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Rubber, vulcanized or thermoplastic — Determination of rebound resilience

Caoutchouc vulcanisé ou thermoplastique — Détermination de la résilience de rebondissement

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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 4662 was prepared by Technical Committee ISO/TC 45, *Rubber and rubber products*, Subcommittee SC 2, *Testing and analysis*.

This third edition cancels and replaces the second edition (ISO 4662:1986), which has been technically revised. The main change is the incorporation of a second method using a tripsometer. This method gives generally similar results, but uses a smaller test piece. Reference is also made to ISO 23529, which has replaced ISO 471, ISO 3383 and ISO 4661-1.

Introduction

When rubber is deformed, an energy input is involved; part of which is returned when the rubber returns to its original shape. That part of the energy which is not returned as mechanical energy is dissipated as heat in the rubber.

The ratio of the energy returned to the energy applied is termed the resilience. When the deformation is an indentation due to a single impact, this ratio is termed the rebound resilience.

The value of the rebound resilience for a given material is not a fixed quantity, but varies with temperature, strain distribution (determined by the type of indentor and test piece and by their dimensions), strain rate (determined by the velocity of the indentor,), strain energy (determined by the mass and velocity of the indentor) and strain history. Strain history is particularly important in the case of filler-loaded polymers, where the stress-softening effect necessitates a mechanical conditioning.

This variation of resilience with conditions is an inherent property of polymers, which can therefore only be fully evaluated if tests are carried out over a wide range of conditions. The factors described may have a different quantitative influence on resilience. While temperature may critically affect resilience near transition regions of the material tested, factors connected with time and amplitude of indentation have only moderate effects, and fairly wide tolerances may be admissible for them.

Ideally, rebound resilience should be measured on a test piece the back surface of which is bonded to a rigid support in order to avoid friction losses due to slippage during the impact. Since the use of bonded test pieces is impractical in many applications, unbonded test pieces are used. Frictional losses are avoided by secure clamping of the test piece.

To approach these ideal conditions in a practical apparatus, it is necessary to put limitations upon the hardness (see ISO 48) of the rubber that may be tested: on the hard side to avoid unusual requirements of rigidity in the apparatus; on the soft side to avoid difficulties in clamping.

If a defined set of mechanical conditions and an appropriate apparatus are selected, a standard value of rebound resilience at any temperature can be obtained with a satisfactory degree of reproducibility.

Rubber, vulcanized or thermoplastic — Determination of rebound resilience

WARNING — Persons using this International Standard should be familiar with normal laboratory practice. This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to ensure compliance with any national regulatory conditions.

CAUTION — Certain procedures specified in this International Standard may involve the use or generation of substances, or the generation of waste, that could constitute a local environmental hazard. Reference should be made to appropriate documentation on safe handling and disposal after use.

1 Scope

This International Standard specifies two methods for determining the rebound resilience of rubber the hardness of which lies between 30 IRHD and 85 IRHD. They are the pendulum method and the tripsometer method.

With the pendulum method, a mass with a spherical end impacts a flat test piece, firmly held but free to bulge. The kinetic energy of the impacting mass is measured immediately before and after impact.

With the tripsometer method, a flat test piece is impacted by a hemisphere mounted on the periphery of a disc which is supported on an axle and caused to rotate by an off-axis mass. The kinetic energy of the impacting mass is measured immediately before and after impact.

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 48, *Rubber, vulcanized or thermoplastic — Determination of hardness (hardness between 10 IRHD and 100 IRHD)*

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
rebound resilience
ratio between the returned and the applied energy of a moving mass which impacts a test piece

NOTE It is usually expressed as a percentage.

4 Principle

A test piece with plane, parallel surfaces is impacted on one surface by a linearly or circularly oscillating body, the impacting surface of which is spherical. The rebound resilience is determined by measurement of the energy of the impacting mass immediately before and after impact.

NOTE Conventionally, the input and output energies of the moving mass have been determined by observing the potential energy of the mass when at rest before moving to impact the test piece and on reaching zero velocity after rebound. The detailed descriptions of the apparatus described in this document follow this convention. However, it is equally acceptable to measure the input and output energies of the moving mass by observing its velocity immediately before and after impact and calculating the kinetic energies.

