INTERNATIONAL STANDARD

ISO 10846-2

First edition
1997-10-15

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

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

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

Partie 2: Raideur dynamique en translation des supports élastiques — Méthode directe

Reference number
ISO 10846-2:1997(E)

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.

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.

International Standard ISO 10846-2 was prepared jointly by Technical Committees ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*, and ISO/TC 108, *Mechanical vibration and shock*.

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

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet central@iso.ch
X.400 c=ch; a=400net; p=iso; o=isocs; s=central

Printed in Switzerland

Introduction

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

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

The laboratory conditions described in this part of ISO 10846 include the application of static preload. The results of the direct method are useful for isolators which are used to prevent low-frequency vibration problems and to attenuate structure-borne sound. The method is not sufficiently appropriate to characterize completely isolators which are used to attenuate shock excursions.

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

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

1 Scope

This part of ISO 10846 specifies a method for determining the dynamic transfer stiffness for translations of elastic supports, under specified preload. The method concerns the laboratory measurement of vibrations on the input side and blocking output forces and is called the direct method.

The method is applicable to elastic supports with parallel flanges (see figure 1).

NOTE 1 Vibration isolators which are the subject of this part of ISO 10846 are those which are used to reduce:

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

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 the available test rig(s) may restrict the use of very small or very large elastic supports.

NOTE 3 When an elastic support has no parallel flanges, an auxiliary fixture should be included as part of the test element to arrange for parallel flanges.

NOTE 4 Portions of continuous supports of strips and mats are used as test samples in this method. Whether or not the portion describes the behaviour of the complex system sufficiently is the responsibility of the user of this part of ISO 10846.

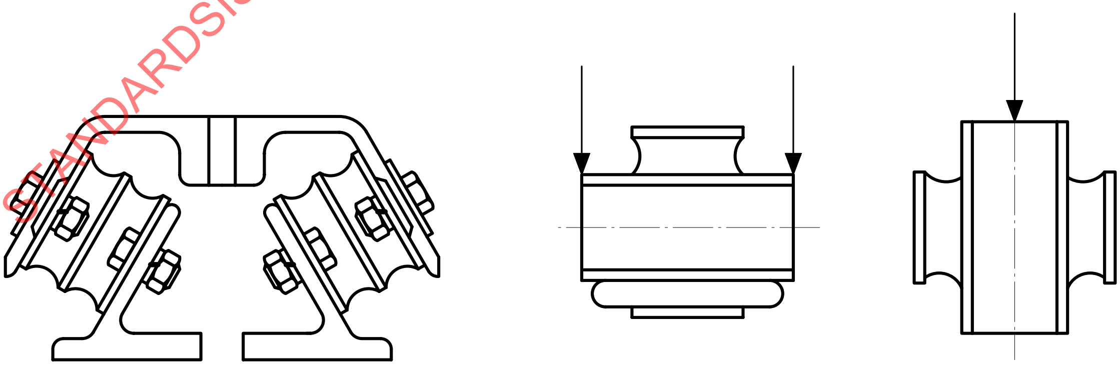

Figure 1 — Example of elastic supports with parallel flanges

Measurements for translations normal and transverse to the flanges are covered in this part of ISO 10846.

The method covers the frequency range from 1 Hz up to a frequency f_1, which is usually determined by the test rig.

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

— product information provided by manufacturers and to suppliers;

— information during product development;

— quality control;

— calculation of the transfer of vibrational energy through isolators.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 10846. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 10846 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of ISO maintain registers of currently valid International Standards.

ISO 266:—[1)], *Acoustics — Preferred frequencies.*

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

ISO 10846-1:1997, *Acoustics and vibration — Laboratory measurement of vibro-acoustic transfer properties of resilient elements — Part 1: Principles and guidelines*.

ISO 5347-3:1993, *Methods for the calibration of vibration and shock pick-ups — Part 3: Secondary vibration calibration*.

ISO 5348:1987**,** *Mechanical vibration and shock — Mechanical mounting of accelerometers*.

ISO 7626-1:1986, *Vibration and shock — Experimental determination of mechanical mobility — Part 1: Basic definitions and transducers*.

ISO 7626-2:1990, *Vibration and shock — Experimental determination of mechanical mobility — Part 2: Measurements using single-point translational excitation with an attached vibration exciter*.

