resilient supports for translatory motion

Acoustique et vibrations — Mesurage en laboratoire des propriétés de transfert vibro-acoustique des éléments élastiques —

Partie 3: Méthode indirecte pour la détermination de la raideur dynamique en translation des supports élastiques

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 10846 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 10846-3 was prepared jointly by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*, and ISO/TC 108, *Mechanical vibration and shock*.

ISO 10846 consists of the following parts, under the general title *Acoustics and vibration — Laboratory measurement of vibro-acoustic transfer properties of resilient elements*:

— *Part 1: Principles and guidelines*

— *Part 2: Dynamic stiffness of elastic supports for translatory motion — Direct method*

— *Part 3: Indirect method for determination of the dynamic stiffness of resilient supports for translatory motion*

— *Part 4: Dynamic stiffness of elements other than resilient supports for translatory motion*

— *Part 5: Driving point method for determination of the low frequency dynamic stiffness of elastic supports for translatory motion*

Annexes A, B and C of this part of ISO 10846 are for information only.

Introduction

Passive vibration isolators of various kinds are used to reduce the transmission of vibrations. Examples are automobile engine mounts, resilient supports for buildings, resilient mounts and flexible shaft couplings for shipboard machinery and small isolators in household appliances.

This part of ISO 10846 specifies an indirect method for measuring the dynamic transfer stiffness function of linear resilient supports. This includes resilient supports with non-linear static load-deflection characteristics provided that the elements show an approximate linearity for vibrational behaviour for a given static preload. This part of ISO 10846 belongs to a series of International Standards on methods for the laboratory measurement of vibro-acoustic properties of resilient elements, which also includes parts on measurement principles and on a direct and a driving point method. ISO 10846-1 provides global guidance for the selection of the appropriate International Standard.

The laboratory conditions described in this part of ISO 10846 include the application of static preload, where appropriate.

The results of the indirect method are useful for isolators, which are used to reduce the transmission of structureborne sound (primarily frequencies above 20 Hz). The method does not characterize isolators completely, which are used to attenuate low frequency vibration or shock excursions.

Acoustics and vibration — Laboratory measurement of vibro-acoustic transfer properties of resilient elements —

Part 3:
Indirect method for determination of the dynamic stiffness of resilient supports for translatory motion

1 Scope

This part of ISO 10846 specifies a method for determining the dynamic transfer stiffness for translations of resilient supports, under specific preload. The method concerns the laboratory measurements of vibration transmissibility and is called the indirect method. This method is applicable to test elements with parallel flanges (see Figure 1).

NOTE 1 Vibration isolators which are the subject of this part of ISO 10846 are those which are used to reduce the transmission of audiofrequency vibrations (structureborne sound, 20 Hz to 20 kHz) to a structure which may, for example, radiate unwanted fluidborne sound (airborne, waterborne or other).

NOTE 2 In practice the size of the available test rig(s) can give restrictions for very small and for very large resilient supports.

NOTE 3 Samples of continuous supports of strips and mats are included in the method. Whether or not the sample describes the behaviour of the complex system sufficiently, is the responsibility of the user of this part of ISO 10846.

Measurements for translations normal and transverse to the flanges are covered in this part of ISO 10846. Annex A provides guidance for the measurement of transfer stiffnesses which include rotatory components.

The method covers the frequency range from f_2 up to f_3. The values of f_2 and f_3 are determined by the test set-up and the isolator under test. Typically 20 Hz $\leqslant f_2 \leqslant$ 50 Hz and 2 kHz $\leqslant f_3 \leqslant$ 5 kHz.

