INTERNATIONAL STANDARD

ISO 10846-5

First edition
2008-08-15

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

Reference number
ISO 10846-5:2008(E)

PDF disclaimer

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

COPYRIGHT PROTECTED DOCUMENT

© ISO 2008

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either ISO at the address below or ISO's member body in the country of the requester.

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

Published in Switzerland

--`,,```,,,,````-`-`,,`,,`,`,,`---

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Contents

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 2.

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.

INTERNATIONAL STANDARD **ISO 10846-5:2008(E)**

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.

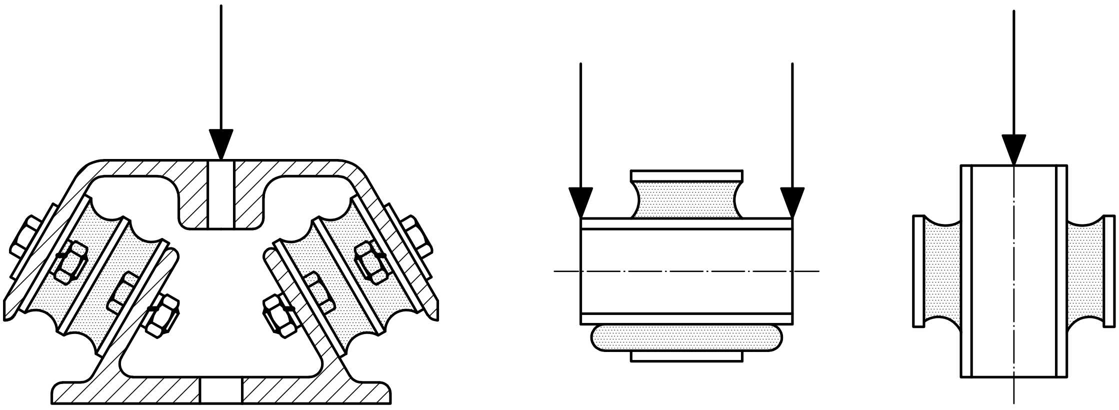
NOTE 3 Samples of continuous supports of strips and mats are included in the method. Whether or not the sample describes the behaviour of the complex system sufficiently is the responsibility of the user of this part of ISO 10846.

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*)

---

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 $\underline{F}_{2,b}$ on the output side of a resilient element to the displacement phasor $\underline{u}_1$ on the input side

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

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).

5.1.5 Acceleration measurement system

Acceleration measurements shall be made on the input and output sides of the test element. When mid-point positions are not accessible, indirect measurement of mid-point accelerations shall be performed by making an appropriate signal summation, for example, by taking the linear average for two symmetrically positioned accelerometers.

As an option, instead of accelerometers, displacement or velocity transducers may be used, provided that their frequency range is appropriate.

5.1.6 Dynamic excitation system

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

a) a hydraulic actuator, which also can provide a static preload;

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

c) one or more piezoelectric exciters.

Vibration isolators may be used for dynamic decoupling of exciters to reduce flanking transmission via the frame for applying static preload. However, in the test rigs, which use a hydraulic actuator for both static and dynamic loading, such a decoupling is usually inconvenient, because of its adverse effects on low-frequency measurements.

5.2 Transverse translations

5.2.1 Overview

Schematic examples of test arrangements for resilient supports exposed to translational vibrations perpendicular to the normal load direction are shown in Figures 3 and 4. The test arrangement shall include the items described in 5.2.2 to 5.2.6.

5.2.2 Resilient support under test

The test element is positioned on a heavy, rigid foundation table (see Figure 3) or between stiff columns on a rigid foundation (see Figure 4).

5.2.3 Static preloading system

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

a) Use a hydraulic actuator. This actuator is mounted in a load frame together with the test element.

b) Use a frame which provides static preload only.

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.

5.2.4 Force measurement system

The dynamic force measurement system shall consist of one of the following options:

a) one or more force transducers for the measurement of dynamic shear forces (see Figure 3);

b) one or more force transducers for the measurement of normal dynamic forces (see Figure 4);

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).

5.2.5 Acceleration measurement system

Acceleration measurements shall be made on the input and output sides of the test element.

The accelerometers on the test element flanges or on the force distribution plate shall be placed on horizontal symmetry axes of these components. When such places are not accessible, indirect measurement of the acceleration along a symmetry axis may be performed by making an appropriate signal summation, for example, by taking the linear average for two symmetrically positioned accelerometers.

Provided that displacement or velocity transducers have the appropriate frequency response, they may be used instead of accelerometers.

5.2.6 Dynamic excitation system

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

a) hydraulic actuator;

b) one or more electrodynamic exciters with connection rods;

c) one or more piezoelectric exciters.

5.3 Suppression of unwanted vibrations

5.3.1 General

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.

However, due to asymmetries in excitation, in boundary conditions and in test elements properties, others than the intended input vibration component may show unwanted strong responses at certain frequencies. Qualitative measures to suppress unwanted input vibrations are discussed next. A special category of test arrangements is that in which two nominally equal resilient elements are tested in a symmetrical configuration (see Figure 4). This may be advantageous to suppress unwanted input vibrations. In 6.1.3, quantitative requirements are formulated.

5.3.2 Normal direction

For excitation in the normal direction, a symmetrical positioning of the exciter or a pair of exciters shall be the favourable method for suppressing transverse and rotational vibrations on the input side.