3 Definitions

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

3.1
resilient element
(see vibration isolator)

3.2
vibration isolator
isolator designed to attenuate the transmission of vibration in frequency range [ISO 2041:1990, 2.110]

3.3
elastic support
vibration isolator suitable for supporting part of the mass of a machine, a building or another type of structure

1) To be published. (Revision of ISO 266:1975)

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 complex ratio of the force on the input side of a vibration isolator with the output side blocked to the complex displacement on the input side during simple harmonic vibration

NOTE 1 $k_{1,1}$ may depend on static preload, temperature and other conditions.

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

3.6
dynamic transfer stiffness
$k_{2,1}$
frequency-dependent complex ratio of the force on the blocked output side of a vibration isolator to the complex displacement on the input side during simple harmonic vibration

NOTE 1 $k_{2,1}$ may depend on static preload, temperature and other conditions.

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

3.7
loss factor of resilient element
η
frequency-dependent ratio of the imaginary part of $k_{2,1}$ to 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

3.8
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

3.9
point contact
contact area which vibrates as the surface of a rigid body

3.10
normal translation
translational vibration normal to the flanges of the isolator and parallel to the direction of the static preload

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 $\alpha x_1(t) + \beta x_2(t)$ produces the output $\alpha y_1(t) + \beta y_2(t)$. This must hold for all values of α, β and $x_1(t)$, $x_2(t)$; α and β 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. 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
direct method
method in which either the input displacement, velocity or acceleration and the blocking output force are measured

3.14
indirect method
method in which the vibration transmissibility (for displacement, velocity or acceleration) of an isolator is measured, with the output loaded by a known mass

3.15
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 vibration isolator blocked

3.16
vibratory force level
L_F
level calculated by the following formula:

$$L_F = 20 \lg \frac{F_{\text{rms}}}{F_0} \text{ dB}$$

where F_{rms} is the r.m.s. value of the force in a specific frequency band and F_0 is the reference force ($F_0 = 10^{-6}$ N)

3.17
vibratory acceleration level
L_a
level calculated by the following formula:

$$L_a = 20 \lg \frac{a_{\text{rms}}}{a_0} \text{ dB}$$

where a_{rms} is the r.m.s. value of the acceleration in a specific frequency band and a_0 is the reference acceleration ($a_0 = 10^{-6}$ m/s^2)

3.18
level of dynamic transfer stiffness
$L_{k_{2,1}}$
level calculated by the following formula:

$$L_{k_{2,1}} = 20 \lg \frac{|k_{2,1}|}{k_0} \text{ dB}$$

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

3.19
level of frequency-averaged dynamic transfer stiffness
$L_{k_{\text{av}}}$
level calculated by the following formula:

$$L_{k_{\text{av}}} = 20 \lg \frac{k_{\text{av}}}{k_0} \text{ dB}$$

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

3.20
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 elastic support under test

4 Principle

The measurement principle of the direct method is discussed in ISO 10846-1. The basic principle is that the blocking output force is measured between the output side of the vibration isolator and a foundation. The foundation must provide a sufficient reduction of the vibrations on the output side of the test object compared to those on the input side.

5 Apparatus

5.1 Normal translations

A schematic representation of a test rig for resilient supports exposed to normal translational vibrations is shown in figure 2. The test rig shall include the items listed in 5.1.1 to 5.1.5.

5.1.1 Resilient support under test, positioned on a heavy and stiff foundation table.

The resilient support under test is mounted using a force measurement system and under the appropriate static preload.

NOTE — In principle the static and dynamic actuator may be placed underneath the test object and the force measurement system on top between the test object and the moveable frame traverse. However, in practice this may lead to a more limited frequency range for valid measurements.

5.1.2 Preloading system, consisting of one of the following options:

a) a hydraulic actuator in a frame, which serves also as vibration exciter;

b) a frame, which provides static preload only (if this is applied, auxiliary vibration isolators shall be used for dynamic decoupling of the test object from the frame, see figure 2);

c) gravity load using a mass on top of the test object (with or without support frame).

NOTE — In many cases it will be necessary to apply a force distribution plate directly on top of the elastic support. Besides its function of load distribution, it also provides a uniform vibration of the top flange under dynamic forces.

