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

Part 5:

Driving point method for determination of the low-frequency transfer stiffness of resilient supports for translatory motion

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

Partie 5: Méthode du point d'application pour la détermination de la raideur dynamique de transfert basse fréquence en translation des supports élastiques

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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.

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

ISO 10846-5 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*, and ISO/TC 108, *Mechanical vibration, shock and condition monitoring*.

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: Direct method for determination of the dynamic stiffness of resilient supports for translatory motion*
- *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 transfer stiffness of resilient supports for translatory motion*

Introduction

Passive vibration isolators of various kinds are used to reduce the transmission of vibration. 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 driving point method for measuring the low-frequency 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 vibration 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 documents on measurement principles, on a direct method and on an indirect 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 method described in this part of ISO 10846 are useful for resilient supports that are used to prevent low-frequency vibration problems and to attenuate structure-borne sound in the lower part of the audible frequency range. However, for complete characterization of resilient elements that are used to attenuate low-frequency vibration or shock excursions, additional information is needed, which is not provided by this method.

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

Part 5:
Driving point method for determination of the low-frequency transfer stiffness of resilient supports for translatory motion

1 Scope

This part of ISO 10846 specifies a driving point method for determining the low-frequency transfer stiffness for translations of resilient supports, under a specified preload. The method concerns the laboratory measurement of vibrations and forces on the input side with the output side blocked, and is called the “driving point method”.

The stiffness resulting from measuring the input displacement (velocity, acceleration) and input force is the dynamic driving point stiffness. Only at low frequencies, where the driving point stiffness and the transfer stiffness are equal, can this method be used for determination of the dynamic transfer stiffness.

NOTE 1 In ISO 10846-2, the direct method for measuring the dynamic transfer stiffness is covered. The direct method covers the determination of the low-frequency dynamic transfer stiffness and it covers, in principle, a wider frequency range than the driving point method. Nevertheless, the driving point method is covered in the ISO 10846 series of international standards as well. It is considered as a valuable option for owners of (often expensive) test rigs for driving point stiffness measurements, to extend the use of these rigs with the determination of low-frequency dynamic transfer stiffness.

The method is applicable to test elements with parallel flanges (see Figure 1).

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

a) the transmission of vibration in the lower part of the audible frequency range (typically 20 Hz to 200 Hz) to a structure which may, for example, radiate unwanted fluid-borne sound (airborne, waterborne or others), 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 vibration is too severe.

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

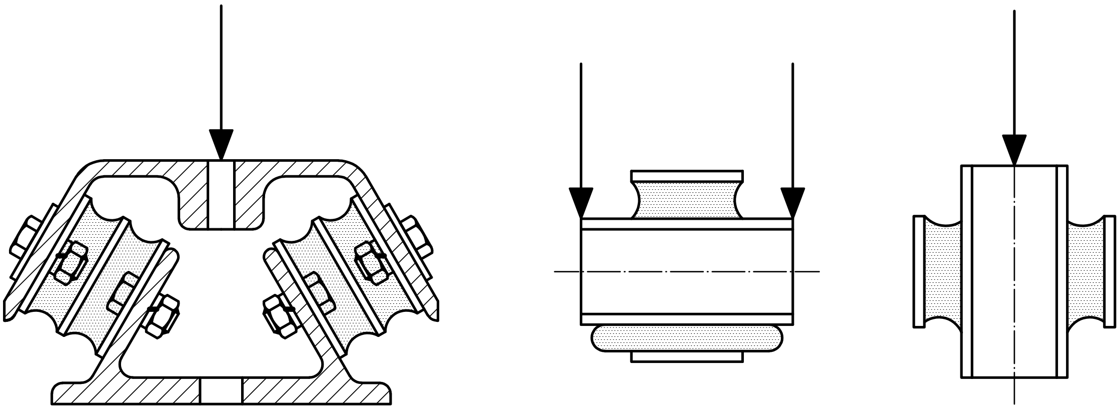
NOTE 3 Samples of continuous supports of strips and mats are included in the method. Whether or not the sample describes the behaviour of the complex system sufficiently is the responsibility of the user of this part of ISO 10846.

Measurements for translations normal and transverse to the flanges are covered in this part of ISO 10846. The method covers the frequency range from $f_1 = 1$ Hz to the upper limiting frequency f_{UL}. Typically 50 Hz $\leqslant f_{UL} \leqslant$ 200 Hz.

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

— 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 — Example of resilient supports with parallel flanges

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:—1), *Mechanical vibration, shock and condition monitoring — 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 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 to a reference transducer*

ISO/IEC Guide 98-32) , *Uncertainty of Measurement — Part 3: Guide to the expression of uncertainty in measurement* (*GUM:1995*)

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1) To be published. (Revision of ISO 2041:1990)

2) ISO/IEC Guide 98-3 will be published as a re-issue of the *Guide to the expression of uncertainty in measurement* (GUM), 1995.

3 Terms and definitions

For the purposes of this document, 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 the vibration in a certain frequency range

NOTE Adapted from ISO 2041:—1), definition 2.120.

3.2
resilient support
vibration isolator(s) suitable for supporting a machine, a building or another type of structure

3.3
test element
resilient support undergoing testing 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 a zero displacement output

3.5
dynamic driving point stiffness
$k_{1,1}$
frequency-dependent ratio of the force phasor $\underline{F}_1$ on the input side of a vibration isolator with the output side blocked to the displacement phasor $\underline{u}_1$ on the input side

$$k_{1,1} = \underline{F}_1 / \underline{u}_1$$

NOTE 1 The subscripts “1” denote that the force and displacement are measured on the input side.

