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

Part 3:
Cantilever shear beam method

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

Partie 3: Méthode du faisceau par cisaillement en encorbellement

Reference number
ISO 18437-3:2005(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 18437-3 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*.

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 2: Resonance method*

— *Part 3: Cantilever shear beam method*

Part 4 (*Impedance method*) is under preparation.

Introduction

Visco-elastic materials are used extensively to reduce vibration magnitudes in structural systems through the 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 is 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 and strain magnitude. The choice of a specific material for a given application determines the system performance. The goal of this part of ISO 18437 is to provide details on the principle of operation of a cantilever shear beam method that avoids common clamping errors through the use of fixed ends, the measurement equipment, in performing the measurements, and analysing the resultant data. A further intent is to assist users of this method and to provide uniformity in the use of this method. This part of ISO 18437 applies to the linear behaviour observed at small strain magnitudes.

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

Part 3:

Cantilever shear beam method

1 Scope

This part of ISO 18437 defines a cantilever shear beam method for determining from laboratory measurements the dynamic mechanical properties of the resilient materials used in vibration isolators. Common errors due to clamping the specimen are avoided by using fixed ends so there is no rotational motion of the beam at its ends. This part of ISO 18437 is applicable to shock and vibration systems operating from a fraction of a hertz to about 20 kHz.

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

a) transmissions of unwanted vibrations from machines, structures or vehicles that radiate sound (fluid-borne, airborne, structure-borne, or others), and

b) the transmission of low-frequency vibrations that act upon humans or cause damage to structures or sensitive equipment when the vibration is too severe.

The data obtained with the measurement methods that are outlined in this part of ISO 18437 and further detailed in ISO 18437-2 are used for

- the design of efficient vibration isolators,
- the selection of an optimum material for a given design,
- the theoretical computation of the transfer of vibrations through isolators,
- information during product development,
- product information provided by manufacturers and suppliers, and
- quality control.

The condition for the validity of the measurement method is linearity of the vibrational behaviour of the isolator. This includes elastic elements with nonlinear static load deflection characteristics, provided that the elements show approximate linearity in their vibrational behaviour for a given static preload.

Measurements using this method are made over two decades in frequency (typically 0,3 Hz to 30 Hz) at a number of temperatures. By applying the time-temperature superposition principle, the measured data are shifted to generate dynamic mechanical properties over a much wider range of frequencies (typically 10^{-3} Hz to 10^{9} Hz at a single reference temperature) than initially measured at a given temperature.

NOTE For the purpose of this part of ISO 18437, the term “dynamic mechanical properties” refers to the determination of the fundamental elastic properties, e.g. the complex Young's modulus as a function of temperature and frequency and, if applicable, a static preload.

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 472:1999, *Plastics — Vocabulary*

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

ISO 4664-1:2005, *Rubber, vulcanized or thermoplastic — Determination of dynamic properties — Part 1: General guidance*

ISO 6721-1:2001, *Plastics — Determination of dynamic mechanical properties — Part 1: General principles*

ISO 10112:1991, *Damping materials — Graphical presentation of the complex modulus*

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

ISO 23529:2004, *Rubber — General procedures for preparing and conditioning test pieces for physical test methods*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 472, ISO 2041, ISO 4664-1, ISO 6721-1, ISO 10112, ISO 10846-1, ISO 23529 and following terms and definitions apply.

3.1
Young's modulus
E^*
quotient of normal stress (tensile or compressive) to resulting normal strain, or fractional change in length

NOTE 1 Unit is the pascal (Pa).

NOTE 2 Young's modulus for visco-elastic materials is a complex quantity, having a real part E' and an imaginary part E''.

NOTE 3 Physically, the real component of Young's modulus represents elastic-stored mechanical energy. The imaginary component is a measure of mechanical energy loss. See 3.2.

3.2
loss factor
ratio of the imaginary part of the Young's modulus of a material to the real part of the Young's modulus (the tangent of the argument of the complex Young's modulus)

NOTE When there is energy loss in a material, the strain lags the stress by a phase angle, δ. The loss factor is equal to tan δ.

3.3
time-temperature superposition
principle by which, for visco-elastic materials, time and temperature are equivalent to the extent that data at one temperature are superimposed upon data taken at a different temperature merely by shifting the data curves along the frequency axis

3.4
shift factor
measure of the amount of shift along the logarithmic (base 10) axis of frequency for one set of constant-temperature data to superpose upon another set of data

3.5

glass transition temperature

T_g

temperature at which a visco-elastic material changes state from glassy to rubbery, and corresponds to a change in slope in a plot of specific volume against temperature

NOTE 1 Unit is degrees Celsius (°C).

NOTE 2 The glass transition temperature is typically determined from the inflection point of a specific heat vs. temperature plot and represents an intrinsic material property.

NOTE 3 T_g is not the peak in the dynamic mechanical loss factor. That peak occurs at a higher temperature than T_g and varies with the measurement frequency; hence is not an intrinsic material property.

3.6

resilient material

visco-elastic material intended to reduce the transmission of vibration, shock or noise

NOTE 1 It is sometimes referred to as an elastic support, vibration isolator, shock mounting, absorber or decoupler.

NOTE 2 The reduction may be accomplished by the material working in tension, compression, torsion, shear, or a combination of these.