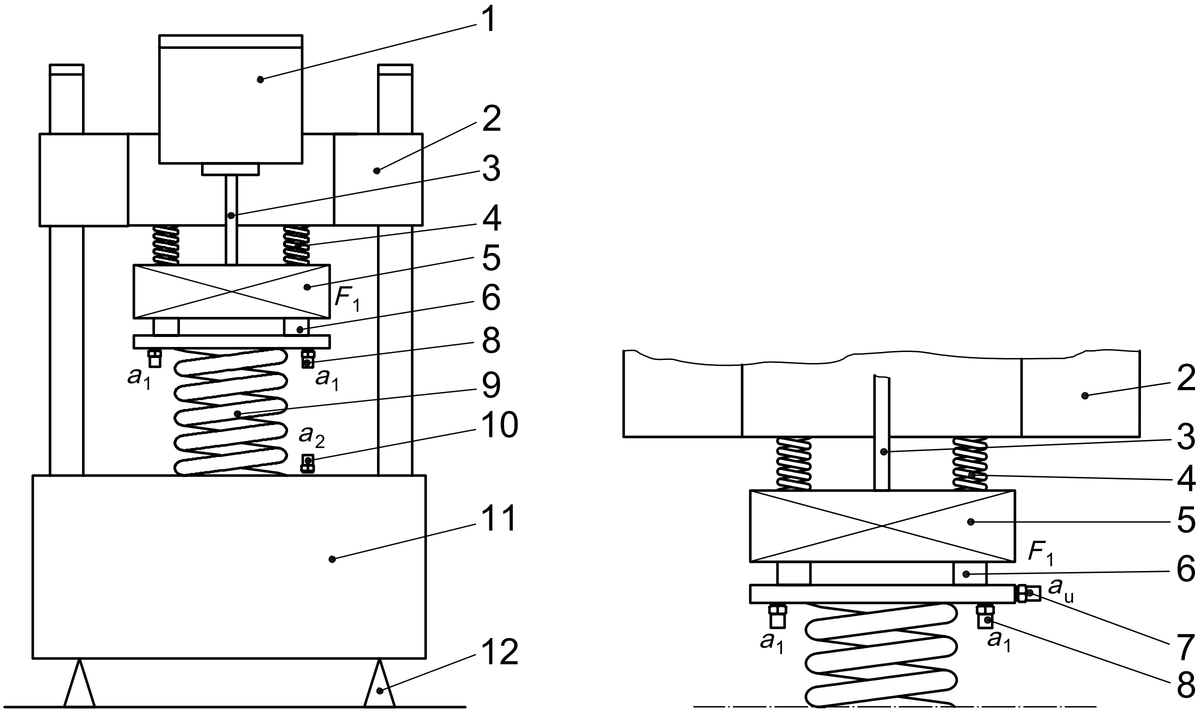
Nevertheless, the properties of the test object itself may cause coupling between the normal and other vibration directions. A method of suppressing unwanted input vibrations is the use of a symmetrical arrangement with two or four nominally identical test objects, or of a ‘guiding’ system on the sides of the excitation mass, for example, roller bearings [see Figure 2 c)].

NOTE When low-friction bearings are used as a guiding system, the force transducers for measuring the input force F_1 are to be placed between this guiding system and the test element to avoid errors due to uncertain transmission properties of these guiding components.

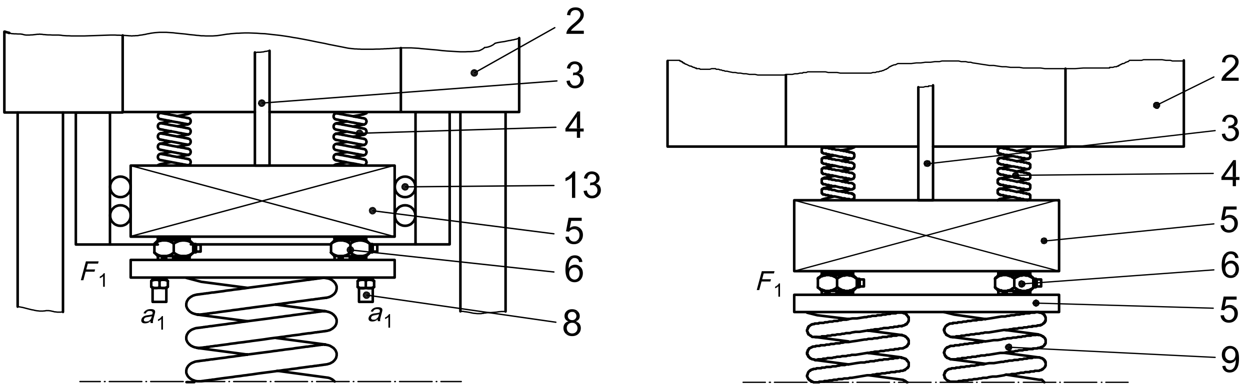
5.3.3 Transverse direction

For excitation in the transverse direction, coupling between the transverse and rotational input vibrations will always occur.

In Figures 3 and 4, examples of measures are shown, which may enhance unidirectional vibrations on the input side. Figure 3 shows as example of how a guiding system can be used to suppress input rotations. Figure 4 shows a symmetrical arrangement with two nominally equal test objects.



a) Overview **b) Input side** (details)

