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

Part 4:

Dynamic stiffness of elements other than resilient supports for translatory motion

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

Partie 4: Raideur dynamique en translation des éléments autres que les supports élastiques

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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.

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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.

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ISO 10846-4 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*, in collaboration with 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 the determination of the low frequency dynamic stiffness of elastic supports for translatory motion*

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 a direct and an indirect method for measuring the dynamic transfer stiffness function of linear resilient elements (other than resilient supports) such as resilient bellows, hoses, shaft couplings, power supply cables and pipe hangers. This part of ISO 10846 belongs to a series of International Standards on methods for the laboratory measurement of the vibro-acoustic properties of resilient elements, which also includes documents on measurement principles and on a direct, an indirect and a driving point method for resilient supports. 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 method described in this part of ISO 10846 are useful for resilient elements that are used to reduce the transmission of structure-borne sound (primarily frequencies above 20 Hz). The method does not characterize completely elements that are used to attenuate low-frequency vibration or shock excursions.

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

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

1 Scope

This part of ISO 10846 specifies two methods for determining the dynamic transfer stiffness for translations of resilient elements other than resilient supports. Examples are resilient bellows, shaft couplings, power supply cables, hoses and pipe hangers (see Figure 1). Elements filled with liquids, such as oil or water, are excluded.

NOTE 1 Pipe hangers are extensionally deflected, as opposed to elastic supports which are compressed. Therefore, the test conditions are different from those described in ISO 10846-2 and ISO 10846-3.

The methods are applicable to resilient elements with flat flanges or flat clamp interfaces. It is not necessary that the flanges be parallel.

Resilient elements which are the subject of this part of ISO 10846 are those that are used to reduce

a) the transmission of audiofrequency vibrations (structure-borne sound, 20 Hz to 20 kHz) to a structure which may, for example, radiate unwanted sound (airborne, waterborne or other), and

b) the transmission of low-frequency vibrations (typically 1 Hz to 80 Hz), which may, for example, act upon human subjects or cause damage to structures of any size when the vibration is too severe.

In practice, the size of the available test rig(s) determines restrictions for very small and for very large resilient elements.

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

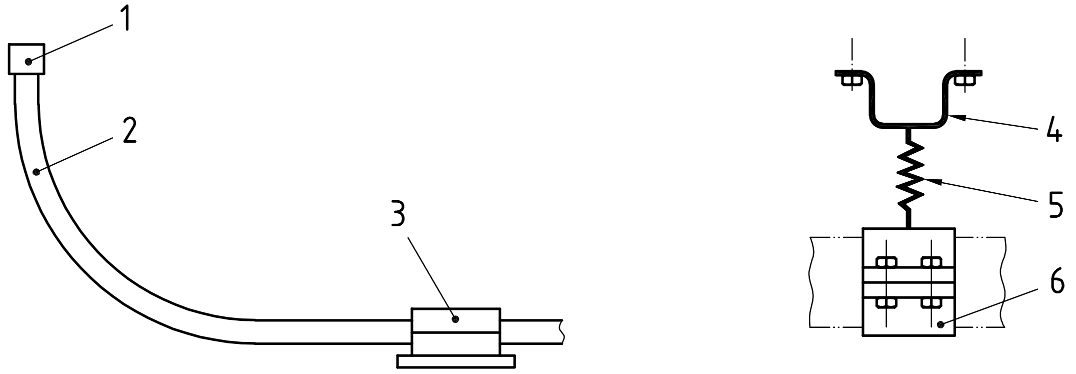
The direct method can be applied in the frequency range from 1 Hz up to a frequency that is usually determined by the lowest resonance frequency of the test arrangement frame (typically 300 Hz for test rigs with dimensions of the order of 1 m).

NOTE 2 In practice, the lower frequency limit depends on the dynamic excitation system.

The indirect method covers a frequency range that is determined by the test set-up and the isolator under test. The range is typically from a lower frequency between 20 Hz and 50 Hz, to an upper frequency between 2 kHz and 5 kHz.

