INTERNATIONAL STANDARD

ISO 13753

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Mechanical vibration and shock — Hand-arm vibration — Method for measuring the vibration transmissibility of resilient materials when loaded by the hand-arm system

Vibrations et chocs mécaniques — Vibrations main-bras — Méthode pour mesurer le facteur de transmission des vibrations par les matériaux résilients chargés par le système main-bras

Reference number
ISO 13753:1998(E)

Foreword

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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 13753 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 4, *Human exposure to mechanical vibration and shock*, in close collaboration with CEN/TC 231, *Mechanical vibration and shock*.

Annex A forms an integral part of this International Standard. Annexes B to F are for information only.

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Introduction

This International Standard was developed in response to the growing demand to protect people from the risks of vibration damage caused by exposure to hand-transmitted vibration.

Various standards refer to measurement and assessment of risk to vibration exposure and to methods of type testing specific tools and processes.

Resilient materials are used to cover handles and make gloves. It is hoped that both of these will reduce the magnitude of the vibration exposure. This International Standard describes a method of measuring the vibration attenuation of a sample of the material in the form of a flat sheet or layer. In some cases the material may be of two or more layers forming a sheet. It is a laboratory measurement and offers a reproducible and reliable procedure.

This International Standard assumes that the material behaves in a linear way and that it has negligible mass compared with the mass loading. (A correction could be made for the material mass if required.) The method determines the impedance of the material when loaded by a mass providing a compression force equivalent to that found when the material is gripped by the hand. This is done by measuring the transfer function of the mass-loaded material at all the required frequencies. The vibration transmission when loaded by the hand is computed using standard values of hand-arm impedance and the measured values of the material impedance. The impedances used in this International Standard are for the palm of the hand when gripping a circular handle. The resulting transmissibility may not be applicable to the fingers. The impedance for the z_h direction of the hand-arm system where the material is under compression is used. The mathematical basis of the method is contained in annex B.

If the results of this measurement procedure show transmissibilities greater than 0,6 at all frequencies up to 500 Hz, then the material would probably not provide greater attenuation in the practical situation in the same frequency range. In the practical situation, the transmissibility as a function of frequency should be appropriate to the frequency spectrum of the source.

Mechanical vibration and shock — Hand-arm vibration — Method for measuring the vibration transmissibility of resilient materials when loaded by the hand-arm system

1 Scope

This International Standard specifies a procedure to determine the vibration transmissibility of a resilient material when loaded by the hand-arm system.

The method is applicable to all materials which behave in a linear way. It is expected that this is realized in most elastic foam and rubber materials and, provisionally, in woven cloths. The method can be applied to mixed systems, e.g. a cloth material attached to a foam or rubber base.

It is expected that the results of this laboratory test will be used in screening materials used for vibration attenuation on the handles of tools and for gloves. This will enable rank ordering of materials for gloves, but will not necessarily predict the transmissibility of the gloves fabricated from these materials (for this purpose, see ISO 10819).

2 Normative references

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

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

ISO 5349:1986, *Mechanical vibration — Guidelines for the measurement and the assessment of human exposure to hand-transmitted vibration.*

ISO 5805:1997, *Mechanical vibration and shock — Human exposure — Vocabulary*.

ISO 10068:—[1)], *Mechanical vibration and shock — Free, mechanical impedance of the human hand-arm system at the driving point*.

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 2041, ISO 5349 and ISO 5805 apply.

NOTE For hand-transmitted vibration, see ISO 5805. For transmissibility, see ISO 2041.

1) To be published.

4 Symbols

The following symbols are used:

a_1 acceleration measured on the shaker

a_2 acceleration measured on the mass m loading the material

real subscript used to denote the real part of a complex quantity

imag subscript used to denote the imaginary part of a complex quantity

$| \; |$ denotes modulus of a complex quantity

m mass loading the resilient material

T transmissibility

Z_M impedance of the resilient material

Z_H impedance of the hand-arm system. This value is obtained from ISO 10068 (see annex A).