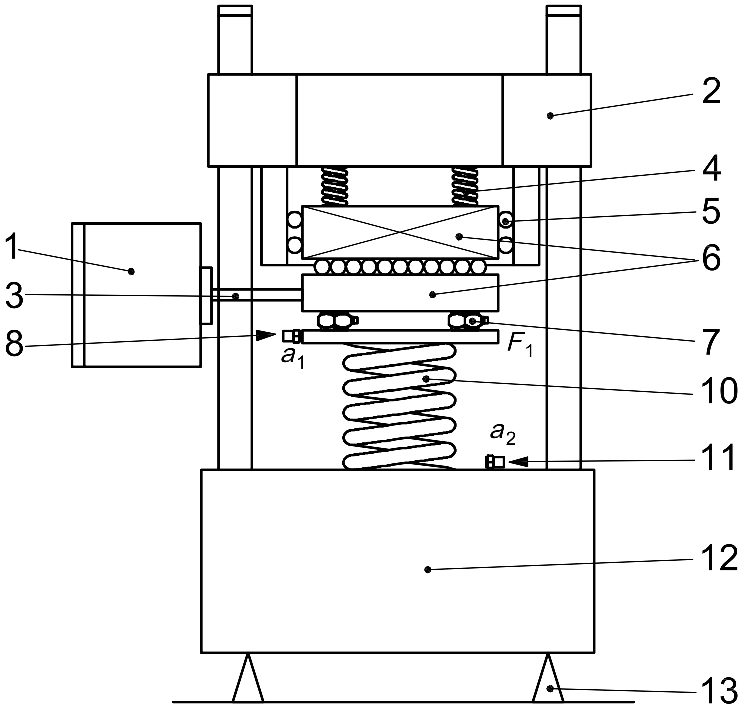


c) Guiding low-friction bearing(s) **d) Symmetrical set-up of test elements**

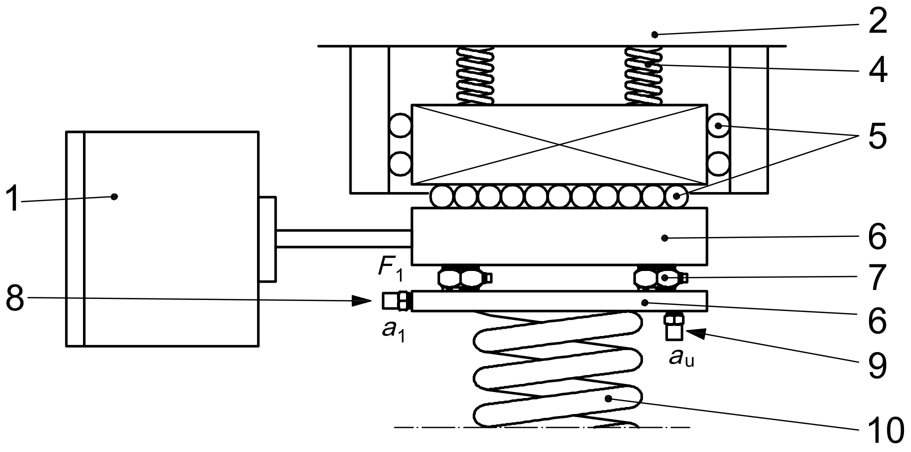
Key

1	exciter
2	traverse
3	connection rod
4	dynamic decoupling spring, static preload
5	force distribution plate
6	input-force measurement (F_1)
7	measurement of unwanted acceleration (a_u)
8	input acceleration measurement (a_1)
9	test element
10	output acceleration measurement (a_2)
11	rigid foundation
12	suspension
13	low-friction bearing

Figure 2 — Example of laboratory test rig for measuring the dynamic driving point stiffness for normal translations



a) **Overview**

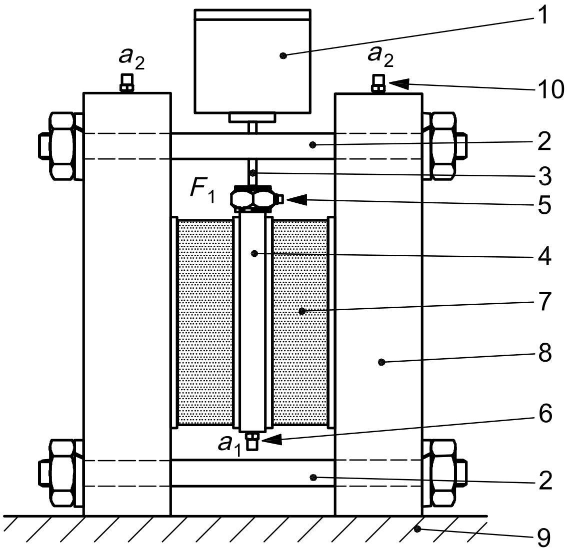


b) **Input side** (details)

Key

1	exciter
2	traverse
3	connection rod
4	dynamic decoupling spring, static preload
5	low-friction bearing
6	force distribution plate
7	input shear force measurement (F_1)
8	input acceleration measurement (a_1)
9	measurement of unwanted acceleration (a_u)
10	test element
11	output acceleration measurement (a_2)
12	rigid foundation
13	suspension

Figure 3 — Example of laboratory test rig for measuring the dynamic driving point stiffness for transverse translations



Key

1	exciter	6	input acceleration measurement (a_1)
2	preloading device	7	nominally equal test elements
3	connection rod	8	stiff columns
4	force distribution plate	9	rigid foundation
5	input-force measurement (F_1)	10	output acceleration measurement (a_2)

Figure 4 — Example of symmetrical test arrangement for measuring the dynamic driving point stiffness for transverse translations

6 Criteria for adequacy of the test arrangement

6.1 General requirements

6.1.1 Frequency range

Each test facility has a limited frequency range in which valid tests can be performed. One limitation is given by the usable bandwidth of the vibration actuator.

Other limitations follow from the requirements for measuring the acceleration and the input force, and from the unwanted vibration.

6.1.2 Limitation due to the acceleration of the output flange

In Figures 2 to 4, the following dynamic measurement quantities are indicated:

— F_1 input force;

— a_1 acceleration of the input flange and the Input-force distribution plate, which is on the test element;

— a_2 acceleration of the output flange.

The stiffness measurements according to this part of ISO 10846 are valid only for those frequencies where

$$\Delta L_{1,2} = L_{a_1} - L_{a_2} \geqslant 20\text{ dB} \tag{1}$$

NOTE A too-small value for the level difference $\Delta L_{1,2}$ can be explained by an insufficient stiffness mismatch between the test element and the foundation or by flanking transmission. Use of vibration isolators to decouple the top of the test element from the load frame (see e.g. Figure 2), and also to decouple the vibration exciter from the frame, would reduce flanking transmission significantly.

6.1.3 Limitation due to unwanted input vibrations

Input accelerations in directions other than those of the excitation shall be suppressed according to 5.3. Measurements according to this part of ISO 10846 are valid only for those frequencies where the input acceleration in the excitation direction exceeds that in the other directions perpendicular to it by at least 15 dB, i.e.

$$L_{a(\text{excitation})} - L_{a(\text{unwanted})} \geqslant 15\text{ dB} \tag{2}$$

For normal excitation, the input acceleration in the excitation direction a_{1z} is along the line of excitation and at the interface between the force distribution plate and the input flange of the resilient element. The unwanted inputs in perpendicular transverse directions a_{1x} and a_{1y} shall be measured at the edge of the force distribution plate between the force transducers and input flange [see Figure 2 b)].

For transverse excitation (in the x- or y-direction), the unwanted inputs a_{1z} and a_{1y} or a_{1x} shall be measured at the edge of the force distribution plate between the force transducers and input flange [see Figure 3 b)].

6.2 Determination of upper limiting frequency

The upper limiting frequency f_{UL}, above which the dynamic driving point stiffness shall not be used to represent the dynamic transfer stiffness, is determined by comparing the measured driving point stiffness level at frequency f with the constant low-frequency value (defined as the average for 1 Hz to 20 Hz). The lowest frequency, at which the driving point stiffness level becomes 2 dB smaller than the low-frequency stiffness, is f_{UL}.

6.3 Force transducers

Force transducers shall be calibrated at the laboratory temperature in the frequency range of interest and having a sensitivity level which is frequency independent within 0,5 dB. Calibration shall be carried out according to the mass-loading technique as described in ISO 7626-1.

If there is an appropriate compensation routine (i.e. digital application of an appropriate transfer function), the resultant sensitivity-level function shall meet the 0,5 dB requirement.

The force transducers shall be sufficiently insensitive to extraneous environmental effects such as relative humidity, magnetic fields, electrical fields, acoustical fields and strain, and the sensitivity to cross-axis forces shall be smaller than 5 % of the main axis of sensitivity.