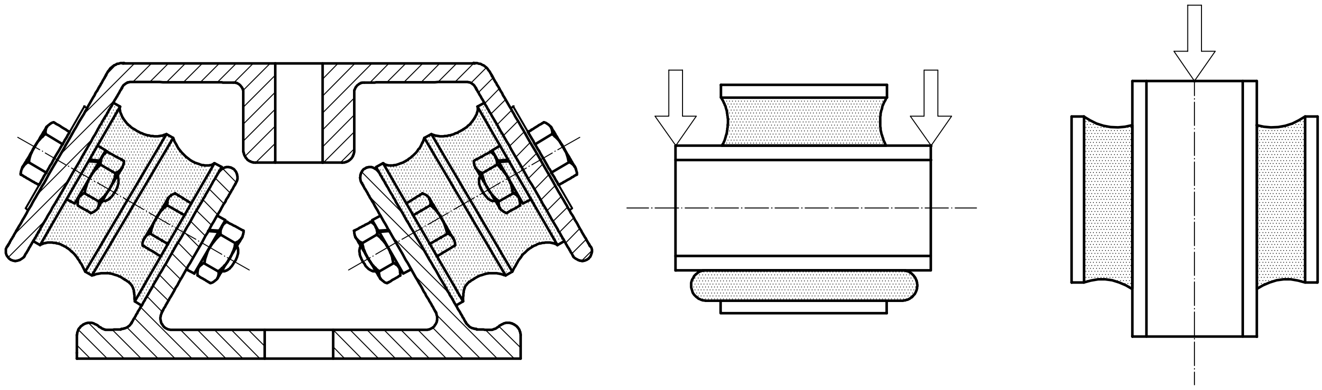
The data obtained according to the method specified in this part of ISO 10846 can be used for

— product information provided by manufacturers and suppliers,

— information during product development,

— quality control, and

— calculation of the transfer of vibration through isolators.



NOTE 1 When a resilient support has no parallel flanges, an auxiliary fixture should be included as part of the test element to arrange for parallel flanges.

NOTE 2 Arrows indicate load direction.

Figure 1 — Examples of resilient supports with parallel flanges

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 10846. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 10846 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 266, *Acoustics — Preferred frequencies*

ISO 2041:1990, *Vibration and shock — Vocabulary*

ISO 5347-3[1)], *Methods for the calibration of vibration and shock pick-ups — Part 3: Secondary vibration calibration*

ISO 5348, *Mechanical vibration and shock — Mechanical mounting of accelerometers*

ISO 7626-1, *Vibration and shock — Experimental determination of mechanical mobility — Part 1: Basic definitions and transducers*

ISO 7626-2, *Vibration and shock — Experimental determination of mechanical mobility — Part 2: Measurements using single-point translation excitation with an attached vibration exciter*

1) To be revised as ISO 16063-21.

3 Terms and definitions

For the purposes of this part of ISO 10846, the terms and definitions given in ISO 2041 and the following apply.

3.1
vibration isolator
resilient element
isolator designed to attenuate the transmission of vibration in a frequency range

[ISO 2041:1990, definition 2.110]

3.2
resilient support
vibration isolator suitable for supporting part of the mass of a machine, a building or another type of structure

3.3
test element
resilient support under test including flanges and auxiliary fixtures, if any

3.4
blocking force
F_b
dynamic force on the output side of a vibration isolator which results in zero displacement output

3.5
dynamic transfer stiffness

$k_{2,1}$
ratio of complex force on the blocked output side of a resilient element to complex displacement on the input side during sinusoidal vibration

NOTE 1 The indices “1” and “2” denote the input and output side respectively.

NOTE 2 The value of $k_{2,1}$ can be dependent upon static preload, temperature and other conditions. At low frequencies $k_{2,1}$ is solely determined by elastic and dissipative forces and $k_{2,1} = k_{1,1}$ ($k_{1,1}$ denotes the ratio of force and displacement on the input side).

NOTE 3 At higher frequencies inertial forces in the resilient element play a role as well and $k_{2,1} \neq k_{1,1}$.

3.6
loss factor of resilient element
η
ratio of the imaginary part of $k_{2,1}$ and the real part of $k_{2,1}$ (i.e. tangent of the phase angle of $k_{2,1}$) in the low frequency range, where inertial forces in the element are negligible

3.7
frequency-averaged dynamic transfer stiffness
k_{av}
function of frequency of the average value of the dynamic stiffness over a frequency band Δf (see 8.2)

3.8
point contact
contact area which vibrates as the surface of a rigid body

3.9
normal translation
translational vibration normal to the flange of a resilient element

3.10
transverse translation
translational vibration in a direction perpendicular to that of the normal translation

3.11
linearity
property of the dynamic behaviour of a resilient element, if it satisfies the principle of superposition

NOTE 1 The principle of superposition can be stated as follows. If an input $x_1(t)$ produces an output $y_1(t)$ and in a separate test an input $x_2(t)$ produces an output $y_2(t)$, superposition holds if the input $[a \cdot x_1(t) + b \cdot x_2(t)]$ produces the output $[a \cdot y_1(t) + b \cdot y_2(t)]$. This must hold for all values of a, b and $x_1(t)$ and $x_2(t)$; a and b are arbitrary constants.

