

Determining the rebound resilience of rubber using the Schob pendulum

DIN
53512

ICS 83.060

Supersedes
December 1988 edition.

Prüfung von Kautschuk und Elastomeren – Bestimmung der Rückprall-Elastizität (Schob-Pendel)

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

Foreword

This standard has been prepared by Technical Committee *Prüfung physikalischer Eigenschaften von Kautschuk und Elastomeren* of the *Normenausschuss Materialprüfung* (Materials Testing Standards Committee), and its specifications with regard to the Schob pendulum correspond to those in ISO 4662.

ISO 4662 describes two pendulum designs, the Lüpke and the Schob pendulums. Extensive tests at national and international levels have shown that both designs yield similar results provided that the test piece thickness is increased from 6 mm to 12,5 mm for the Schob pendulum. It is important to keep the friction of the pendulum low or to allow for correction with friction up to a particular degree. ISO 4662 permits the use of other designs if the apparent strain density lies within given tolerances, which are sufficiently great for both the Lüpke and Schob designs.

The standard test temperatures (including tolerances) specified here are those specified in ISO 4662. Clause 3 includes reference to the relationship between rebound resilience and the loss factor, $\tan \delta$, which is particularly significant for the test piece thickness specified here (12,5 mm). However, when these parameters are compared, it should be taken into consideration that the loss factor is a function of the temperature, frequency and amplitude of oscillation. Since amplitude and frequency are not exactly known, only a rough comparison can usually be made.

Amendments

This standard differs from the December 1988 edition in that use of a maximum pointer with the Schob pendulum has been omitted, and the standard has been editorially revised.

Previous editions

DIN 53512: 1940-12, 1959-01, 1965-12, 1976-07, 1981-03, 1988-12.

1 Scope

The method specified here serves to determine the resilience of rubber having a Shore A or IRHD hardness of between 30 and 85 (see DIN 53519-1) when subjected to impact. This method is particularly suitable for a rough assessment of the dynamic behaviour of rubber using simple equipment. When rubber is deformed, it absorbs energy which is partly recovered when it regains its original shape. Energy that is not returned as mechanical energy is dissipated as heat in the rubber.

2 Normative references

This standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the titles of the publications are listed below. For dated references, subsequent amendments to or revisions of any of these publications apply to this standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

Continued on pages 2 to 5.

Translation by DIN-Sprachendienst.

In case of doubt, the German-language original should be consulted as the authoritative text.

DIN 53513	Determination of viscoelastic properties of rubber under forced vibration beyond resonance
DIN 53519-1	Determination of indentation hardness (IRHD) of soft rubber using standard specimens
ISO 471 : 1995	Rubber – Temperatures, humidities and times for conditioning and testing
ISO 4661-1 : 1993	Vulcanized rubber and thermoplastics – Preparation of samples and test pieces

3 Concept

Rebound resilience

Rebound resilience, R , is the ratio of energy returned to energy applied.

NOTE 1: In the test described here, the resilience is established as the ratio of the height of rebound of a pendulum by its height of fall.

NOTE 2: For low values of loss factor, $\tan \delta$, the relationship between rebound resilience and this factor is expressed by $R \sim (1 - \pi \cdot \tan \delta)$ (see DIN 53513).

NOTE 3: The rebound resilience for a given material is a function of:

- temperature, which critically affects resilience near the transition region of the material tested;
- the strain history of the material, which makes mechanical conditioning necessary, particularly in the case of filler-loaded rubber;
- design-related factors (e.g. type and dimensions of indenter and test piece, and the rate of strain and strain energy). Factors related to time and strain amplitude have only moderate effects and fairly wide tolerances may be admissible for them.

4 Apparatus

4.1 General

Rebound resilience shall be measured using a one-degree-of-freedom mechanical oscillatory device. Various types are available, all of which produce similar values for rebound resilience, provided their parameters lie within the limits specified in subclause 4.2.5.

4.2 Oscillatory device

The oscillatory device shall consist of a stand with an anvil, a test piece holder, a pendulum with an indenter and an indicating device.

4.2.1 Frame/Stand and anvil

The stand and anvil shall have a combined mass at least 100 times the impacting mass of the pendulum.

4.2.2 Test piece holder

The test piece holder shall be designed to ensure that the test piece is held firmly, without lateral restraint being required. Its grip shall be as effective as if the test piece were bonded to the anvil. The difference in rebound resilience of a clamped and bonded test piece shall be less than two units. This condition shall be met for both highly resilient (rebound resilience around 90 %) and very hard (Shore A or IRHD hardness of 80 to 85) test pieces. The holder may be designed as a mechanical clamping device, a suction holder or as a combination of the two.