6.4 Accelerometers

Accelerometers shall be calibrated at the laboratory temperature in the frequency range of interest and shall have a sensitivity level which is frequency independent to within 0,5 dB. Calibration shall be carried out according to ISO 16063-21.

The accelerometers shall be sufficiently insensitive to extraneous environmental effects such as relative humidity, magnetic fields, electrical fields, acoustical fields and strain, and the sensitivity to cross-axis accelerations shall be smaller than 5 % of the main axis of sensitivity.

If displacement or velocity transducers are used, the same requirements as for accelerometers apply.

6.5 Summation of signals

If signals from force transducers or from accelerometers are added, this shall be performed with a maximum tolerance of 5 %. One way to realize this purpose is to use identical transducers with sensitivities within 5 % of each other. Another way is to perform the summation with the aid of a multi-channel analyser. In that case corrections shall be made to compensate both for differences in transducer sensitivities larger than 5 % and for differences in channel gain factors (see 6.6).

6.6 Analysers

Narrow-band analysers shall be used which fulfil the following requirements:

a) In the frequency range of interest the spectral resolution shall provide at least five distinct frequencies per one-third-octave band.

b) The difference in frequency responses between the channels (including signal conditioning equipment), which are used for the acceleration measurements on the input and output sides, shall be less than 0,5 dB for a measurement with the same frequency resolution as used for testing the resilient support. Otherwise, corrections have to be made to compensate for the differences in channel gain factors.

One way in which channel gains can be compared is as follows. One broadband signal (e.g. white noise) is applied as input to both channels. Then the narrow-band spectrum of the magnitude level of the output ratio should be less than 0,5 dB, otherwise the measured gain ratio has to be used as a correction factor for the measured dynamic stiffness.

7 Test procedures

7.1 Installation of the test elements

The test element is attached to the force distribution plate and to the foundation, in a way which ensures good contact over the entire surface of the flanges. Devices, which are not part of the resilient element in practical application, shall be de-activated and removed.

NOTE 1 To improve a good contact between the resilient support and the test rig on both sides, grease or double-sided tape can be added. However, in the latter case, problems may occur in the high-frequency range. For test elements with big flanges, flattening might be necessary to obtain unambiguous test results.

Test elements that contain rubber-type components will show change of load or deflection due to creep. For such elements preloading shall be applied to 100 % of the permissible static load. Change of load or deflection due to creep should be less than 10 % per day before valid measurements can be performed.

NOTE 2 Transducers for measuring static load or static displacements and documentation for their application are commonly available. An appropriate selection will take into account the required load or deflection range of the resilient test element.

No particular preloading procedure is required for steel springs, but the appropriate preload shall be applied.

7.2 Selection of force measurement system and force distribution plates

Depending upon the size and symmetry of the test isolator and on the maximum permissible load, one or more (up to 4) force transducers shall be applied.

The force distribution plate(s) shall be as small and as light as possible, and the resonances of the system shall not occur in the frequency range of interest. The minimum lateral dimension is determined by the size of the test object.

To check the rigid body behaviour of the force measurement system, excite the system by a point force in the centre. The frequency response function determined from this point force, measured with a calibrated force transducer, and the output signal of the force measurement system shall be flat in the frequency range of interest.

7.3 Mounting and connection of accelerometers

Accelerometers shall be mounted on the input and output sides of the test element, to measure a_1 and a_2, respectively (see Figures 2 to 4). The connection shall be rigid. Mounting shall be carried out in accordance with ISO 5348.

Positions on the force distribution plates or on the flanges of the test object shall be carefully selected for placement of the transducers. If the vibration is predominantly in the vertical direction or the transverse direction, a single accelerometer, usually at a position outside the axis of symmetry, may be sufficient. In case of such a measurement, it shall be checked that the influence of rotational vibration does not lead to errors of more than 0,5 dB.

NOTE Measuring the accelerations at different distances from the symmetry axis can perform the check on rotational vibration.

To prevent errors due to flange rotations, the signals from two accelerometers that are positioned symmetrically with respect to the vertical symmetry axis may be averaged.

7.4 Mounting and connections of the vibration exciter

A connection rod may be necessary between the vibration exciter and the input side of the test element. It shall be designed in such a way that strong transverse vibration and sound radiation are avoided due to resonance of this rod.

7.5 Source signal

One of the following source signals shall be used:

- a discretely stepped sinusoidal signal;
- a swept sine signal;
- a periodically swept sine signal;
- a bandwidth-limited white noise signal.

The source signal shall be applied sufficiently long to allow for averaging such that the measured results do not differ by more than 0,1 dB when the averaging time is doubled. When discretely stepped sinusoidal signals or periodically swept sine signals are used, the spacing of the frequencies of the source signal shall be 0,2 Hz for $f \leqslant 20$ Hz. For $f > 20$ Hz, each one-third-octave band shall contain at least five frequencies of the source signal.

7.6 Measurements

7.6.1 General

The measurements shall be carried out under one or more specified load conditions, representing the range of loads in practice.

The measurements shall be carried out under one or more specified environmental temperatures, representing the range of the environmental temperatures in practice. The environmental temperature shall be monitored during the measurements. The resilient elements under test shall be exposed for at least 24 h to the appropriate environmental temperature within a tolerance of 3 °C, before they are tested.

If it is known or if it is reasonable to expect that the dynamic stiffness of the element under test is very sensitive to changes in temperature or humidity, tolerances for the temperature and humidity shall be defined within which the measurement results are considered as valid.

In a pre-run, the force level L_{F_1} and the acceleration level L_{a_1} shall be determined with and without the vibration source in operation. If possible, and unless otherwise specified, the source output shall be adjusted to obtain a minimum level difference of 15 dB in all frequency bands of interest, compared to measurements with the source switched off.

A further pre-run shall be performed to check that the acceleration in the excitation direction exceeds the acceleration in other directions. Measurement results, which do not meet the condition of Inequality (2), shall be excluded from the evaluation of the dynamic stiffness function.

Another pre-run shall be performed to check the appropriate accelerometer positions, when single accelerometers are used for measuring a_1 and a_2.

The main measurements shall be carried out for the acceleration a_{1x}, a_{1y} and a_{1z} on the input side of the test object, for the force F_1 on the input side, and for the acceleration a_{2x}, a_{2y} or a_{2z} on the output side. The z-direction corresponds with the normal direction and the x- and y- directions with the perpendicular transverse directions. Measurement results, which do not meet the requirements of 6.1 and 6.2, shall be excluded from the evaluation of the dynamic stiffness function.