3.7

linearity

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

NOTE 1 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 $x_1(t)$, $x_2(t)$, where α and β are arbitrary constants.

NOTE 2 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 Test equipment (see Figure 1)

4.1 Electro-dynamic vibration generator

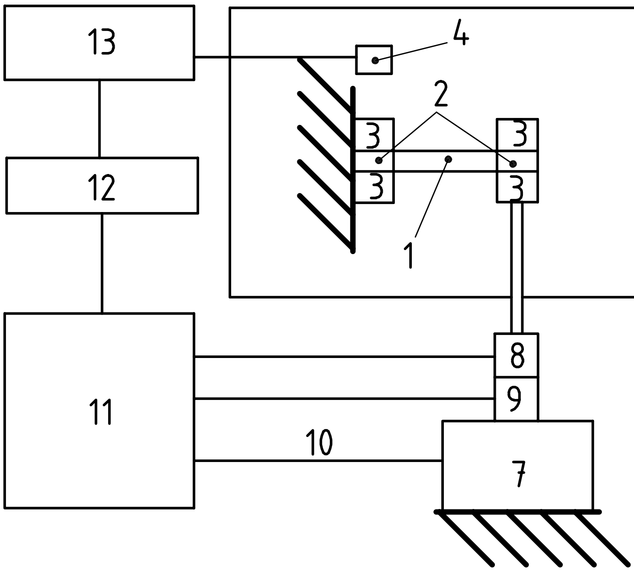
The vibration generator induces an oscillating sinusoidal cantilever shear strain into the sample beam at the selected frequency. An electro-dynamic vibration generator, with the following specifications, is typical of that required to provide a driving force for the specimen in a typical test:

- frequency range: 0,3 Hz to 30 Hz;
- force rating: $>$ 10 N;
- amplitude: $\approx$ 100 µm.

4.2 Force measurement

Typically the force is inferred by measuring the magnitude and phase of the current driving the electro-dynamic vibration generator. The force shall be calibrated using a known mass. The following specifications apply:

- frequency range: 0,3 Hz to 30 Hz;
- uncertainty: $<$ 0,5 %.



Key

1	beam specimen
2	specimen end blocks
3	specimen clamps
4	temperature probe
5	environmental chamber
6	drive shaft
7	electro-dynamic vibration generator
8	force sensor
9	displacement sensor
10	driver input
11	instrument controls for force, displacement and driver units
12	computer
13	temperature probe

NOTE The drive shaft is rigidly attached to the sample clamp and vibration generator so motion is that of a shear beam.

Figure 1 — Schematic diagram of test apparatus

4.3 Displacement transducer

To eliminate inertial effects, a non-contacting sensor (typically an eddy current type or an optical encoder that is appropriately calibrated) with the following specifications shall be used to measure the specimen complex displacement, magnitude and phase:

— frequency range: 0,3 Hz to 30 Hz;

— uncertainty: $<$ 0,5 %.

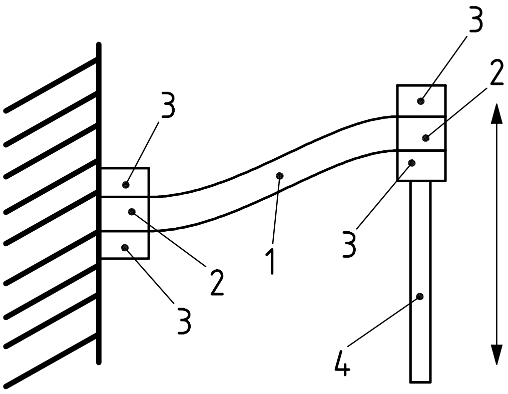
4.4 Clamping system

One end of the specimen is clamped rigidly to a frame using the attached end block. (See 5.1.) The driven end block is clamped into a fixture actuated by an electro-dynamic vibration generator via a rigid drive shaft.

The rigidity of the drive shaft and clamping fixture shall be tens to hundreds times larger that the bending stiffness of the specimen so that all of the measured displacement may be attributed to sample deformation.

This clamping system assures that the sample motion is confined to a cantilever shear beam mode with fixed-fixed ends. Figure 2 shows the required mode of deformation.

While in the past it was common not to use end blocks, their use has been found necessary in order to obtain reproducible and reliable results[1].



Key

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

Figure 2 — Schematic diagram of sample deformation

4.5 Environmental chamber

An environmental chamber is required to cool the test sample to a temperature below room temperature. This temperature shall be maintained until the sample has reached equilibrium, then the temperature of the sample shall be increased in increments of typically 5 °C. The chamber should be capable of operating over the temperature range from − 60 °C to 70 °C and be controllable within 0,5 °C. The temperature sensor shall be appropriately calibrated.

NOTE 1 The required temperature range is appropriate for a visco-elastic material having a glass transition temperature greater than − 45 °C. Materials with lower glass transition temperatures will require a lower starting temperature point.

NOTE 2 Some materials are sensitive to humidity and it may be desirable to control or at least record the relative humidity in the chamber.

4.6 Computer

The use of a computer is advantageous to automate the calibration, data acquisition and processing.

5 Operating procedure

5.1 Sample preparation and mounting

5.1.1 General

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. Specimens shall be uniform along each axis, and the ends shall be square to promote adhesion to the