5 Pendulum method

5.1 Apparatus

5.1.1 General

The rebound resilience shall be measured by means of an apparatus consisting of a pendulum-like one-degree-of-freedom mechanical oscillatory device and a heavy and secure test piece holder.

The two items shall be suitably fixed together for rebound resilience measurements, and either item can be removed for purposes of adjustment or checking of the oscillatory device.

Means shall be provided for measuring the rebound of the pendulum, either using a calibrated scale or an electrical signal.

Various practical designs of apparatus which conform to these specifications are available (see Annexes B and C).

NOTE 1 The various types of apparatus designed to operate within the ranges specified for the various parameters (see below) and correctly calibrated give substantially the same values of rebound resilience.

The apparatus and impacted test piece characteristics shall be such as to fall within the following specified ranges:

- indentor diameter (D): 12,45 mm to 15,05 mm;
- test piece thickness (d): (12,5 ± 0,5) mm;
- impacting mass (m): 0,34 kg to 0,35 kg;
- impact velocity (v): 1,4 m/s to 2,0 m/s;
- apparent strain energy density (mv^2/Dd^2): 324 kJ/m^3 to 463 kJ/m^3.

NOTE 2 The conditions and apparatus specified in this International Standard involve the selection of a spherical indentor and of a flat test piece and are assumed to be essentially dependent on the fundamental parameters D, d, m and v listed above. In addition, the ratio of impact energy to an equivalent volume, or “apparent strain energy density” (mv^2/Dd^2), which under simplifying assumptions is related to impact strain, has to be maintained within the narrow range specified.

NOTE 3 The ranges are such that they embrace the requirements for the Lüpke pendulum method (12,5 mm, 12,5 mm, 0,35 kg, 1,4 m/s, 351 kJ/m^3) and the modified Schob pendulum method (15,0 mm, 12,5 mm, 0,25 kg, 2 m/s, 427 kJ/m^3).

In addition, allowance has been made for

a) a small tolerance (± 0,05 mm) to allow for mechanical imperfections of spheres of 12,5 mm and 15 mm nominal diameter;

b) an additional tolerance ($^{+112}_{-27}$ kJ/m^3) on mv^2/Dd^2 to allow for the effect of variation in test piece thickness (± 0,5 mm).

5.1.2 Oscillatory device

The oscillatory device shall consist of a rigid body or hammer terminating in an indenting spherical surface, supported so as to oscillate linearly or circularly under the action of a restoring force which can be due to gravity or produced by the elastic reaction of springs or by a wire in torsion. The velocity of the indenting spherical surface at the point of impact shall be in the horizontal direction and perpendicular to the surface of the test piece.

5.1.3 System for following the motion of the hammer

The motion of the hammer shall be followed either by means of a system comprising a pointer and a fixed scale or by a system which measures the position or velocity of the hammer to furnish electrical signals.

For pendulums in which the restoring force is due to gravity, the rebound resilience R is given by

$$R = \frac{h}{H}$$

where

h is the height of rebound;

H is the drop height.

It is usually convenient for the scale to measure either the horizontal rebound distance or, for rigid-arm pendulums in particular, the angle of rebound. For pendulums in which the restoring force is due to a torsion wire or to the elastic reaction of springs, the rebound resilience is given by

$$R = \frac{\alpha_R^2}{\alpha_I^2}$$

where

α_R is the angle of rebound;

α_I is the angle of impact.

For this form of apparatus, it is convenient for the scale to be used to measure the angle of rebound.

The scale can be graduated uniformly or be calibrated directly in units of resilience. For uniformly graduated scales, conversion equations, charts or tables to allow the determination of the resilience are also necessary.

5.1.4 Test piece holder

The disc-shaped test piece shall be securely held during mechanical conditioning and rebound measurement.

The surface against which the back of the test piece is applied shall be metallic, flat and smoothly finished, vertical and perpendicular to the impact velocity direction.

This backplate is part of an anvil which shall either be free, in which case it shall have a mass of at least 200 times the impacting mass, or shall be rigidly fastened to a very rigid system, such as a masonry structure.