7.6.2 Validity of the measurements

Further conditions for the validity of the measurement method are the following:

a) approximate linearity of the vibration behaviour of the isolator (see 7.7),

b) the contact interfaces of the vibration isolator with the adjacent source and receiver structures can be considered to be point contacts.

It is the responsibility of the user to demonstrate the frequency range of validity.

7.6.3 Measurement uncertainty

The uncertainty of results obtained from the measurements according to this part of ISO 10846 shall be evaluated, preferably in compliance with ISO/IEC Guide 98-3. If reported, the expanded uncertainty together with the corresponding coverage factor for a stated coverage probability of 95 % as defined in ISO/IEC Guide 98-3 shall be given.

Guidance on the evaluation of uncertainty and on the determination of the expanded uncertainty is given in Annex B.

NOTE Full application of ISO/IEC Guide 98-3 for determination of the expanded uncertainty is not expected to be possible at present, except for a few specialized laboratories. The existing knowledge on (possible) major uncertainty contributions and on reproducibility data is considered insufficient for the time being. Systematic investigations of the various sources of uncertainty as described in Annex B are needed to improve this situation. However, given the large variety of test elements and test apparatus and the limited funding for such investigations, progress on this item is expected to be slow.

7.7 Test for linearity

In the ISO 10846 series, the concept of dynamic transfer stiffness and the methods to measure it are based upon linear models for the vibration behaviour of resilient elements. However, real vibration isolators show at best only approximate linear behaviour. Therefore, to define precisely what is accepted in this part of

ISO 10846 as approximately linear, the validity of dynamic transfer stiffness data in relation to input vibration levels will be considered.

Because a full test on linearity is impractical, data measured according to this part of ISO 10846 shall be checked with respect to the degree of proportionality, in terms of the ratio of input force to the input acceleration (or velocity, or displacement); see 3.12, Notes 1 and 2.

The validity of dynamic driving point stiffness data measured according to this part of ISO 10846 may only be claimed for input amplitudes which are equal to or lower than those applied in the tests and for which approximate proportionality between input force and input displacement have been proved. This upper bound of input levels for which valid data can be claimed, shall be specified in the test report.

For the proportionality test, the following procedure shall be applied.

a) Let A be a one-third-octave-band spectrum of input levels.

b) Let B be another input spectrum, with one-third-octave-band levels at least 10 dB lower than A.

c) If the driving point stiffness levels for both excitation spectra A and B do not differ by more than 1,5 dB, then the driving point stiffness data shall be considered as valid in the range of input levels (or corresponding input amplitudes) equal to or lower than those of A.

d) If the maximum levels of A, which are possible in the test rig, are lower than typical input levels in practical applications of the tested elements, the test rig has to be modified or another test rig shall be used in order to obtain valid data for those applications.

e) If the tests, as described under c), lead to unacceptable results, the tests shall be repeated with lower input levels, until a valid input level range has been determined for proportionality between input force and input displacement (or acceleration if that is measured).

The range of valid input levels shall be specified as the values of one-third-octave-band levels of the input displacements (or accelerations if input accelerations have been measured), which are equal to or lower than those in the test with the higher input levels and with valid results.

NOTE On the basis of the upper bound of input levels, simplified test information can be derived, which may be presented optionally. For example, this can be a maximum of r.m.s. input displacement.

If a test element fails to meet the above-mentioned criteria for proportionality between input force and displacement, it shall be considered as non-linear. This part of ISO 10846 does not provide a measurement procedure for such cases. Nevertheless, large parts of it can then still be used to define application-oriented test procedures, e.g. for sinusoidal excitations with specified amplitudes.

8 Evaluation of test results

8.1 Calculation of dynamic driving-point stiffness

When input forces F_1 and accelerations a_1 have been measured, the calculation of dynamic driving-point stiffness requires conversion of accelerations to displacements u_1.

For simple harmonic vibration and using phasor notation:

$$k_{1,1}(f) = \frac{\underline{F}_1}{\underline{u}_1} = -(2\pi f)^2 \frac{\underline{F}_1}{\underline{a}_1} \tag{3}$$

The dynamic driving-point stiffness is a complex quantity with magnitude $\left|k_{1,1}(f)\right|$ and phase angle $\varphi_{1,1}(f)$.

Determination of the loss factor $\eta(f)$, as defined in 3.7, is optional. It may be estimated from

$$\eta(f) = \mathrm{Im}\left\{k_{1,1}(f)\right\} / \mathrm{Re}\left\{k_{1,1}(f)\right\} \tag{4}$$

This loss factor is also the tangent of the phase angle

$$\tan\varphi_{1,1}(f) = \eta(f) \tag{5}$$

8.2 One-third-octave-band values of the frequency-averaged dynamic driving-point stiffness

One-third-octave-band averages of $k_{1,1}$ shall be obtained as follows:

$$k_{\mathrm{av}(1,1)} = \left\{ \frac{1}{n} \sum_{i=1}^{n} \left| k_{1,1}(f_i) \right|^2 \right\}^{1/2} \tag{6}$$

where the summation is performed over a minimum of $n = 5$ frequencies.

NOTE 1 Averaging over the squared magnitude is chosen to emphasize the maxima in the stiffness values, which are usually the most important ones.

NOTE 2 The result of Equation (6) is the result measured directly with a real time one-third-octave-band analyser, in case of a flat power spectral density function of the input displacement u_1.

NOTE 3 It is evident that the presentation in terms of one-third-octave-band stiffness forms a practical reduction of the produced data. However, phase information is lost.

8.3 One-third-octave-band values of the frequency-averaged transfer stiffness

One-third-octave-band averages of $k_{2,1}$ shall be obtained by using the results of Equation (6) as follows:

$$k_{\mathrm{av}} = k_{\mathrm{av}(2,1)} \approx k_{\mathrm{av}(1,1)} \tag{7}$$

If $f \leqslant f_{\mathrm{UL}}$, then the accuracy of the approximation in Equation (7) is equal to or within 2 dB.

The results are presented in terms of the "level of frequency-band-averaged dynamic transfer stiffness" in accordance with 3.17.

Geometric centre frequencies f_{m} for one-third-octave pass bands shall be used in accordance with ISO 266.

