INTERNATIONAL STANDARD

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Mechanical vibration and shock — Characterization of the dynamic mechanical properties of visco-elastic materials —

Part 1:
Principles and guidelines

Vibrations et chocs mécaniques — Caractérisation des propriétés mécaniques dynamiques des matériaux visco-élastiques —

Partie 1: Principes et lignes directrices

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Contents

Page

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 18437-1 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*.

ISO 18437 consists of the following parts, under the general title *Mechanical vibration and shock — Characterization of the dynamic mechanical properties of visco-elastic materials*:

- — *Part 1: Principles and guidelines*
- — *Part 2: Resonance method*
- — *Part 3: Cantilever shear beam method*
- — *Part 4: Dynamic stiffness method*
- — *Part 5: Poisson ratio based on comparison between measurements and finite element analysis*

Introduction

Visco-elastic materials are used extensively to reduce vibration amplitudes in structural systems through dissipation of energy (damping) or isolation of components, and in acoustical applications that require a modification of the reflection, transmission or absorption of energy. Such systems often require specific dynamic mechanical properties in order to function in an optimum manner. Energy dissipation is due to interactions on the molecular scale and can be measured in terms of the lag between stress and strain in the material. The visco-elastic properties, modulus, and loss factor of most materials depend on frequency, temperature, strain amplitude, and pre-strain. In addition to modulus and loss factor, sometimes Poisson ratio is an important property required for predictions. The choice of a specific material for a given application determines the system performance. The goal of this International Standard is to provide brief descriptions of the three methods for elastic modulus and loss factor and two methods for Poisson ratio, the details of construction of each apparatus, measurement range, and the limitations of each apparatus. This International Standard applies to the linear behaviour observed at small strain amplitudes.

INTERNATIONAL STANDARD ISO 18437-1:2012(E)

Mechanical vibration and shock — Characterization of the dynamic mechanical properties of visco-elastic materials —

Part 1:
Principles and guidelines

1 Scope

This part of ISO 18437 establishes the principles underlying ISO 18437-2 to ISO 18437-5 for the determination of the dynamic mechanical properties (i.e. elastic modulus, shear modulus, bulk modulus, loss factor, and Poisson ratio) of isotropic visco-elastic resilient materials used in vibration isolators from laboratory measurements. It also provides assistance in the selection of the appropriate part of this International Standard.

This part of ISO 18437 is applicable to isotropic resilient materials that are used in vibration isolators in order to reduce:

a) the transmissions of audio frequency vibrations to a structure that can, for example, radiate fluid-borne sound (airborne, structure-borne or other);

b) the transmission of low frequency vibrations which can, for example, act upon humans or cause damage to structures or sensitive equipment when the vibration is too severe;

c) the transmission of shock and noise.

The data obtained with the measurement methods that are outlined in this part of ISO 18437 and further specified in ISO 18437-2 to ISO 18437-5 can be used for:

1) the design of efficient vibration isolators;

2) the selection of an optimum resilient material for a given design;

3) the theoretical computation of the transfer of vibrations through vibration isolators;

4) information during product development;

5) product information provided by manufacturers and suppliers;

6) quality control.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 472, *Plastics — Vocabulary*

ISO 2041, *Mechanical vibration, shock and condition monitoring — Vocabulary*

ISO 4664-1, *Rubber, vulcanized or thermoplastic — Determination of dynamic properties — Part 1: General guidance*

ISO 6721-1, *Plastics — Determination of dynamic mechanical properties — Part 1: General principles*

ISO 10846-2, *Acoustics and vibration — Laboratory measurement of vibro-acoustic transfer properties of resilient elements — Part 2: Direct method for determination of the dynamic stiffness of resilient supports for translatory motion*

ISO 23529, *Rubber — General procedures for preparing and conditioning test pieces for physical test methods*

3 Terms and definitions

For the purposes of this part of ISO 18437, the terms and definitions given in ISO 472, ISO 2041, ISO 4664-1, ISO 6721-1, ISO 10846-2, ISO 23529 and the following apply.

3.1

Young modulus
modulus of elasticity
E
ratio of the normal stress to linear strain

[SOURCE: ISO 80000-4:2006,[2] 4.1, modified.]

Note 1 to entry: The Young modulus is expressed in pascals.

Note 2 to entry: The complex Young modulus, E^*, for a visco-elastic material is represented by $E^* = E' + \mathrm{i}E''$, where E' is the real (elastic) component of the Young modulus and E'' is the imaginary (loss modulus) component of the Young modulus. The real component represents elastically stored mechanical energy, while the imaginary component is a measure of mechanical energy loss.