ω angular frequency

j denotes the square root of minus one

$A_i(\mathrm{j}\omega)$ or in short A_i: Fourier transform of a_i.

EXAMPLE:

$\left[\frac{A_1(\mathrm{j}\omega)}{A_2(\mathrm{j}\omega)}\right]_{\mathrm{real}}$ denotes the real part of the complex ratio $A_1(\mathrm{j}\omega)$ and $A_2(\mathrm{j}\omega)$.

5 Principle

The method uses a vibration excitation system (shaker) on which the resilient material is placed with the loading mass m on the top. Accelerometers measure the vibration on the shaker, a_1, and the vibration of the mass m, a_2. The shaker may be driven by a wide-band random signal or a sinusoidal signal.

6 Measuring equipment

6.1 General requirements

A frequency analyser (preferably twin-channel), two transducers and two channels of measuring equipment are required.

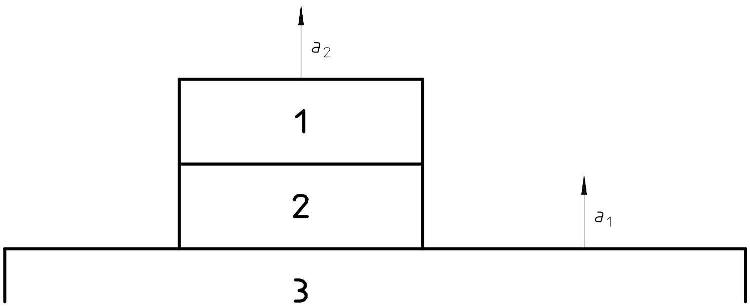
The measuring setup is shown in figure 1.

6.2 Acceleration transducers and preamplifiers

The transducers (accelerometers) and preamplifiers chosen shall be suitable for the frequency range 5 Hz to 1 000 Hz. An overload indication shall be provided.

6.3 Transducer mounting

The two transducers shall be rigidly mounted to flat surfaces on the shaker and the loading mass m. The mounting may be achieved using a screw, glue or beeswax. The mounting shall be such that the transfer function between the two transducers is unity up to at least 1 000 Hz without the material sample.



Key

1 Mass m
2 Resilient material
3 Shaker

Figure 1 — Measurement setup

7 Test sample and mass m

The sample shall be flat and of constant thickness, containing a circular area of at least 45 mm radius. The sample should not spread over the edge of the shaker table. A circular cylinder of metal (e.g. steel), with radius 45 mm and mass 2,5 kg shall be used to load the resilient material.

8 Measurement procedure

8.1 Measure simultaneously the accelerations a_1 and a_2, measured on the shaker and on top of the mass m.

8.2 The shaker may be excited using a wide-band random signal. The power spectral density should be constant within ±10 % between 10 Hz and 500 Hz with a magnitude of at least $2{,}5 \times 10^{-2}$ $(\text{m/s}^2)^2/\text{Hz}$.

8.3 Alternatively, the shaker may be excited by sinusoidal signals. The excitation magnitude a_1 should be at least 1 m/s^2.

NOTE The coherence function of the two signals should be measured at each frequency and should be greater than 0,95, although it may fall lower than this value at the resonance frequency.

8.4 Measurement of the ratio A_1/A_2 shall be performed (in terms of both modulus and phase or in terms of real and imaginary parts) at each frequency. This ratio is a complex function.

8.5 For the purpose of the test report, measurement of transmissibility should be made at the one-third-octave band centre frequencies between 50 Hz and 500 Hz. It is recommended to measure at lower frequencies, down to 10 Hz, if possible.

9 Evaluation of results

First determine the material impedance Z_M and use this value with the hand-arm impedance Z_H to determine the transmissibility.