8.4 Presentation of one-third-octave-band results

The presentation of dynamic transfer stiffness levels for one-third-octave bands shall be in tables and/or in graphical form. A table shall contain centre frequencies of one-third-octave bands, levels of dynamic stiffness in decibels and a specification of the reference value (i.e. 1 N/m).

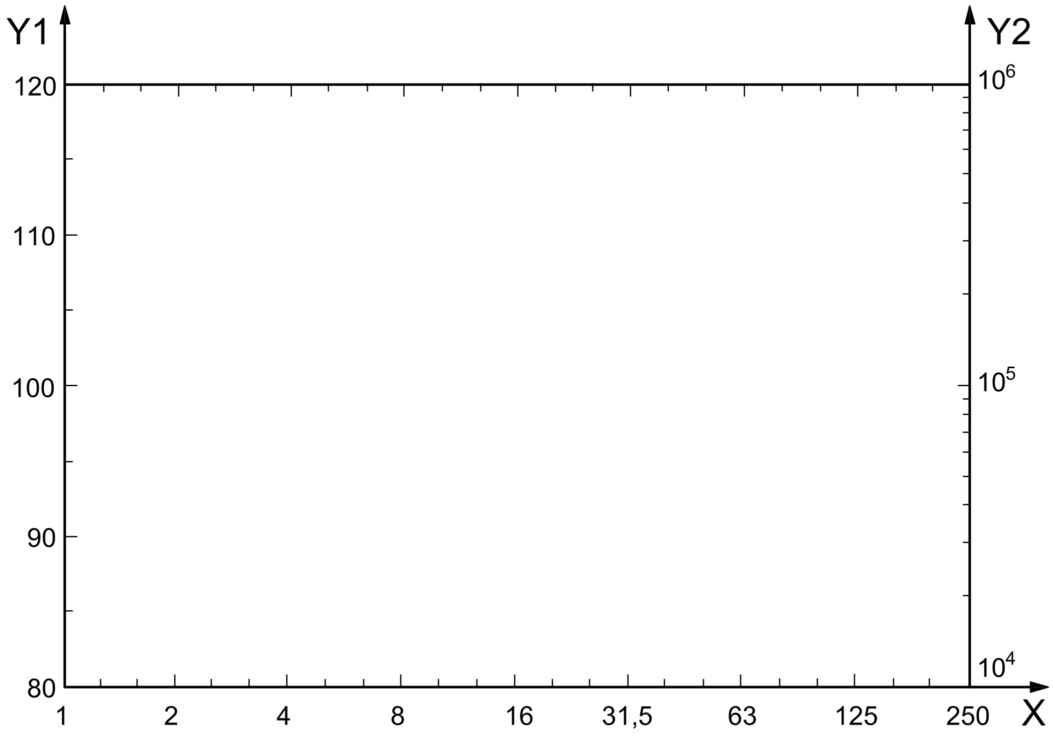
The format of the graphs shall be as follows:

- vertical scale: 20 mm for 10 dB or equivalently for a factor $10^{1/2}$ in magnitude;
- horizontal scale: 5 mm per one-third-octave band.

These dimensions may be enlarged or reduced in print, as long as the proper ratio is maintained. Grids may be used for sake of clarity.

NOTE An example of the graph format is shown in Figure 5. In addition to the decibel scale (vertical scale on the left) a logarithmic vertical scale in newtons per metre is given on the right.

The presentations shall include a clear description of the transfer stiffness concerned, i.e. for normal direction or for which transverse direction. Moreover, the temperature, the static preload and any other relevant special test conditions shall be specified.



Key

X frequency, Hz

Y1 $L_{k_{\text{av}}}$, dB (ref. 1 N/m)

Y2 k_{av}, N/m

F_{static} = ... N, T = ... °C

Figure 5 — Example of the graph for presenting one-third-octave-band levels of the dynamic transfer stiffness at specified test conditions with an example of scale values

8.5 Presentation of narrow-band data

Optionally, the magnitude and phase spectra of the dynamic transfer stiffness and spectra of the loss factor may be presented. The frequency resolution of the narrow-band analysis shall then be used.

NOTE 1 It is the responsibility of the user of this part of ISO 10846 to provide sufficient complementary information on the accuracy of the narrow-band phase or loss factor data.

The presentation of the level of magnitude of the dynamic stiffness shall be in graphical form and shall specify the reference value (i.e. 1 N/m). The format of the graphs should preferably be as follows:

- vertical scale: 20 mm for 10 dB or equivalently for a factor of magnitude $10^{1/2}$;
- horizontal scale: 15 mm per octave band.

The presentation of the phase data shall be in graphical form.

The format of the graphs should preferably be as follows:

- vertical scale: 40 mm for the range −180° to +180°;
- horizontal scale: 15 mm per octave band.

The presentation of the loss factor shall be in graphical form. The format of the graphs should preferably be as follows:

- vertical scale: 20 mm for a factor 10 in loss factor η;
- horizontal scale: 15 mm per octave band.

Linear scales for frequency and stiffness are allowed for narrow-band data in the frequency range 0 Hz up to 20 Hz.

NOTE 2 Concerning the above-mentioned graphical formats, also see the remarks in 8.4 on printing.

9 Information to be recorded

All relevant information shall be recorded, such as:

a) the name of the organization that performed the test;

b) information on the test element, including

  - manufacturer, type, serial number,
  - description of the element; in cases where this is not self-evident, the test element and non-test elements (auxiliary parts not included in the tests) shall be clearly defined,
  - data provided by the manufacturer in relation to the application as a vibration attenuator;

c) photograph(s) or diagrams of the resilient element and test arrangement; description of auxiliaries for static preload(s);

d) descriptions of force distribution plate(s) (dimensions, material, mass), of the foundation and its attachment to the test elements;

e) spectra of acceleration level differences to check that Inequalities (1) and (2) are respected;

f) measurement data validating the use of measurement positions which do not lie on an axis of symmetry;

g) static preload(s), in newtons;

h) environmental temperature(s) and its variation during the tests, in degrees Celsius;

i) other test conditions, such as:

  - relative humidity, in percent,
  - pre-conditioning of the test element,
  - any other relevant special condition (e.g. static deflection and super-imposed low-frequency vibration: amplitude, frequency);

j) description of test signal(s);

k) spectrum of acceleration level La_1 at the input side of the test element (displacement levels if displacements have been measured);

l) the measurement and analysis equipment used, including the type, location, serial number, calibration and manufacturer;

m) presentation of frequency-averaged dynamic transfer stiffness, in one-third-octave-band levels;

NOTE For $f \leqslant 20$ Hz it is acceptable to present narrow-band data on the dynamic driving point stiffness levels.

n) description of the linearity test (see 7.7), including data on levels or amplitude range of the acceleration a_1 or the displacement u_1 for which the test data are considered to be valid;

o) description of tests on the possible influence of background noise;

p) tolerances for the environmental temperature or humidity within which the test values are considered valid, for those resilient elements of which it is known or reasonable to expect that the dynamic stiffness is very sensitive to these environmental conditions.