NOTE 2 In practice the above test for linearity is impractical and a limited check of linearity is done by measuring the dynamic transfer stiffness for a range of input levels. In effect this procedure checks for a proportional relationship between the response and the excitation (see 7.6).

3.12
direct method
method in which either the input displacement, velocity or acceleration and the blocking output force are measured

3.13
indirect method
method in which the vibration transmissibility (for displacement, velocity or acceleration) of a resilient element is measured, with the output loaded by a compact body of known mass

NOTE The term “indirect method” may include loads of any known impedance other than a mass-like impedance. However, this part of ISO 10846 does not cover such methods.

3.14
transmissibility
T
ratio $\underline{u}_2/\underline{u}_1$ of the complex displacements $\underline{u}_2$ on the output side and $\underline{u}_1$ on the input side of the test element during sinusoidal vibration

NOTE For velocities v and accelerations a, transmissibilities are defined in a similar way and have the same value.

3.15
force level
L_F
level calculated by the following formula

$$L_F = 10 \lg \frac{F^2}{F_0^2} \text{ dB}$$

where F^2 denotes the mean square value of the force in a specific frequency band and $F_0 = 1$ μN is the reference force

3.16
acceleration level
L_a
level calculated by the following formula

$$L_a = 10 \lg \frac{a^2}{a_0^2} \text{ dB}$$

where a^2 denotes the mean square value of the acceleration in a specific frequency band and $a_0 = 10^{-6}$ m/s^2 is the reference acceleration

3.17
level of dynamic transfer stiffness
$L_{k_{2,1}}$
level calculated by the following formula

$$L_{k_{2,1}} = 10 \lg \frac{|k_{2,1}|^2}{k_0^2} \text{ dB}$$

where $|k_{2,1}|^2$ is the square magnitude of the dynamic transfer stiffness (see 3.5) at a specified frequency and $k_0 = 1 \text{ N}\cdot\text{m}^{-1}$ is the reference stiffness

3.18
level of frequency band averaged dynamic transfer stiffness
$L_{k_{av}}$
level calculated by the following formula

$$L_{k_{av}} = 10 \lg \frac{k_{av}^2}{k_0^2} \text{ dB}$$

where k_{av} is defined in 3.7 and where k_0 denotes the reference stiffness (= 1 N·m^{-1})

3.19
flanking transmission
forces and accelerations at the output side caused by the vibration exciter at the input side but via transmission paths other than through the test element

4 Principle

The measurement principle of the indirect method is discussed in ISO 10846-1.

The basic principle is that the blocking output force is derived from acceleration measurements on a compact body of mass m_2, which provides sufficiently small vibrations on the output side of the test element. This blocking mass shall be dynamically decoupled from the other parts of the test arrangement to prevent flanking transmission.

For sinusoidal vibration and using complex notation, the relation between the dynamic transfer stiffness (see 3.5) of the element under test and the measured vibration transmissibility (see 3.14) is given by

$$k_{2,1} = \underline{F}_{2,b} / \underline{u}_1 \approx -(2\pi f)^2 (m_2 + m_f) T \quad \text{for } |T| << 1 \tag{1}$$

where

m_f denotes the mass of the output flange of the test element;

indices “1” and “2” denote the input and output side respectively.

A valid indirect determination of a blocking force according to the right-hand term of equation (1) requires that this blocking force solely determines the corresponding vibration measured on the blocking mass. Therefore, in principle, the vibration to be measured is that of the mass centre of the compact body composed of the blocking mass and of the output flange of the test element, and in the direction of the wanted force.

5 Requirements for apparatus

5.1 Normal translations

5.1.1 Overview

In Figures 2 to 4, schematic examples are shown of test arrangements for resilient supports. These are exposed to translatory vibration in the normal load direction. The test element shall be mounted in a way which is representative of its use in practice.