The data obtained according to the methods 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 resilient elements.



a) Power cable including connector and clamping device

b) Pipe hanger

Key

1	connector
2	cable
3	clamp
4	fixture
5	flexible element
6	pipe clamp

Figure 1 — Examples of resilient elements with flat flanges or clamps

2 Normative references

The following referenced documents are indispensable for the application 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 266, *Acoustics — Preferred frequencies*

ISO 2041, *Vibration and shock — Vocabulary*

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*

ISO 10846-1, *Acoustics and vibration — Laboratory measurement of vibro-acoustic transfer properties of resilient elements — Part 1: Principles and guidelines*

ISO 16063-21, *Methods for the calibration of vibration and shock transducers — Part 21: Vibration calibration by comparison with a reference transducer*

GUM:1993, *Guide to the expression of uncertainty in measurement.* BIPM/IEC/IFCC/ISO/IUPAC/IUPAP/OIML

3 Terms and definitions

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

3.1
resilient element
element of which one of the functions is the reduction of the vibration transmission in a certain frequency range

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

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

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

3.5
dynamic transfer stiffness
$k_{2,1}$
frequency-dependent ratio of the complex blocking force $\underline{F}_{2,\mathrm{b}}$ on the output side of a resilient element to the complex displacement $\underline{u}_1$ on the input side during simple harmonic motion, defined by the following formula

$$k_{2,1} = \underline{F}_{2,\mathrm{b}}/\underline{u}_1$$

NOTE The value of $k_{2,1}$ can be dependent upon the static preload, temperature and other conditions.

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 the frequency of the average value of the modulus of the dynamic transfer stiffness over a frequency band Δf

NOTE See 8.3.

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 $\mathrm{a}\cdot x_1(t) + \mathrm{b}\cdot x_2(t)$ produces the output $\mathrm{a}\cdot y_1(t) + \mathrm{b}\cdot y_2(t)$. 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 7.7).

3.12
direct method

method in which 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

3.14
transmissibility

T

ratio of the complex displacements on the output side $\underline{u}_2$ to those on the input side $\underline{u}_1$ of the test element during simple harmonic motion, defined by the following formula

$$T = \underline{u}_2 / \underline{u}_1$$

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 $F_0 = 10^{-6}$ N 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

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

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

3.18

level of frequency-band-averaged dynamic transfer stiffness

$L_{k_{\text{av}}}$

level calculated by the following formula

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

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

3.19

flanking transmission

transmission of vibrations to the output side via paths other than through the resilient element under test

4 Principles

The measurement principles of the direct and the indirect method are discussed in ISO 10846-1.

In the *direct* method, the basic principle is that the blocking output force is measured between the output side of the resilient element and a foundation. The foundation shall provide a sufficient reduction of the vibrations on the output side of the test object compared to those on the input side.

In the *indirect* method 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 relationship between the dynamic transfer stiffness of the element under test and the measured vibration transmissibility (3.14) is given by the following approximation

$$k_{2,1} \approx -(2\pi f)^2 (m_2 + m_f) T \qquad \text{for } |T| \ll 1 \qquad (1)$$

where m_f denotes the mass of the output flange of the test element. The 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 centre of mass of the compact body composed of the blocking mass and the output flange of the test element, and in the direction of the wanted force.

5 Test arrangements

5.1 General

In Figures 2 to 8, examples are given of test arrangements for resilient elements other than resilient supports. The sketches are schematic. Examples are given of test arrangements for single elements as well as for symmetrically paired ones.

NOTE The collection of examples is by no means exhaustive and is not intended to form a limitation for test arrangement principles. It is meant as an illustration of solutions that have been applied to meet requirements for the adequacy of the test arrangements (see Clause 6).

To be suitable for measurements according to this part of ISO 10846, a test arrangement shall include the components given in 5.3, when applicable. Other aspects concerning test rig properties are discussed in 5.4 and 5.5.