9.1 Determination of material impedance Z_M

The material impedance is calculated using equation (1):

$$Z_M = \frac{j\omega m}{\left[\frac{A_1}{A_2}\right] - 1} \qquad \text{. . . (1)}$$

9.2 Determination of the transmissibility T

The transfer function A_2/A_1 when the material is loaded by the hand-arm system is the required vibration transmissibility. This is calculated using Z_M obtained in 9.1, and the values of Z_H which are obtained from ISO 10068 (see annex A):

$$T = \left| \frac{Z_M}{Z_H + Z_M} \right| \qquad \text{. . . (2)}$$

NOTE Equations (1) and (2) contain complex quantities. The full evaluation of these equations is given in annex C. Examples of calculations of the transmissibility T are shown in annex D.

9.3 Accuracy of measurement of the transmissibility T

The accuracy (repeatability) of the measured transmissibility is expected to be about 10 %. This will depend on the linearity of the sample, the accuracy of the impedance value Z_H and other measurement parameters (see annex E).

NOTE 1 The accuracy of the measured transmissibility of non-linear material can be much higher than 10 %.

NOTE 2 The tolerances of the shaker and the measurement instrumentation can also produce variations in results.

10 Test report

The test report shall contain the following:

a) a reference to this International Standard;

b) name and address of material manufacturer;

c) description of material including thickness, dimensions, mass and type of material;

d) number of samples tested;

e) name and address of testing laboratory and date of test;

f) description of measuring system;

g) type of excitation signal (sinusoidal or random) and its characteristic data;

h) environmental conditions including temperature and humidity;

i) values of transmissibilities at frequencies (in hertz):

50, 63, 80, 100, 125, 160, 200, 250, 315, 400, 500

and if possible at 10, 12,5, 16, 20, 25, 31,5 and 40.

Annex A
(normative)

Values of the hand-arm impedance Z_H

Table A.1 gives the values of Z_H taken from ISO 10068. They are quoted in terms of modulus and phase and also in terms of the real and imaginary parts which are used in the evaluation of the transmissibility T.

Table A.1 — Values of the hand-arm impedance Z_H

Frequency Hz	**Modulus** $\lvert Z_H \rvert$ N·s/m	**Phase** degrees	**Real part** $(Z_H)_{real}$ N·s/m	**Imaginary part** $(Z_H)_{imag}$ N·s/m
10	156	30	135,1	78
12,5	170	28	150,1	79,8
16	185	24	169	75,2
20	198	19	187,2	64,5
25	210	15	202,8	54,4
31,5	225	8	222,8	31,3
40	228	1	228	4
50	210	– 4	209,5	– 14,6
63	181	– 6	180	– 18,9
80	161	– 3	160,8	– 8,4
100	165	2	164,9	5,8
125	180	8	178,2	25,1
160	190	14	184,4	46
200	205	18	195	63,3
250	221	19	209	72
315	236	20	221,8	80,7
400	251	20	235,9	85,8
500	270	23	248,5	105,5

Annex B
(informative)

Mathematical basis for the measurement of the vibration transmissibility of resilient materials

B.1 Evaluation

The material is compressed using a mass of 2,5 kg over an area with a 45 mm radius. The transfer function is measured using transducers on the mass and on the base. The material impedance is evaluated.

$\frac{A_1(\mathrm{j}\omega)}{A_2(\mathrm{j}\omega)}$ is a complex function.

At a single frequency there is $\frac{A_1(\mathrm{j}\omega)}{A_2(\mathrm{j}\omega)} = magnitude \times [\cos(phase) + \mathrm{j}\sin(phase)]$

where

magnitude is the magnitude of the ratio denoted by A_1/A_2;

phase is the phase difference between A_1 and A_2.