5.1.3 Force measurement system on the output side of the elastic support, consisting of one or more force transducers.

NOTE 1 It may be necessary to apply a force distribution plate between the test element and the force transducers.

NOTE 2 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 bottom flange.

5.1.4 Acceleration measurement systems on the input and output sides of the test object.

The accelerometers on the flanges or on the force distribution plates may be placed on the vertical axis of symmetry. When such a placement is not feasible, the measurement may be made by taking the linear average of the signals of two symmetrically positioned accelerometers.

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

5.1.5 Dynamic excitation system, consisting of either

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

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

NOTE Dynamic decoupling of the vibration source from the test frame reduces the flanking transmission via the frame. In rigs which use a hydraulic actuator for both static and dynamic loading, such decoupling is usually avoided because it would have adverse affects on low-frequency measurements.

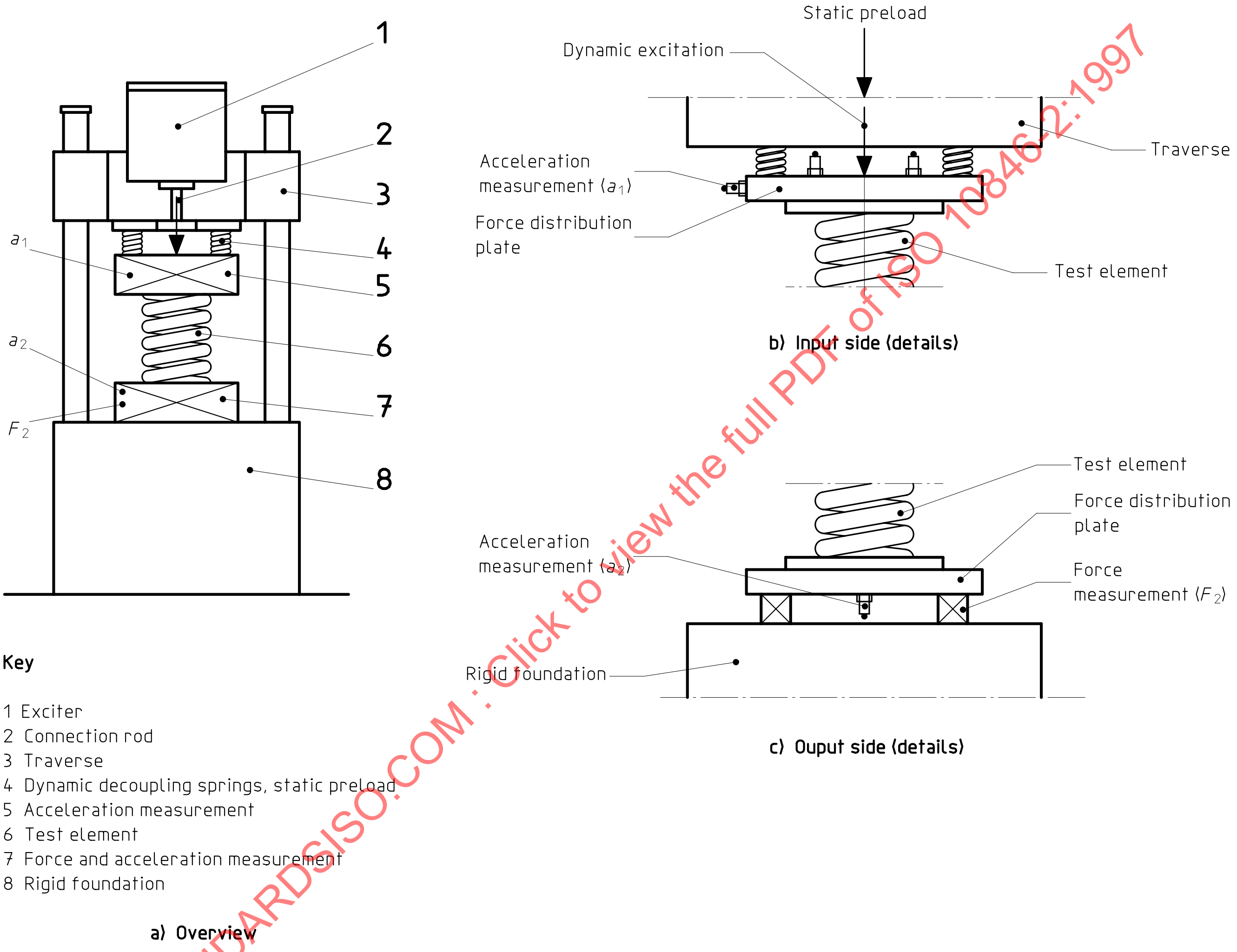

Figure 2 — Example of laboratory test rig for measuring the dynamic transfer stiffness for normal translations