5.2 Local coordinate systems

For the resilient elements which are tested according to this part of ISO 10846, the directions normal to flanges or fixtures on the input and on the output side may be not the same (see Figures 7 and 8). For non-planar test elements, they are even out-of-plane. Therefore, for each test configuration, the local Cartesian coordinate systems and the local corresponding forces, torques, displacements and rotatory displacements shall be defined in agreement with Figure 9. The positive directions of the z-axes shall coincide with the directions normal to the input and output flanges and shall point away from the test element. In the case of a "planar" test element, the x-axis shall be chosen out-of-plane on the input as well as on the output side. In the case of a non-planar test element, the transverse axis directions shall be defined according to the requirements of the applications. The naming of the x- and y-directions is the responsibility of the user of this part of ISO 10846. Thus, the definition of dynamic transfer stiffnesses of cables and hoses is dependent on the test element and on the test arrangement.

The naming of the dynamic transfer stiffnesses shall be in agreement with the following notation:

$k_{2x,1x}$; $k_{2x,1y}$; $k_{2x,1z}$

$k_{2y,1x}$; $k_{2y,1y}$; $k_{2y,1z}$

$k_{2z,1x}$; $k_{2z,1y}$; $k_{2z,1z}$

where the subscripts $2x$, $2y$, $2z$ refer to the local coordinate system for the blocking output forces, and the subscripts $1x$, $1y$, $1z$ to the local coordinate system for the input displacements.

In cases where confusion is unlikely, simpler notations may be used. For example, for an axially symmetrical test component as in Figure 2, it can suffice to define two transfer stiffnesses as follows: $k_{2,1}$(axial); $k_{2,1}$(radial).

5.3 Test rig components

5.3.1 Resilient elements under test

The test element shall be mounted in a way that is representative of its use in practice. This shall include the static preload and the fixture arrangements on the input and output sides. Auxiliary fixtures shall be considered as parts of the test element (see 3.3).

NOTE Resilient elements with a strongly non-linear static load deflection curve show strongly preload dependent dynamic behaviour as well. However, in contrast to the resilient supports covered in ISO 10846-3, the static preloads in this part of ISO 10846 are not primarily due to gravity. For example, the static preload for a resilient shaft coupling may be a torque load [Figure 3 b)].

5.3.2 Force measurement system on the output side

When the *direct* method is used, the force measurement system on the output side of the resilient element shall consist of one or more force transducers.

It may be necessary to apply a force distribution plate between the test element and the force transducers (see Figure 8).

NOTE Besides its function of load distribution, the force distribution plate also provides a high contact stiffness to the force transducers. Moreover, it provides a uniform vibration of the output flange or clamp.

5.3.3 Blocking mass on the output side

When the *indirect* method is used, one function of the blocking mass is the estimation of the blocking output force by measuring the acceleration of the mass. A second function is to provide a spatially uniform vibration of the output flange of the test object over the frequency range of interest.

5.3.4 Acceleration measurement systems

Accelerometers shall be mounted on the input and output side of the test object and on the foundation of the test arrangement. 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.

When the *indirect* method is used, the transverse accelerometers of the blocking mass that are needed are those along the x- and y-axes through the centre of mass of the compact body composed of the blocking mass and the output flange of the test element (see Figure 10).

Provided that their frequency range is appropriate, displacement or velocity transducers may be used instead of accelerometers.

5.3.5 Dynamic excitation system

The dynamic excitation system shall be appropriate for the frequency range of interest. Any suitable type of exciter is permitted. Examples are

a) a hydraulic exciter,

b) one or more electrodynamic vibration exciters (shakers) with connection rods, and

c) one or more piezo-electric exciters.

Vibration isolators may be used for dynamic decoupling of exciters to reduce flanking transmission.

5.3.6 Excitation mass on the input side

The excitation mass on the input side of the test object has one or more of the following functions:

a) to provide a uniform vibration of the input flange under dynamic forces;

b) to enhance unidirectional vibration of the input flange.

If the test element contains a solid-mass-type input flange, which can provide the above-mentioned functions, the special excitation mass may be omitted.