4.2.3 Pendulum

The pendulum shall consist of an arm and a hammer incorporating an indenter with a hemispherical surface (see figure 1). The pendulum shall be suspended so that it oscillates circularly under the effect of gravity. It shall be possible to raise the hammer through an angle of 90° from its rest position. With the arm in the vertical position, the indenter shall just touch the test piece surface, the direction of impact of the indenter being perpendicular to the test piece surface.

4.2.4 Indicator

The indicator shall, as far as possible, provide for a friction-free measurement of the angle of rebound, α , from which the rebound resilience, R , is calculated as a percentage, using the following equation:

$$R = (1 - \cos \alpha) \cdot 100 \quad (1)$$

See also clause 9.

4.2.5 Parameters

The pendulum parameters shall be as follows:

indenter diameter, $D = 12,45$ mm to 15,05 mm;

effective impacting mass, $m = 0,247$ kg to 0,35 kg;

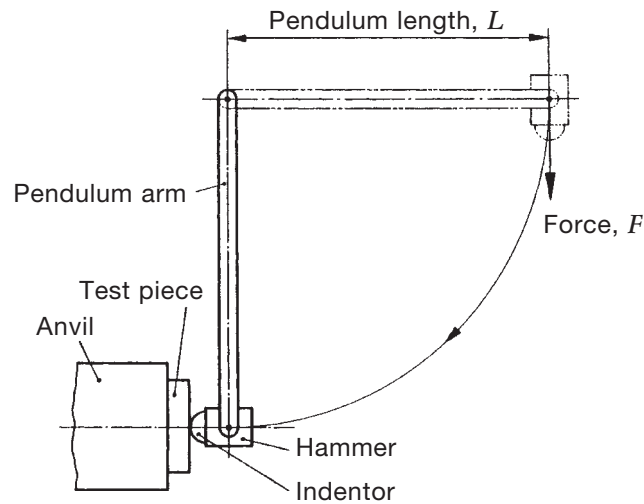


Figure 1: Principle of test apparatus

impact velocity, $v = 1,4 \text{ m/s}$ to $2,04 \text{ m/s}$;

apparent strain energy density $= m \cdot v^2 / (D \cdot d^2)$: $(351^{+112}_{-27}) \text{ kJ/m}^3$.

The Schob design has the following parameters:

diameter, $D = (15,00 \pm 0,05) \text{ mm}$;

impacting mass, $m = (0,255 \pm 0,003) \text{ kg}$;

pendulum length, $L = (200 \pm 0,5) \text{ mm}$.

On the basis of these parameters and a standard test piece thickness of $(12,5 \pm 0,5) \text{ mm}$, an apparent strain energy density of 427 kJ/m^3 is obtained, the energy of the Schob pendulum, A_N , being equal to $(500 \pm 9) \text{ mJ}$. See subclause 5.4 for the permissible friction of the apparatus.

5 Checking the apparatus

The following points are particularly relevant in the case of the Schob pendulum.

5.1 Force acting on the pendulum

In order to check the mass effective at impact on the test piece, m , force F acting on the pendulum in the horizontal position at distance L from its pivot (see figure 1) shall be measured. This force shall be $(2,50 \pm 0,03) \text{ N}$ (2).

5.2 Reduced pendulum length

The reduced pendulum length, L_{red} , shall be determined from the oscillation period, T , as follows:

$$L_{\text{red}} = \frac{g \cdot T^2}{4\pi^2} \quad (3)$$

where $g = 9,807 \text{ m/s}^2$.

It shall be $(200 \pm 1,5) \text{ mm}$ (4).

The mean value of T shall be determined as an average from 50 oscillations, with the apparatus placed at an angle of 45° , and the pendulum set in motion with an initial deflection of 5° .

From the mass and the reduced length, the energy of the pendulum, A_N , is to be calculated using the following equation:

$$A_N = m \cdot g \cdot L_{\text{red}} = m \cdot v^2 / 2 \quad (5)$$

It shall be $(500 \pm 9) \text{ mJ}$ (6).

5.3 Impact velocity

The impact velocity, v , is to be calculated from L_{red} using the following equation:

$$v = \sqrt{2 \cdot g \cdot L_{\text{red}}} \quad (7)$$

It shall be $(1,98 \pm 0,01)$ m/s (8).

5.4 Friction

5.4.1 Test set-up

An arrangement similar to that described in subclause 5.2, permitting angles of impact up to 40° and allowing observation of the rebound angle, shall be used to check for frictional losses.