5.2 Transverse translations

A schematic representation of a test rig for elastic supports exposed to translational vibrations perpendicular to the normal load direction is shown in figure 3 a). The test rig shall include the items listed in 5.2.1 to 5.2.5.

5.2.1 Resilient support under test, positioned on a heavy, stiff foundation table [if necessary with auxiliary supports, see figure 3 c)]. The foundation table shall provide a high degree of stiffness to the force measurement system in the measurement direction.

5.2.2 Preloading system, [see figure 3 b)] consisting of:

a) a force distribution plate (see the note in 5.1.2);

b) low friction bearings;

c) a top plate or beam for applying the static preload;

d) a hydraulic actuator or a mass supported by a frame, to apply the required static preload.

5.2.3 Force measurement system, consisting of one of the following options.

a) One or more force transducers for the measurement of shear forces [see figure 3 d)]. It may be necessary to apply a force distribution plate between the test element and the force transducers (see note 2 in 5.1.3).

b) Low friction bearings and one or more normal force transducers [see figure 3 c)]. It may be necessary to apply a force distribution plate between the test element and the force transducers (see note 2 in 5.1.3).

5.2.4 Acceleration measurement systems on the input and output sides of the test object.

The accelerometers on the flanges or on the force distribution plates may be placed on a horizontal symmetry axis of these components. Alternatively the measurement may be made by taking the linear average of the signals of two symmetrically positioned accelerometers.

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

5.2.5 Vibration exciter, with connection rod.

NOTE — See the note in 5.1.5 on dynamic decoupling of the exciter.

6 Criteria for adequacy of the test arrangement

6.1 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. Another limitation follows from the requirements for measuring the blocking output force. In figures 2, 3 and 4 the following dynamic measurement quantities are given:

F_2 blocking output force;

a_1 acceleration of input flange and input force distribution plate;

a_2 acceleration of output flange and output force distribution plate.

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

$$\Delta L_{12} = L_{a_1} - L_{a_2} \geq 20 \text{ dB} \quad (1)$$

NOTE — A too small value for the level difference ΔL_{12} can be explained by an insufficient stiffness mismatch between the test element and the foundation table or flanking transmission via the traverse and the columns to the output side of the test elements or by airborne sound. Use of vibration isolators to decouple the top test element from the load frame (see figure 2) and also to decouple the vibration exciter from the frame would reduce flanking transmission significantly.