3.2

loss factor
ratio of the imaginary component to the real component of a complex modulus

Note 1 to entry: When a material shows a phase difference or loss angle, δ, between dynamic stress and strain in harmonic deformations, the loss factor is equal to tan δ.

3.3

linearity
property of the dynamic behaviour of a resilient material if it satisfies the principle of superposition

Note 1 to entry: The principle of superposition is 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 holds for all values of α, β and $x_1(t)$, $x_2(t)$; α and β are arbitrary constants.

Note 2 to entry: In practice the above test for linearity is impractical. Measuring the dynamic modulus for a range of input levels can provide a limited check of linearity. For a specific preload, if the dynamic transfer modulus is nominally invariant, the system measurement is considered linear. In effect this procedure checks for a proportional relationship between the response and the excitation.

4 Measurement principles

4.1 General

The Young modulus of a visco-elastic material is dependent on frequency and temperature. Theoretical details of the various modes of vibration, types of moduli and commonly used test arrangements are well known, are adequately covered in ISO 6721-1 and ISO 4664-1, and are not repeated here. ISO 18437-2 to ISO 18437-4 specify three additional methods that are in use to obtain the appropriate test data. Because they are complementary with respect to their strong and weak points, they are all described in this part of ISO 18437. In addition, ISO 18437-4 can include the application of static preload. Finally, ISO 18437-5 specifies a method for determining the Poisson ratio of a material by comparing measurements with finite element calculations. The four methods described here are limited to the measurement of the linear behaviour of materials observed at small strain amplitudes.

The conditions for the validity of the measurement methods are:

a) linearity of the vibrational behaviour of the isolator;

NOTE The term isolator includes elastic elements with non-linear static load deflection characteristics as long as the elements show approximate linearity for vibration behaviour for a given static preload.

b) equal distribution of the interfaces of the vibration isolator with the adjacent source and receiver structures;

c) no interaction between the vibration isolator and the surrounding fluid (usually air) medium.

It is possible that condition c) is not fulfilled for vibration isolators made up from an open-cell poro-elastic material, e.g. foam. For frequencies typically greater than 100 Hz, the interaction of the fluid and solid phases of the material can be great enough to modify its rigidity and loss.

4.2 Resonance method

4.2.1 Introduction

In the resonance method, the transmissibility (of displacement, velocity or acceleration) of a specimen is measured with the input side driven by a vibration source and the output loaded by a mass. The magnitude and phase information, mass specimen density and length provide the data required to determine the complex Young modulus. Figure 1 shows the principle of the method.

4.2.2 Test equipment

The following test equipment is required:

a) electro-dynamic driver;

b) accelerometers;

c) amplifiers;

d) test stand;

e) environmental chamber;

f) dual-channel spectrum analyser;

g) computer.

4.2.3 Test specimen preparation and mounting

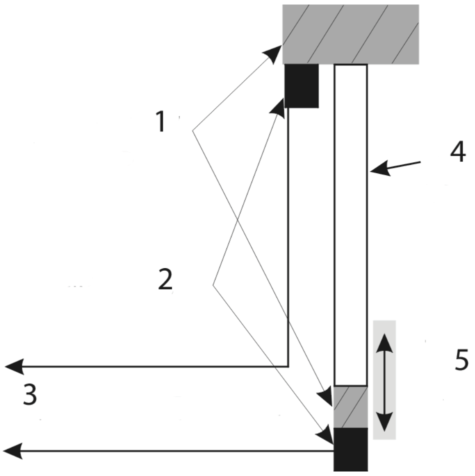
Test specimens are moulded into the shape of a bar that is typically 100 mm long with cross-sectional dimensions of 6 mm to 7 mm. The specimen cross-section may be square or circular. The length, density and mass of the specimen shall be determined before the specimen is mounted. The specimen is bonded between the mounting blocks, and accelerometers are also bonded as shown in Figure 1. A rigid adhesive such as epoxy or cyanoacrylate is acceptable. The finished assembly is rigidly mounted to the driver so as to produce pure extensional waves in the specimen.

4.2.4 Data acquisition

Typically the driver is excited with a random signal; the two-channel spectrum analyser acquires the data and performs a fast Fourier transform (FFT) analysis and averaging. This contains information concerning the mass spring response of the assembly and wave effects in the test specimen. The mass of the mounting block and specimen length shall be chosen so that the lowest frequency resonance is that of the mass spring system. The lowest frequency resonance shall be clearly separated from the higher frequency wave effects. A typical frequency range is 100 Hz to 5 000 Hz.