5.4.2 Checking pendulum bearing friction and air friction

In order to check the pendulum bearing friction and air friction, the pendulum shall be deflected by about 40° and released. The number of full oscillations until the pendulum stops shall be counted, and shall be greater than 300.

5.4.3 Error of the indicated rebound resilience

The error of the indicated rebound resilience shall be determined in five stages, at about 10 %, 20 %, 30 %, 50 % or 60 %, and 80 % of the test scale. The pendulum shall be raised and supported or fixed. The angle of impact, α , shall then be measured using a cathetometer or a spirit level. Uncertainty of measurement shall not be greater than $\pm 0,065^\circ$. The theoretical rebound resilience, R_t , is to be calculated, as a percentage, using the following equation:

$$R_t = (1 - \cos \alpha) \cdot 100 \quad (9)$$

where α is the angle of rebound, in degrees.

The indicator error is given by $R - R_t$, where R is the rebound resilience indicated by the apparatus. The permissible error shall be $\pm 0,5$ %.

6 Test pieces

6.1 Test piece preparation

Test pieces having a thickness of $(12,5 \pm 0,5)$ mm and a diameter of 29 mm to 53 mm shall be used. They shall be prepared by moulding or cutting and shall have smooth and parallel surfaces. If the surface to be impacted is tacky, it shall be dusted with talcum. If test pieces of the specified thickness are not available (e.g. where they are cut from finished parts), a stack of no more than three sheets of the same material may be used, provided the sheets have parallel surfaces and the same thickness throughout. Test pieces shall not contain textile or other reinforcing material. If the surface is not uniformly smooth, it shall be ground as specified in ISO 4661-1.

NOTE: In the case of thin test pieces, test piece deformation may be influenced by the rigidity of the anvil. An international interlaboratory test using test pieces 6 mm and 12 mm thick produced differences of 2 % to 6 % in the resilience values, such differences being a function of the hardness of the rubber, and reaching a maximum for very soft rubber.

6.2 Number of test pieces

At least two pieces shall be tested.

6.3 Conditioning of test pieces

Testing shall be carried out not earlier than 16 hours and not later than four weeks after vulcanization. At least during the last three hours of this period, the test pieces shall be conditioned at a temperature of $(23 \pm 2)^\circ\text{C}$. In the case of finished parts, the interval between vulcanization and testing should not exceed three months; otherwise, testing shall commence not later than two months after delivery to the customer.

7 Test temperature

Testing shall normally be carried out at a temperature of $(23 \pm 1)^\circ\text{C}$, although test temperatures of -70°C , -55°C , -40°C , -25°C , -10°C , 0°C , 40°C , 55°C , 70°C , 85°C and 100°C are also acceptable. For testing, test piece, anvil and test piece holder shall be brought to the test temperature, $\pm 1^\circ\text{C}$, or $\pm 2^\circ\text{C}$ if test temperatures are below 0°C (see DIN ISO 471).

The conditioning period is a function of the characteristics of the conditioning device and whether the test piece is made up of a stack of sheets. The period required for test pieces 12,5 mm thick and a test temperature of 100 °C shall normally be 40 minutes. If the test pieces and the test apparatus are brought to test temperature separately, the test pieces, after they are fitted into the holder, shall be allowed a further conditioning period of three minutes before testing commences.

At low test temperatures, measures shall be taken to prevent frost forming on the test pieces. If the entire apparatus is placed in a conditioning chamber for testing, friction shall remain within the limits specified in this standard.

8 Procedure

After the test piece has been placed in the holder and conditioning has been completed, the pendulum shall be allowed to fall from the horizontal position six times to strike the same point on the test piece, and shall be caught each time before it impacts again. The first three impacts serve to mechanically condition the test piece and the last three to establish its rebound resilience. The median of the last three readings shall be determined (see DIN 53598-1).

9 Evaluation

The rebound resilience, R , as a percentage, is given by the following equation:

$$R = \frac{h_R}{h_0} \cdot 100 \quad (10)$$

where

h_R is the rebound height;

h_0 is the height of fall.

The arithmetic mean of the rebound resilience shall be calculated from the medians for at least two test pieces, determined from the three values read off as percentages to the nearest integer.

10 Test report

The test report shall refer to this standard and provide the following information:

- a) type and designation of test pieces;
- b) conditioning of test pieces;
- c) number of test pieces;
- d) thickness of test pieces, in mm;
- e) history of test pieces (e.g. vulcanization conditions);
- f) conditioning period, in minutes, and temperature, in °C;
- g) test temperature, in °C;
- h) test apparatus and type of test piece holder;
- i) rebound resilience, R , as a percentage (arithmetic mean value);
- j) any deviation from this standard;
- k) date of testing.