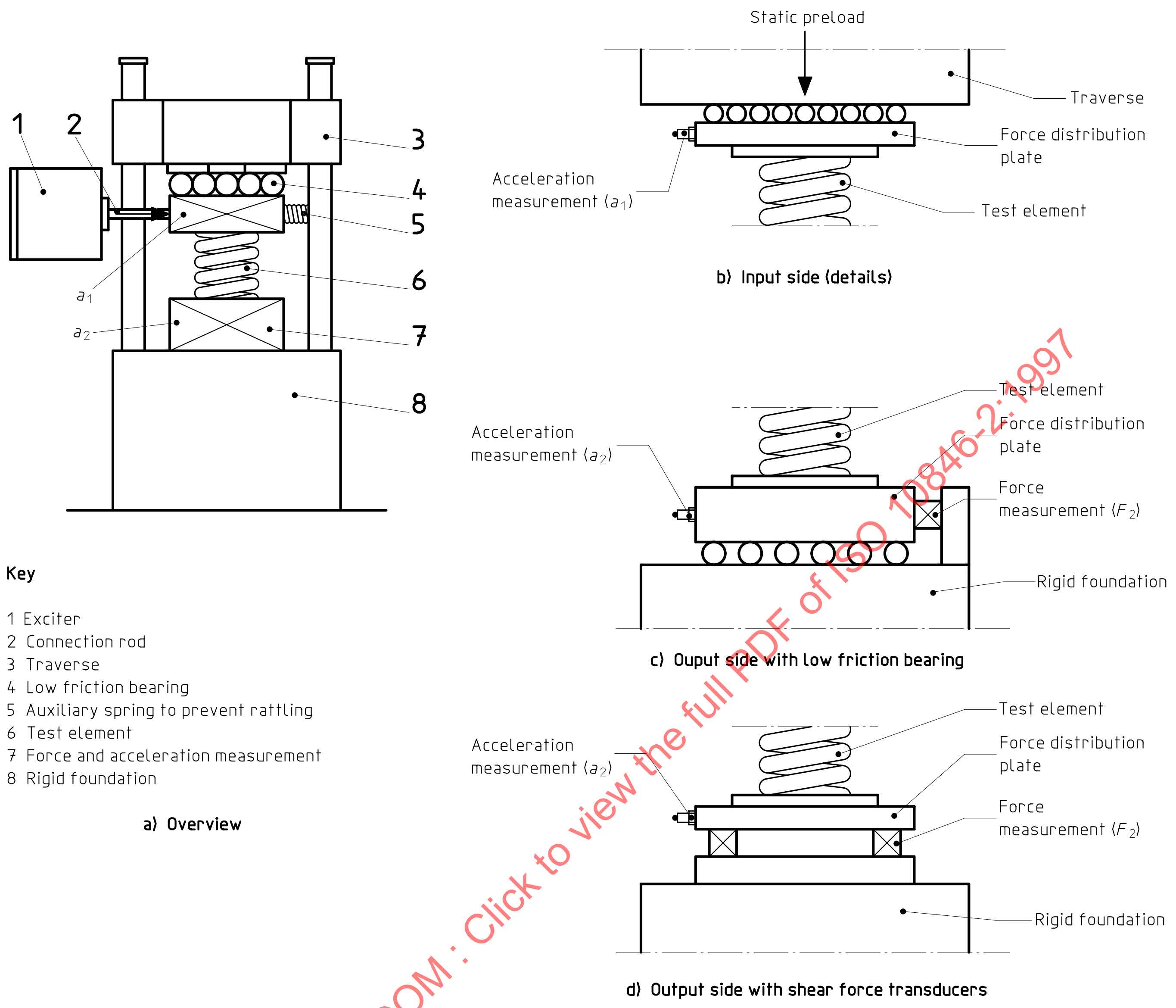

Figure 3 — Example of laboratory test rig for measuring the dynamic transfer stiffness for transverse translation

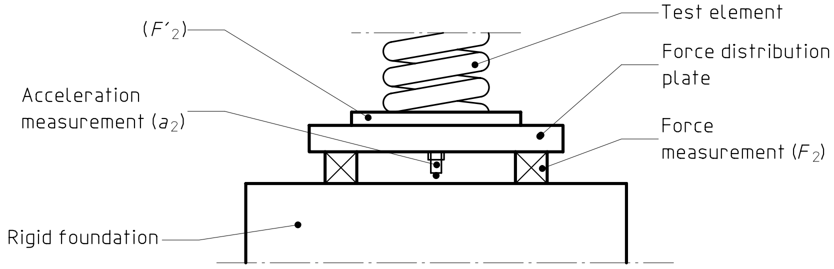

Figure 4 — Forces and acceleration on output side of the isolator

6.2 Measurement of blocking force

The mass between the test isolator and the output force transducers causes a bias error in the measurement of the blocking force. Using the symbols in figure 4, the difference between the approximated blocking force F'_2 and the measured force F_2 is equal to the inertia force $m_2 a_2$.

The mass m_2 is the sum of the mass of the output force distribution plate and half the mass of the force transducers and shall respect the following inequality:

$$m_2 \leq 0{,}06 \times \frac{10^{L_{F2}/20}}{10^{L_{a2}/20}} \text{ kg} \qquad (2)$$

NOTE 1 Inequality (2) is equivalent to the requirement that $\left| L_{F'_2} - L_{F_2} \right| \leq 0{,}5$ dB

NOTE 2 If inequality (2) is not respected then either a decrease of m_2 or an increase of force transducer(s) stiffness is needed. The latter may imply the use of more transducers or a larger transducer.