Any type of suitable holding device can be used provided that it gives rebound resilience values that deviate by not more than 0,02 (absolute rebound resilience) from those obtained with test pieces bonded to a rigid backplate. This shall be checked using one compound of high rebound resilience (approximately 0,90) and one of high hardness (approximately 85 IRHD).

No lateral restraint shall be applied to the test piece. A clearance of at least 2 mm shall be left around it in order to allow it to bulge freely when impacted.

Examples of suitable holding devices include suction holding devices (by vacuum), mechanical clamping devices and combinations of the two. In any of these cases, the holding device shall not cause excess deformation of the surface to be impacted and shall not allow shuffling or slipping. A recommended mechanical clamping device consists of a metal ring (see Figure 1) with a 20 mm internal diameter and 35 mm external diameter and able to exert on the front of the test piece a force of (200 ± 20) N given, for example, by springs. In this case, the indenting sphere shall enter, at its rest position, the centre of the retaining ring. Another recommended method of holding is by suction on the back of the test piece. This can be applied through a circular groove, 25 mm in diameter and 2 mm in width, evacuated by a pump which maintains an absolute pressure not greater than 10 kPa. In this case, the force exerted by the retaining ring can be reduced to (150 ± 15) N.

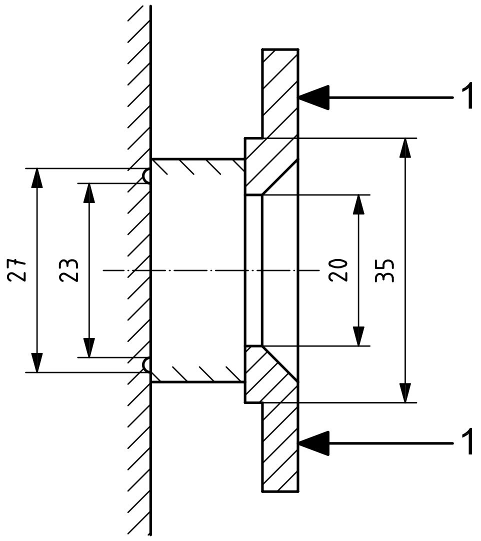
5.1.5 Temperature control

If measurements are to be carried out at a series of temperatures different from standard laboratory temperature, the pendulum can be placed and operated in a suitable oven or cold chamber operating in accordance with ISO 23529. In this case, the apparatus shall be checked for correct operation (see 5.1.6) over the range of temperatures used.

Alternatively, suitable provisions shall be made for heating or cooling the test piece holder by means of circulating fluids (see Figure 2). A heated or cooled gas curtain over the front opening of the holder is recommended in order to ensure that the test piece is completely surrounded by a temperature-controlled medium.

Thermocouples or other instruments shall be provided for measuring the temperature of the holder at a position as close as possible to the test piece.

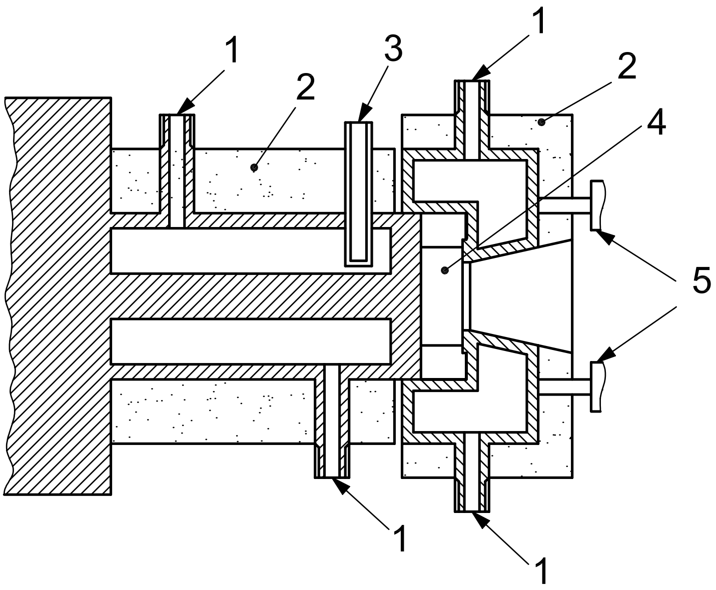
Dimensions in millimetres



Key

1 holding force: (150 ± 15) N with suction or (200 ± 20) N without suction

Figure 1 — Mechanical clamping device (optional)