4.2.5 Analysis of results

The real and imaginary parts of the complex Young modulus are determined from the length, mass, and density of the specimen and from parameters obtained from solutions to the wave equation consisting of two coupled transcendental equations. The solution is obtained by numerical computation using the Newton–Raphson method at the experimentally determined resonant parameters (i.e. amplitude of the transfer function, frequency and mode number). Details are given in ISO 18437-2.



Key

1 mounting blocks
2 accelerometers
3 accelerometer outputs
4 test specimen
5 direction of vibration

Figure 1 — Principle of the resonance method

4.3 Cantilever shear beam method

4.3.1 Introduction

In the cantilever shear beam method, a specimen is rigidly mounted at one end and the free end is driven so as to bend or flex the specimen. In order to ensure a specific mode of bending, specific mounting requirements need to be met and these are specified in ISO 18437-3. The measurement of the complex force necessary to displace the specimen and the resulting complex displacement provides the data required to compute a complex Young modulus. Figure 2 shows the principle of the measurement.

4.3.2 Test equipment

The following test equipment is required:

a) electro-dynamic driver;

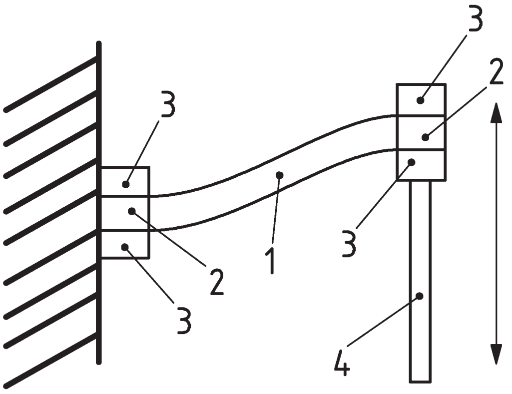
b) force sensor;

c) displacement sensor;

d) clamping system;

e) environmental chamber;

f) computer.



Key

1	beam specimen
2	specimen end blocks
3	specimen clamps
4	drive shaft

Figure 2 — Schematic diagram of the cantilever shear beam method

4.3.3 Test specimen preparation and mounting

Test specimens are typically cut from a sheet moulded or cast to the desired thickness using a small band saw or razor. It has been found that machining specimens from a thicker sample often affects the properties of the material. A typical specimen has length, $l = (12 \pm 0{,}5)$ mm by width, $b = (10 \pm 0{,}5)$ mm by height, $h = (3 \pm 0{,}25)$ mm. Steel or aluminium end blocks are attached to the ends of the specimen for clamping purposes. The dimensions of the end block are typically $l = (6{,}4 \pm 0{,}2)$ mm by $b = (11{,}0 \pm 0{,}2)$ mm by $h = (4{,}0 \pm 0{,}2)$ mm. The specimen is bonded to the end blocks using a rigid adhesive such as epoxy, urethane or cyanoacrylate. The specimen is mounted in a clamping fixture so as to produce the deformation shown in Figure 2.

4.3.4 Data acquisition

First, determine the complex stiffness of the system suspension by making measurements with no specimen in place. Measurements are made both with and without an end block (which serves as an added mass) at low and high frequencies, typically 1 Hz and 30 Hz. Once the stiffness of the instrument has been determined, measurements are made on the specimen mounted as shown in Figure 2. Force is applied to the specimen at the discrete frequencies, typically 0,3 Hz to 30 Hz, and temperatures selected for the evaluation. Typically the maximum displacement is limited to 64 µm.

4.3.5 Analysis of results

The basic principle of operation of the cantilever shear beam apparatus is to determine the force needed to induce a measurable displacement of the specimen. As the magnitude of the displacement depends on the modulus of the specimen, this value may be calculated by relating force to displacement with an equation which involves such factors as the system stiffness and viscous damping coefficient, vibrating mass, specimen geometry, and Poisson ratio. The solution of the dynamic equation yields the elastic Young modulus and loss factor. Details are given in ISO 18437-3.

4.4 Dynamic stiffness method

4.4.1 Introduction

The dynamic stiffness of the specimen is determined by measuring the input force on one side of the specimen while the displacement, velocity or acceleration is measured on the same or other side of the specimen, depending on the setup. The amplitude and phase relationship between the two measured quantities and the