NOTE The collection of examples is by no means exhaustive and is not intended to form a limitation for test arrangement principles.

To be suitable for the measurements according to this part of ISO 10846, a test rig shall include the items described in 5.1.2 to 5.1.6.

5.1.2 Blocking mass

A mass is connected to the output side the test element. One function of this mass is to block the output. The blocking force is determined from measuring the acceleration of the mass. A second function is to provide a uniform vibration of the output flange of the test element.

5.1.3 Static preloading system

Measurements shall be performed with the test element under a representative and specified preload. Examples of methods for applying the static preload are as follows.

a) Use of a hydraulic actuator, which also serves as the vibration exciter. This is mounted in a load frame together with the test element and the blocking mass on the output side of the test element. The blocking mass is supported by auxiliary vibration isolators to decouple the mass from the load frame. The total low frequency dynamic stiffnesss of these auxiliary isolators is of the same order of magnitude as that of the element under test.

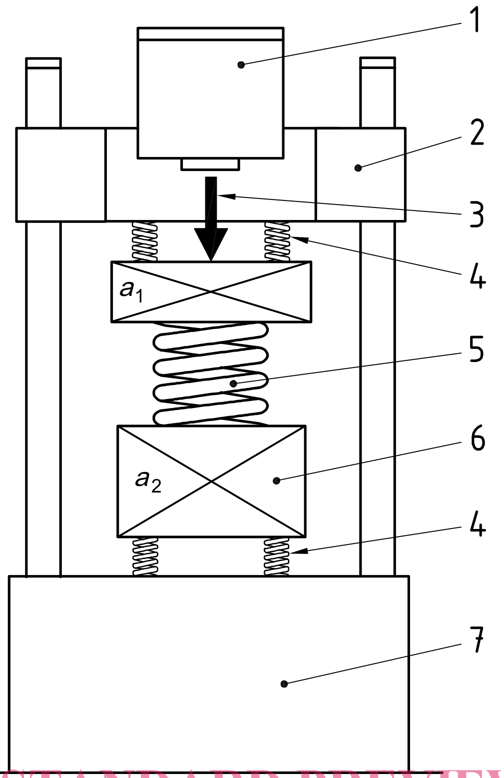
b) Use of a frame which provides static preload only; see Figures 2 and 3. If such a frame is used, auxiliary vibration isolators shall also be applied on the input side of the test element to decouple it from the frame.

c) Use of a gravity load by adding a blocking mass on top of the test element (with or without a support frame; see Figure 4).

5.1.4 Acceleration measurement systems

Accelerometers shall be mounted on the input and output side of the test element and on the foundation which supports the blocking mass. When mid-point positions are not accessible, indirect measurement of the mid-point accelerations shall be performed by making an appropriate signal summation, for example, by taking the linear average for two symmetrically positioned accelerometers.

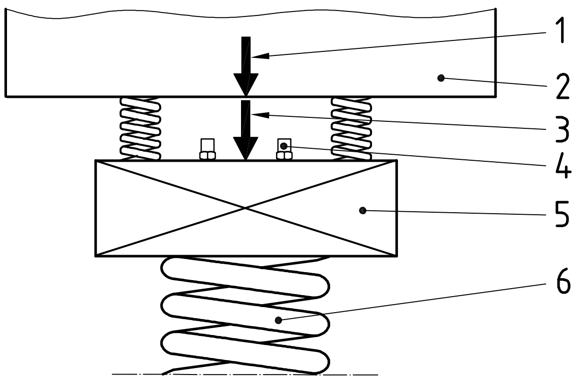
Provided that their frequency range is appropriate, displacement or velocity transducers may be used instead of accelerometers [see Figures 2b) and 4].



Key

1 Exciter
2 Traverse
3 Connection rod
4 Dynamic decoupling springs, static preload
5 Test element
6 Blocking mass
7 Rigid foundation

a) Overview



Key

1 Static preload
2 Traverse
3 Dynamic excitation
4 Acceleration measurement (a_1)
5 Excitation mass
6 Test element

b) Input side (details)

Figure 2 — Example 1 of laboratory test rig for measuring the dynamic transfer stiffness for normal translations (*continued*)