Key

1 inlet/outlet for fluid

2 insulation

3 thermometer pocket

4 test piece

5 spring-loaded levers

Figure 2 — Example of temperature-controlled test piece holder

5.1.6 Adjustment of oscillatory device

The complete apparatus shall be repeatedly operated, impacting test pieces of rubber at the extreme ranges of hardness (30 IRHD and 85 IRHD). Its motion shall be smooth and no form of spurious oscillation mode, such as whip or vibration, shall be caused by the impact because of insufficient stiffness of rigid parts or a defective system of guidance.

For the purpose of initial adjustment or periodic checking, the test piece holder shall be removed from the oscillatory device and the following procedure carried out (measurement of the logarithmic decrement of the Lüpke pendulum may be omitted because it is clear that its logarithmic decrement is less than 0,01).

Weigh and measure the dimensions of the moving hammer and measure its distances from the guiding pivots or suspensions in order to carry out inertial-parameter calculations. From these, verify that the equivalent impacting mass conforms to the specifications in 5.1.1 and that its line of impact is such as not to cause significant reactions on pivots or suspensions.

Ensure that the diameter of the spherical indenting surface conforms to the specification in 5.1.1 and that the area of the spherical surface of the indentor in all cases exceeds the area of the indented surface of the rubber during impact. It is preferable that the impacting surface be a complete half-sphere.

Leave the complete oscillatory device free to attain its rest position. If using a pointer and fixed scale (see 5.1.3), check that this is at the zero point of the scale and that this is the position at which impact takes place. At this point, the indenting sphere shall be moving horizontally.

The following procedure shall be carried out where necessary to correct for frictional losses. It is not necessary where a method of observing impact and rebound velocities is used or the logarithmic decrement can be shown to be less than 0,01.

To correct for frictional losses, determine logarithmic decrements and corresponding damping corrections as follows. Set the oscillatory device in motion. Time its periods of oscillation and measure the amplitudes of successive oscillations (on the same side). Calculate the corresponding logarithmic decrement Λ from the expression

$$\Lambda = \frac{1}{n}\log_{\mathrm{e}}\frac{l_x}{l_{x+n}}$$

$$= \frac{1}{2n}\log_{\mathrm{e}}\frac{R_x}{R_{x+n}}$$

where

n is the number of full oscillations considered;

l_x and l_{x+n} are amplitudes read on a uniform scale;

R_x and R_{x+n} are amplitudes read on a quadratic scale.

For the present purposes, it is immaterial whether the scale has or has not already been corrected for small non-linearity.

If the operation of the instrument involves different damping conditions during the forward and backward impact strokes, due for example to a pawl engaging the pointer, then the measurements described shall be carried out under both conditions and their readings averaged.

Calculate the full period T and logarithmic decrement Λ as the averages of five oscillations for different amplitudes, as follows:

full scale	T_1	Λ_1
one-half scale	T_2	Λ_2
one-quarter scale	T_4	Λ_4

None of the values T_1, T_2 and T_4 shall differ from their average by more than 10 %. While a difference of under 1 % can be neglected, a difference between 1 % and 10 % shall be taken into account by applying suitable non-linearity corrections. These shall be made by correcting the energy of the pendulum at the corresponding point on the scale.

Check the value of the impact velocity from measured dimensions and the average of T_1, T_2 and T_4 or from the values of mass and energy at the unity (100 %) resilience point. It shall conform to the specification in 5.1.1.

None of the values Λ_1, Λ_2 and Λ_4 shall differ from their average by more than 0,01 and none of them shall exceed 0,03. While a value under 0,01 can be neglected, for values between 0,01 and 0,03 a correction shall be applied to the rebound results, preferably by displacing the starting point of the moving mass beyond the unity resilience point by a corresponding amount.

Calculate the damping correction ΔH, in millimetres, to the drop height as follows:

$$\Delta H = H\left(1 - \frac{1}{\mathrm{e}^{2\Lambda_i}}\right) \times \frac{1}{4}$$

where

H is the drop height (mm);

Λ_i is the appropriate logarithmic decrement measured for the drop height.