6.3 Force transducers

Force transducers shall be used which are calibrated 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 insensitive to extraneous environmental effects such as temperature, 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 sensitivity.

6.4 Accelerometers

Accelerometers shall be used which are calibrated in the frequency range of interest and which have a sensitivity level which is frequency independent within 0,5 dB. Calibration shall be carried out according to ISO 5347-3.

The sensitivity of the accelerometer for cross-axis vibrations should be less than 5 % of that for the main axis of sensitivity.

Concerning extraneous environmental effects, the same requirements as for force transducers apply (see 6.3).

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

6.5 Summation of signals

If signals from force transducers or from accelerometers have to be added, this shall be performed using transducers with sensitivities within 5 % of each other and analogue summation.

6.6 Analysers

Narrow-band analysers fulfilling the following requirements shall be used. In the frequency range of interest, the spectral resolution shall provide at least five distinct frequencies per one-third-octave band for frequencies above 20 Hz. For $f \leq 20$ Hz the frequency spacing shall be 0,2 Hz.

The difference in frequency responses between the channels which are used for the blocking force and for the acceleration measurement shall be less than 0,5 dB for a measurement with the same frequency resolution as used for testing the resilient support. Otherwise, corrections shall be made to compensate for the differences in channel gain factors.

NOTE — One way in which channel gains can be compared is as follows. An identical broadband signal (e.g. white noise) is applied as input on both channels. The narrow band spectrum level of the ratio of the channel outputs should then 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 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 are applied.

The force distribution plate shall be as small and light as possible and 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 transfer 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.

7.2 Mounting of the elastic support and preloading

Attach the elastic support to the output force distribution plate so as to ensure good contact over the entire surface. Then connect the static preloading system to the input side. Pre-stressing devices preloading the test object, which are not part of the resilient element in practical applications, shall be deactivated and removed.

NOTE — Grease or double sided tape may be used to ensure a good contact between the elastic support and the force distribution plate. Flattening may be necessary for supports with large flanges in order to obtain unambiguous test results.

Preloading shall be applied to rubber supports up to 100 % of the permissible static load. Change of load or deflection due to creep shall be less than 10 % per day before measurements are performed.

No particular preloading procedure is required for steel springs, but apply the appropriate preload.

7.3 Mounting and connection of accelerometers

Accelerometers are mounted below and above the test object to measure a_1 and a_2, respectively (see figures 2 and 3). The connection shall be stiff. Mounting shall be carried out according with ISO 5348.

Select positions on the force distribution plates or on the flanges of the test object. 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 suffice. Check that the influence of rotational vibrations does not lead to errors of more than 0,5 dB.

NOTE — Such a check can be performed by measuring the accelerations at different distances from the symmetry axis.

To prevent errors due to flange rotations, summed signals can be used from two accelerometers symmetrically positioned with respect to the vertical symmetry axis.

7.4 Mounting and connections of the vibration exciter

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

7.5 Source signal

One of the following source signals may be used:

— a discretely stepped sinusoidal signal;

— a swept sine signal;

— a periodically swept sine signal; or

— a bandwidth-limited white noise signal.

Apply the source signal long enough to allow for averaging, so that the measured quantities do not differ by more than 0,2 dB from the average over a very long time.

When 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 $f < 20$ Hz. For $f > 20$ Hz, each one-third-octave band of the analysis shall contain at least five frequencies of the source signal.

7.6 Measurements

7.6.1 General

Carry out the measurements under one or more specified load conditions, representing the range of loads in practice.

Carry out the measurements under one or more specified environmental temperatures, representing the range of environmental temperatures in practice.

Monitor the environmental temperature during the measurements. Before they are tested, expose the elastic supports under test to the appropriate environmental temperature, within a tolerance of ± 3 °C, for at least 24 h.

If it is known or reasonable to expect that material properties of the element under test (such as damping) are very sensitive to changes in temperature of the element, tolerances for the temperature shall be defined, within which the measurement uncertainly according to 7.6.3. is maintained.

In a pre-run, determine the force level L_{F_2} and acceleration level L_{a_1} with and without the vibration source in operation. If possible, and unless otherwise specified, the source output is adjusted to obtain a minimum level difference of 15 dB in all frequency bands of interest, compared to the measurements with the source switched off.