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

NOTE 3 At low frequencies, elastic and dissipative forces solely determine $k_{1,1}$. At higher frequencies, inertial forces play a role as well.

3.6
dynamic transfer stiffness
$k_{2,1}$
frequency-dependent ratio of the blocking force phasor $\underline{F}_{2,\mathrm{b}}$ on the output side of a resilient element to the displacement phasor $\underline{u}_1$ on the input side

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

NOTE 1 The subscripts “1”and “2” denote the input and output sides respectively.

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

NOTE 3 At low frequencies, $k_{2,1}$ is solely determined by elastic and dissipative forces and $k_{1,1} \approx k_{2,1}$. At higher frequencies, inertial forces in the resilient element play a role as well and $k_{1,1} \neq k_{2,1}$.

3.7
loss factor of resilient element

η

ratio of the imaginary part of $k_{1,1}$ and the real part of $k_{1,1}$, i.e. the tangent of the phase angle of $k_{1,1}$, in the low-frequency range, where inertial forces in the element are negligible

3.8
frequency-averaged dynamic transfer stiffness

k_{av}

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

NOTE See 8.2

3.9
point contact

contact area, which vibrates as the surface of a rigid body

3.10
normal translation

translational vibration normal to the flange of a resilient element

3.11
transverse translation

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

3.12
linearity

property of the dynamic behaviour of a vibration isolator, 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 $[ax_1(t) + bx_2(t)]$ produces the output $[ay_1(t) + by_2(t)]$. 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 performed by measuring the dynamic transfer stiffness for a range of input levels. For a specific preload, if the dynamic transfer stiffness is nominally invariant, the system can be considered linear. In effect, this procedure checks for a proportional relationship between the response and the excitation (see 7.7).

3.13
driving point method

method in which either the input displacement, velocity or acceleration and the input force are measured, with the output side of the resilient element blocked

3.14
force level

L_F

level defined 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 is the reference force ($F_0 = 10^{-6}$ N)

3.15
acceleration level

L_a

level defined 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 is the reference acceleration (a_0 = 10^{-6} m/s^2)

3.16
level of dynamic transfer stiffness

$L_{k_{2,1}}$

level defined by the following formula:

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

where $\left|k_{2,1}\right|^2$ is the square magnitude of the dynamic transfer stiffness (3.6) at a specified frequency and k_0 is the reference stiffness (k_0 = 1 N/m)

3.17
level of frequency-band-averaged dynamic transfer stiffness

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

level defined by the following formula:

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

where k_{av} is the frequency-averaged dynamic transfer stiffness (3.8) and k_0 is the reference stiffness (k_0 = 1 N/m)

3.18
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 resilient element under test

3.19
upper limiting frequency

f_{UL}

frequency up to which $k_{2,1}$ can be determined by using the driving point method, according to the criteria in this part of ISO 10846

NOTE See 6.2.

4 Principle

The measurement principle of the driving point method is discussed in ISO 10846-1. The basic principle is that the input force and either the input displacement, velocity or acceleration are measured with the output side of the vibration isolator blocked. From these measurements, the driving point stiffness $k_{1,1}$ is determined. At low frequencies, up to the frequency f_{UL}, $k_{1,1}$ is about equal to the transfer stiffness $k_{2,1}$.

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.

The mass between the test isolator and the Input-force transducers causes a bias error in the measurement of the input force, which limits the frequency range for the correct measurement of $k_{1,1}$, and is one cause of deviation between $k_{1,1}$ and $k_{2,1}$.

The inertial properties leading to eigenmodes of the resilient element is another cause of deviation between $k_{1,1}$ and $k_{2,1}$.

This part of ISO 10846 gives a method to determine the frequency limit f_{UL}, up to which the accuracy of the equivalency between $k_{1,1}$ and $k_{2,1}$ is equal to or within 2 dB.

The test procedures according to this part of ISO 10846 cover measurements of transfer stiffness for unidirectional excitations one by one in normal and in transverse directions.

5 Test arrangements

5.1 Normal translations

5.1.1 Overview

In Figure 2, an example is given of a test arrangement for resilient supports exposed to normal translational vibration. The sketches are schematic. To be suitable for measurements according to this part of ISO 10846, the test arrangement shall include the items listed in 5.1.2 to 5.1.6.

5.1.2 The resilient support under test

The test element is positioned on a heavy and rigid foundation table.

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 a hydraulic actuator, which also serves as the vibration exciter. This is mounted in a load frame together with the test element;

b) Use a frame that provides static preload only, see Figure 2. 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.

NOTE In many cases, it will be necessary to apply a force distribution plate between the force transducer(s) and the actuator. Besides its function of load distribution, it also provides a uniform vibration input on the resilient element.

5.1.4 Force measurement system

The force measurement system on the input side of the resilient support consists of one or more dynamic force transducers (load cells).

NOTE 1 It might be necessary to apply a force distribution plate between the input flange of the test element and the dynamic force transducer(s). Besides its function of load distribution, this force distribution plate provides a high contact stiffness between the force transducer(s) and the input flange, and enforces uniform vibration of the input flange.

NOTE 2 The mass of a distribution plate between the force transducer(s) and the test element, affects the discrepancy between the measured driving point stiffness and the dynamic transfer stiffness of the element. Keeping this mass as small as possible is favourable for a higher upper limiting frequency f_{UL} (3.19).