The impedance of the material is then obtained using the impedance of the mass and the complex function A_1/A_2:

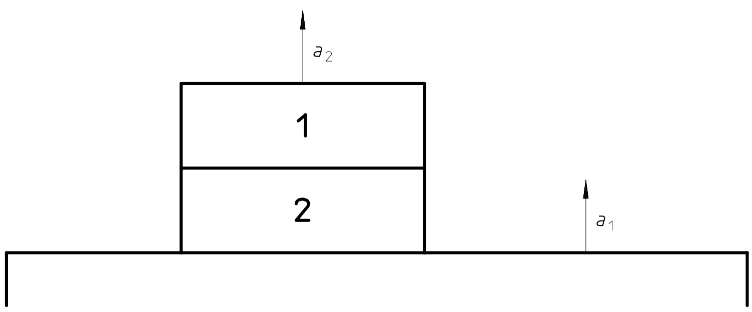
$$Z_\mathrm{M} = \frac{\mathrm{j}\omega m}{\left[\frac{A_1}{A_2}\right] - 1}$$

The transfer function when the material is loaded by the hand-arm system is then computed

$$T = \left|\frac{Z_\mathrm{M}}{Z_\mathrm{H} + Z_\mathrm{M}}\right|$$

where Z_H is the hand-arm impedance.

B.2 Theoretical basis



Key

1 Mass m

2 Resilient material of impedance Z_M

$a_2 = \ddot{x}_2$

$a_1 = \ddot{x}_1$

where x_2 and x_1 are displacements.

Figure B.1 — Theoretical model with mass m

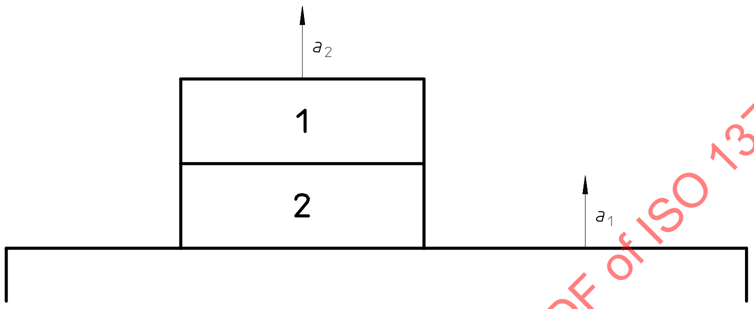
Assuming the material has negligible mass:

$$m\ddot{x}_2 = -Z_M(\dot{x}_2 - \dot{x}_1)$$

(Newton's 2nd law) from which

$$Z_M = \frac{j\omega m}{\left[\frac{A_1}{A_2}\right] - 1}$$

When gripped by the hand the model becomes as shown in figure B.2.



Key

1 Hand-arm impedance Z_H
2 Resilient material of impedance Z_M

Figure B.2 — Theoretical model with hand-arm impedance Z_H

Again assuming the material has negligible mass:

$$Z_H\dot{x}_2 = -Z_M(\dot{x}_2 - \dot{x}_1)$$

from which

$$T = \left|\frac{\dot{x}_2}{\dot{x}_1}\right| = \left|\frac{Z_M}{Z_H + Z_M}\right|$$

Annex C
(informative)

Full evaluation of equations (1) and (2)

This annex shows equations (1) and (2) of clause 9 in their full form showing the real and imaginary parts.

$$Z_M = \frac{j\omega m}{\left[\frac{A_1}{A_2}\right]_{real} - 1 + j\left[\frac{A_1}{A_2}\right]_{imag}}$$

so that

$$(Z_M)_{real} = \frac{\omega m \left[\frac{A_1}{A_2}\right]_{imag}}{\left[\left(\frac{A_1}{A_2}\right)_{real} - 1\right]^2 + \left[\frac{A_1}{A_2}\right]_{imag}^2}$$

$$(Z_M)_{imag} = \frac{\omega m \left[\left(\frac{A_1}{A_2}\right)_{real} - 1\right]}{\left[\left(\frac{A_1}{A_2}\right)_{real} - 1\right]^2 + \left[\frac{A_1}{A_2}\right]_{imag}^2}$$

and

$$T = \left|\frac{A_2}{A_1}\right| = \left|\frac{Z_M}{Z_H + Z_M}\right| = \sqrt{\frac{|Z_M|^2}{|Z_H|^2 + |Z_M|^2 + 2\left[(Z_H)_{real}(Z_M)_{real} + (Z_H)_{imag}(Z_M)_{imag}\right]}}$$