A further pre-run is required to check the appropriate accelerometer positions, when single accelerometers are used for measuring a_1 and a_2.

The main measurements are carried out for the acceleration a_1 on the input side of the test object and for the force F_2 on the output side. In addition, determine the level difference $L_{a_1} - L_{a_2}$. Where these level differences are less than 20 dB, frequency bands must be excluded from evaluation of the dynamic stiffness function.

7.6.2 Validity of the measurements

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

a) approximate linearity of the vibrational 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.

7.6.3 Measurement uncertainty

The standard uncertainty of the dynamic transfer stiffness of an elastic support measured according to this part of ISO 10846, is approximately 1,5 dB in level or approximately 18 % in the magnitude.

NOTE — The standard uncertainty may be frequency dependent. Given the present state of the art, further testing on measurement uncertainty is needed. An interlaboratory test should be organized for this purpose.

7.7 Test for linearity

In parts 1 to 5 of ISO 10846, the concept of dynamic transfer stiffness and the methods of measuring it are based on linear models for the vibration behaviour of resilient elements. However, real vibration isolators show only approximate linear behaviour at best. Therefore, the validity of dynamic transfer stiffness data in relationship to input vibration levels will be considered to define precisely what is accepted as approximately linear according to this part of ISO 10846.

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 between output and input, in terms of the ratio of force output to the input acceleration (or velocity, or displacement); see notes in 3.12.

Validity of dynamic transfer stiffness data measured according to this part of ISO 10846 can only be claimed for input amplitudes which are equal to or lower than those applied in the tests and for which approximate proportionality between output and input has been proved. This upper boundary of input levels for which valid data can be claimed shall be specified in the test report.

The following procedure shall be applied for the proportionality test.

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 transfer stiffness levels for both excitation spectra A and B do not differ by more than 1,5 dB, the transfer stiffness data shall be considered to be valid within the range of input levels (or corresponding input amplitudes) equal to or smaller 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 shall 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 output and input.

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

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

If a test element fails to meet the above mentioned criteria for proportionality between input and output, it shall be considered to be non-linear. This part of ISO 10846 does not specify a measurement procedure for such cases. Nevertheless, large parts of it may 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 transfer stiffness

When blocking forces F_2 and accelerations a_1 have been measured, the calculation of dynamic transfer stiffness requires conversion of accelerations to displacements.

For simple harmonic vibration,

$$k_{2,1}(f) = \frac{F_2}{u_1} = -(2\pi f)^2 \frac{F_2}{a_1} \quad (3)$$

The dynamic transfer stiffness is a complex quantity with magnitude $|k_{2,1}(f)|$ and phase angle $\phi_{2,1}(f)$.

The loss factor $\eta(f)$, as defined in 3.6, may be estimated from

$$\eta(f) = \text{Im}\,\{k_{2,1}(f)\} / \text{Re}\,\{k_{2,1}(f)\} \quad (4)$$

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

One-third-octave-band averages of $k_{2,1}$ are obtained as follows:

$$k_{av} = \left\{ \frac{1}{n} \sum_{i=1}^{n} \left| k_{2,1}(f_i) \right|^2 \right\}^{1/2} \qquad (5)$$

where the summation is performed over the n frequencies within the one-third-octave bands; see 6.6 for the minimum number of lines.

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 (5) is equivalent to 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.

The results are presented as levels according to 3.19 as:

$$L_{k_{av}} = 20 \lg k_{av} / (1 \, \text{N} \cdot \text{m}^{-1}) \text{ dB} \qquad (6)$$

Geometric centre frequencies f_m for one-third-octave pass bands shall be used in agreement with ISO 266. For the calculation according to equation (5), the frequencies f_i shall lie within the following range:

$$0{,}890\,9\, f_m < f_i < 1{,}122\,5\, f_m \qquad (7)$$

8.3 Presentation of one-third-octave-band results

The presentation of the dynamic transfer stiffness levels for one-third-octave bands may be in tables and/or in graphical form. A table shall contain centre frequencies of one-third-octave bands, levels of dynamic transfer stiffness in decibels and specification of the reference level (i.e. 1 $\text{N} \cdot \text{m}^{-1}$).