The following are optional:

q) narrow-band magnitude spectra of dynamic driving-point stiffness;

r) narrow-band phase spectra of dynamic driving-point stiffness;

s) narrow-band spectra of loss factor;

t) simplified information of upper limit of input levels for which the test data are considered to be valid (e.g. a maximum of r.m.s. displacements).

u) static load-deflection curve (see Annex A)

10 Test report

The test report shall make reference to this part of ISO 10846 and shall include at least the items mentioned in Clause 9 under a), b), g), h), l) and m).

The test report shall include an evaluation of uncertainty; see 7.6.3.

Annex A
(informative)

Static load-deflection curve

If considered useful, the static load-deflection curve within the range 0 % to 100 % of the maximum permissible load may be added to the test report, with a description of or a reference to the measurement procedure. See, for example, References [4] and [5].

Annex B
(informative)

Measurement uncertainty

B.1 General

The uncertainty of the dynamic transfer stiffness measured according to this part of ISO 10846 has several origins, each of which leads to a partial contribution to the total uncertainty. Some of the partial contributions are well predictable, whereas others are rather unpredictable, in particular for occasional users of this part of ISO 10846.

The dynamic transfer stiffness is determined from a ratio between input acceleration (or velocity, or displacement) and input force and may be defined as a frequency response function of which the uncertainty may be frequency dependent.

Well-known uncertainty contributions for measuring a frequency response function originate from the measurement instrumentation, notably the accelerometers, force transducers, signal analysers and signal processing parameters. These contributions can be controlled very well, because for the measured quantities and the frequency range of interest, high quality and well understood transducers and signal analysers are available. Moreover, extensive knowledge has been published on transducer and analyser calibrations and on the relevant signal processing.

Uncertainty contributions, which are insufficiently known or difficult to control, are those connected with the variety of laboratory test rigs, which is permitted and with the large variety of resilient elements, which may be tested according to this part of ISO 10846. Because systematic studies and interlaboratory comparisons on these latter sources of uncertainty are lacking, the information on them is very scarce. However, generally speaking, these uncertainty contributions will vary depending on the combination of the test element and laboratory test rig. Therefore, for many intended users of this part of ISO 10846, it will not be possible to determine an accurate value of the uncertainty contributions involved. Especially for very stiff and (or) big test elements, these uncertainty contributions can become much bigger than those due to transducers, analysers and signal processing.

Another uncertainty contribution results from the use in this part of ISO 10846 of the dynamic driving point stiffness to determine the dynamic transfer stiffness. The discrepancy between these two stiffnesses is expected to increase with increasing frequency (c.f. Clause 4 and 6.2).

Because in this part of ISO 10846 several requirements are made to limit specified uncertainty contributions, an useful estimation of the various uncertainty contributions is still considered to be possible. In the following clauses of this annex the sources of uncertainty are discussed one by one and a structure is presented for the evaluation of the partial uncertainty contributions and the resulting total uncertainty.

B.2 Level of frequency-averaged dynamic transfer stiffness

The general expression for the calculation of the level of frequency-averaged dynamic transfer stiffness for one-third-octave bands, $L_{k_{\mathrm{av}}}$, is given by the following equation:

$$L_{k_{\mathrm{av}}} = \widehat{L}_{k_{\mathrm{av}}} + \delta_{\mathrm{ins}} + \delta_{\mathrm{rep}} + \delta_{\mathrm{rig}} + \delta_{\mathrm{dps}} + \delta_{\mathrm{lin}} \qquad \text{(B.1)}$$

where

$\hat{L}_{k_\mathrm{av}}$	is the input quantity determined according to 3.17 from the one-third-octave band value of the measured frequency-averaged dynamic driving point stiffness (see 8.2);
δ_ins	is an input quantity to allow for any uncertainty contribution due to the calibration and use of accelerometers, force transducers (load cells) and analyser and due to the signal processing;
δ_rep	is an input quantity to allow for any uncertainty contribution due to the installation repeatability of the test element in a particular laboratory test rig;
δ_rig	is an input quantity to allow for any uncertainty contribution originating from laboratory test rig properties;
δ_dps	is an input quantity to allow for any uncertainty contribution originating from the discrepancy between the measured dynamic driving point stiffness and the dynamic transfer stiffness;
δ_lin	is an input quantity to allow for any uncertainty contribution due to approximate instead of perfect linear behaviour of the test element as observed in the test for linearity (see 7.7).

NOTE The input quantities included in Equation (B.1) to allow for uncertainty contributions, are those thought to be applicable in the state of knowledge at the time when this part of ISO 10846 was being prepared. However, further research could reveal that there are others.

The partial contributions to the combined uncertainty of the dynamic transfer stiffness level, associated with each of the input quantities are briefly analysed in B.3 and B.4.

B.3 Standard uncertainties

B.3.1 Signal processing and background noise

By obeying the requirements for signal averaging (see 7.5) and for signal-to-noise ratios (see 7.6.1), the standard uncertainty $u_{\hat{L}}$ will not exceed 0,3 dB. Therefore, the user of this part of ISO 10846 is encouraged to use this value, when calculating the combined uncertainty. The uncertainty contribution due to signal processing and background noise is assumed to be a normally distributed random variable.

B.3.2 Instrumentation

The uncertainty due to measurement instrumentation will be caused by systematic and by random effects.

Random effects may originate from transducer calibrations. Systematic effects may originate from frequency-dependent variations in transducer frequency responses (see 6.3 to 6.5), from uncertainties in analyser channel gains (see 6.6) and from the positioning of accelerometers (see 7.3).

The total uncertainty contribution due to the measurement instrumentation is assumed to be a normally distributed random variable with a mean value of 0 dB and a standard uncertainty. Experience has shown that with good choices and precautions the standard uncertainty u_ins will not exceed 0,3 dB. However, when just the minimum instrumentation requirements of this part of ISO 10846 are met, i. e. when no extra efforts are made for using frequency response calibrations of transducers and analysers, a better estimate for the standard uncertainty u_ins is 0,5 dB. Therefore, the user of this part of ISO 10846 is encouraged to report either a reasoned estimate of standard uncertainty u_ins or to postulate that u_ins = 0,5 dB.

