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

**Part 2:
Resonance method**

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

Partie 2: Méthode de résonance

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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 18437-2 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.

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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 in constructing the resonance apparatus, in setting up 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.

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

Part 2: Resonance method

1 Scope

This part of ISO 18437 defines a resonance method for determining from laboratory measurements the dynamic mechanical properties of the resilient materials used in vibration isolators. It 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 18437-3 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 one or two decades in frequency 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} to 10^9 Hz at a single reference temperature) than initially measured at a given temperature.

NOTE For the purposes 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

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For the purposes of this document, the following terms and definitions given in ISO 472, ISO 2041, ISO 4664-1, ISO 6721-1, ISO 10112, ISO 10846-1, ISO 23259 and the following 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 $\tan \delta$.

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 superposed 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 superimpose 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**

An electro-dynamic vibration generator is required to provide a driving force for the test specimen, producing an oscillating displacement in the vertical direction. The dynamic strain level shall be adjusted to assure linear behaviour (see Annex A). The following specifications are typical:

- frequency range: 25 Hz to 10 kHz;
- force rating: > 5 N;
- peak displacement: < 0,1 mm.

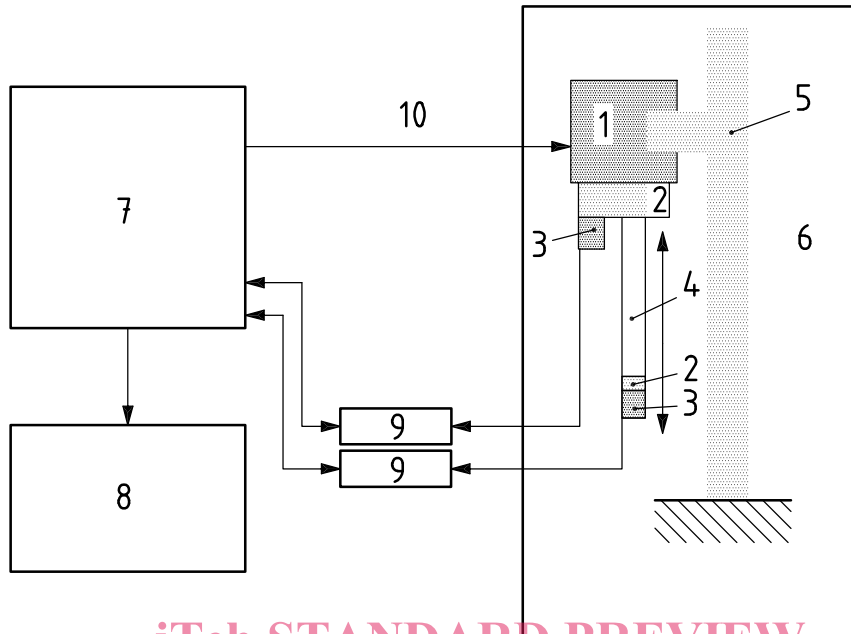
4.2 Accelerometers

A matched pair of accelerometers is required, or a relative calibration correction shall be applied. Piezoelectric accelerometers, with the following specifications, are typical of those required to measure the input and output acceleration of the test sample:

- frequency range: 25 Hz to 10 kHz;
- charge sensitivity: > 1 pC/g.

The mass of the accelerometer plus the lower mounting block should be as small as possible (see 5.1).

NOTE It is possible to use other types of sensors, but they need to be functionally equivalent.



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Key

- 1 electro-dynamic vibration generator
- 2 mounting blocks
- 3 accelerometers
- 4 test specimen
- 5 test stand
- 6 environmental chamber
- 7 dual-spectrum analyser
- 8 computer
- 9 charge amplifiers
- 10 noise source

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Figure 1 — Schematic diagram of the resonance apparatus

4.3 Charge amplifiers

Charge amplifiers with a sensitivity of not less than 1 mV/pC are required to amplify the output signal from the accelerometers. Alternatively, piezoelectric accelerometers with built-in amplifiers may be used.

4.4 Test stand

A test stand is needed to suspend the vibration generator and the test sample in a vertical position, as shown in Figure 1. The sample and vibration generator shall be positioned so as to eliminate or minimize any horizontal motion.

NOTE The presence of horizontal motion will appear as spurious peaks in the spectra.

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 5 °C. The chamber should be capable of operating over the temperature range from 60 °C to 70 °C and should be controllable to 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 Dual-channel spectrum analyser

A dual-channel spectrum analyser with the following capabilities is typical of that required to drive the vibration generator and analyse the accelerometer output signals:

- random noise source;
- two input channels;
- frequency response function (FFT), and coherence analysis;
- r.m.s. signal averaging;
- frequency range: 25 Hz to 10 kHz;
- dynamic range: > 42 dB;
- band selectable zoom FFT resolution: 0,1 Hz.

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4.7 Computer <https://standards.iteh.ai/catalog/standards/sist/dddf2681-d1d9-4262-9dd0-59705dbb2178/iso-18437-2-2005>

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

5 Operating procedures

5.1 Sample preparation and mounting

Mould test specimens into the shape of a bar. The mould should be at least 150 mm long, with uniform square lateral dimensions of $(6,0_{-0,1}^0)$ mm. Trim the moulded specimen of all flash and cut to a length of 100 mm ± 10 mm, using a razor blade. Square the ends of the bar by machining if necessary. The bar shall be able to stand upright on either end without support. Square ends are required to obtain a good bond between the test specimen and mounting blocks.

A uniform circular cross-section of about 6 mm to 8 mm diameter is also acceptable instead of a square bar.

Lengths not less than one-half the 100 mm specified or not more than twice that length are also acceptable.

NOTE 1 Shorter lengths produce resonances at higher frequencies and lead to fewer peaks being observed due to higher absorption at higher frequencies. Longer lengths produce resonances at lower frequencies and lead to problems due to bending of the longer specimen.

Three properties of the specimen that are required in the analyses shall be measured before bonding the specimen to the mounting blocks. In accordance with ISO 23529, determine the length, in metres, to four significant digits. Determine, using a balance, the mass of the specimen, in kilograms, to four significant digits. Determine the density of the specimen in kg/m³ by a water-displacement technique.

NOTE 2 A method such as ASTM D 792^[1] is acceptable.