The format of the graphs shall be as follows:

— vertical scale: 20 mm for 10 dB or equivalently for a factor of magnitude $10^{½}$;

— 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 the sake of clarity.

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.

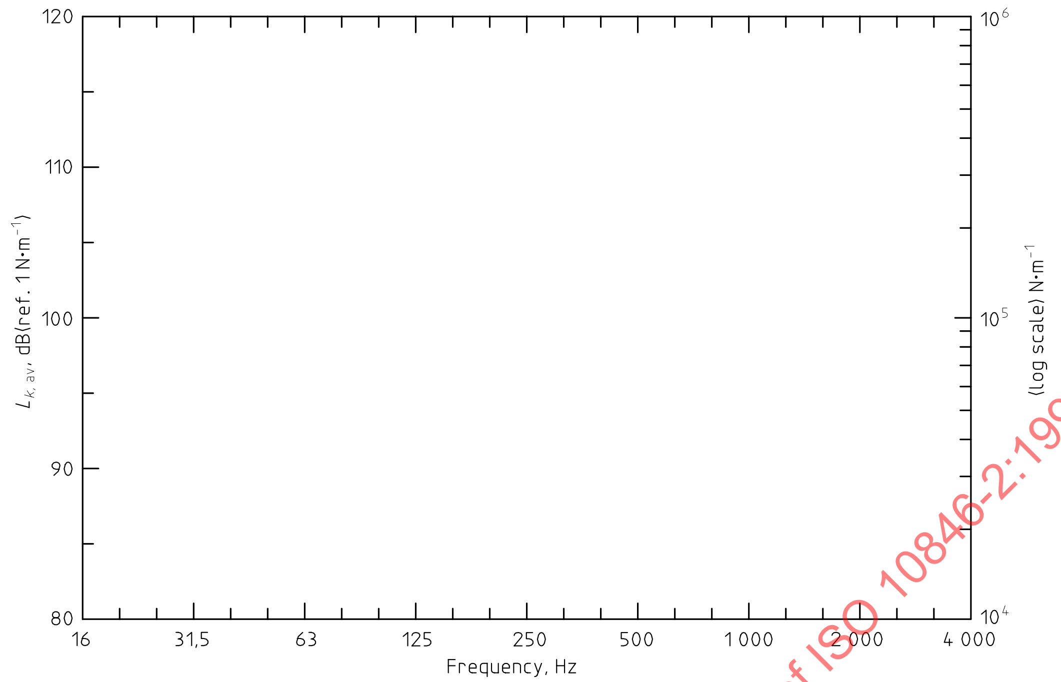

Figure 5 — Example of the format of the graph for presenting one-third-octave-band levels of the dynamic transfer stiffness with an example of scale values

8.4 Presentation of narrow-band data

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

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

— vertical scale: 20 mm for 10 dB or equivalently for a factor of magnitude $10^{½}$;

— 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 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 — See further remarks in 8.3 on printing.

9 Information to be recorded

The following data shall be recorded during the measurements:

— environmental temperature (°C);

— static preload(s) (N).

10 Test report

The test report shall make reference to this part of ISO 10846 and shall include at least the following information:

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

b) information on the test element, including

1) manufacturer, type, serial number,

2) 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,

3) data provided by the manufacturer concerning the application as vibration isolator;

c) photograph(s) of elastic support and test rig;

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

e) measurement data that prove that inequality (1) is respected;

f) measurements validating the use of non-axis of symmetry measurement locations, if appropriate;

g) test conditions:

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

2) if relevant, tolerances of test element temperature within which the maximum measurement uncertainty according to 7.6.3 is maintained (see 7.6.),

3) static preload(s), in newtons,

4) any other relevant special condition (e.g. static deflection and superimposed low-frequency vibration: amplitude, frequency);

h) description of test signal(s);

i) spectrum of acceleration level L_{a_1} at the input side and the acceleration level L_{a_2} at the output side of the test element (displacement levels if displacements have been measured);

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

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

l) presentation of frequency-averaged dynamic transfer stiffness in one-third-octave-band levels and indication of the ranges where the requirements of valid measurements according to equation (1) are not met;

NOTE — For f < 20 Hz it is acceptable to present narrow-band data on the dynamic transfer stiffness levels.