Table B.1 — Uncertainty budget for determination of the level of frequency-averaged dynamic transfer stiffness

Quantity	Estimate dB	Standard uncertainty u_i dB	Probability distribution	Sensitivity coefficient c_i	Uncertainty contribution $c_i u_i$ dB
Level of measured frequency-averaged dynamic transfer stiffness	$\hat{L}_{k_\text{av}}$	0,3	normal	1	0,3
δ_ins	0	0,5	normal	1	0,5
δ_rep	0	$p/\sqrt{3}$ [a]	rectangular	1	$p/\sqrt{3}$
δ_rig	0	0,3	rectangular	1	0,3
δ_dps	0	1,2	rectangular	1	1,2
δ_lin	0	0,5	rectangular	1	0,5

[a] $2p$ is the difference between measured maximum and minimum level in repeatability tests.

B.3.3 Installation of the test element

The uncertainty due to the installation of a test element in a particular laboratory test rig originates from the finite dynamic stiffness of connections between the test element and the test rig or its auxiliaries. Especially, for big test elements or for big auxiliaries, such as force distribution plates, a good quality of the connections may become critical to avoid large connection stiffness uncertainties, which may lead to measurement uncertainties; see 7.1.

In principle, the standard uncertainty u_rep can be determined by performing a series of tests for installation repeatability. However, because of the required large effort this will usually be uneconomic. For this reason, no general test procedures have been prescribed in this part of ISO 10846 for determining this type of uncertainty. Nevertheless, a test laboratory may describe its own repeatability tests or other procedure for making an estimation of the standard uncertainty and the appropriate probability distribution.

If such an effort cannot be made, users of this part of ISO 10846 are encouraged to report at least their experience-based estimation of the maximum error in dB. The latter can be done on the basis of a limited set of repeatability measurements. By the difference between the maximum and minimum measured values of the frequency-averaged dynamic transfer stiffness level equal to $2p$ dB, then, without having specific knowledge of the probability distribution, the standard uncertainty due to installation repeatability may be taken as $u_\text{rep} = p/\sqrt{3}$ dB .

B.3.4 Laboratory test rig

The uncertainty due to the properties of the laboratory test rig is predominantly determined by violation of the requirement for zero vibration on the output side of the test element, because in actual tests always $a_2 \neq 0$. Obeying Inequality (1), as specified in this part of ISO 10846, is supposed to limit the maximum error in the Input-force level due to apparatus properties to within 1 dB.

For quantifying the contribution of the test-rig-related uncertainty to the total uncertainty, users of this part of ISO 10846 are, generally speaking, advised to assume a rectangular probability distribution and a standard uncertainty $u_\text{rig} = 1/(2\sqrt{3}) \approx 0{,}3$ dB .

B.3.5 Difference between driving point stiffness and transfer stiffness

Differences between driving point stiffness and transfer stiffness form an uncertainty contribution, which cannot easily be determined. However, when using f_{UL} (cf 6.2) as the upper limiting frequency for this part of ISO 10846, the difference between the levels of $k_{1,1}$ and $k_{2,1}$ is assumed to lie between + 2 dB and − 2 dB. If no better knowledge is available, the user of this part of ISO 10846 is advised to use a standard uncertainty $u_{\mathrm{dps}} = {}^{2}\!/\!_{\sqrt{3}} \approx 1{,}2\ \mathrm{dB}$.

B.3.6 Test for linearity

The uncertainty contribution due to approximate instead of perfect linear behaviour of the test element, is kept between known limits, due to the restrictions for valid measurement results as defined by the test of linearity. According to 7.7, for valid measurements, a good estimation of the maximum errors in transfer stiffness levels due to non-linear behaviour is 1,5 dB.

For quantifying the contribution of linearity related uncertainty to the total uncertainty, users of this part of ISO 10846 are advised to assume a rectangular probability distribution and a standard uncertainty $u_{\mathrm{lin}} = {}^{1{,}5}\!/\!_{2\sqrt{3}} \approx 0{,}5\ \mathrm{dB}$.

B.4 Contributions to combined measurement uncertainty

The contributions to the combined uncertainty depend on each of the input quantities in Equation (B.1), their respective probability distributions and sensitivity coefficients c_i. The uncertainty budget needed for the calculation of the combined uncertainty is given in Table B.1.

B.5 Calculation of expanded uncertainty for a coverage probability of 95 %

The combined standard uncertainty of the frequency-averaged dynamic transfer stiffness level $u\left(L_{k_{\mathrm{av}}}\right)$ is given by the following equation

$$u(L_{k_{\mathrm{av}}}) = \sqrt{\sum_{i=1}^{6} \left(c_i u_i\right)^2} \tag{B.2}$$

The expanded uncertainty U is defined for a coverage probability of 95 %, meaning that the interval

$\left[\widehat{L}_{k_{\mathrm{av}}} - U, L_{k_{\mathrm{av}}} + U\right]$ covers 95 % of the values of $L_{k_{\mathrm{av}}}$ that might reasonably be attributed to $L_{k_{\mathrm{av}}}$.

Because the combination of the six inputs are assumed to result in a normal distribution, the value of the expanded uncertainty is given by

$$U = 2u(L_{k_{\mathrm{av}}}) \tag{B.3}$$

NOTE Because values of some of the standard uncertainties may be frequency dependent, the calculation according to Equation (B.3) might be performed for each frequency band for which such input data are known.

Bibliography

[1] ISO 1683, *Acoustics — Preferred reference quantities for acoustical levels*

[2] ISO 2017-1, *Mechanical vibration and shock — Resilient mounting systems — Part 1: Technical information to be exchanged for the application of isolation systems*

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

[4] DIN 2096-1, *Zylindrische Schraubendruckfedern aus runden Drähten und Stäben — Güteanforderungen bei warmgeformten Druckfedern* (*Helical compression springs made of round wire and rod — Quality requirements for hot formed compression springs*)

[5] DIN 2096-2, *Zylindrische Schraubendruckfedern aus runden Stäben — Güteanforderungen für Großserienfertigung* (*Cylindrical coil compression springs made from round rods — Quality requirements for mass production*)

ICS 17.140.01

Price based on 26 pages