Determination of tensile stress/strain properties of rubber

DIN 53 504

ICS 83.060

Supersedes March 1985 edition.

Prüfung von Kautschuk und Elastomeren; Bestimmung von Reißfestigkeit, Zugfestigkeit, Reißdehnung und Spannungswerten im Zugversuch

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.

See Explanatory notes for connection with draft International Standard ISO/DIS 37: 1989 published by the International Organization for Standardization.

All dimensions are in mm.
For general tolerances, accuracy grade m as specified in ISO 2768 shall apply.

1 Scope and field of application

The test method specified in this standard serves to determine the tensile strength at break, tensile stress at yield, elongation at break and stress at a given strain of rubber test pieces of specified shape when these are stretched to rupture at a constant rate of traverse.

It is advisable that the full force-extension curve or at least part of it be plotted, since the behaviour of rubber when subjected to tensile stress cannot be adequately characterized by the tensile strength and elongation at break.

2 Concepts

2.1 Tensile strength at break

The tensile strength at break, σ_R, is the ratio of the force at break, F_R, to the initial cross-sectional area of the test piece, A_0.

2.2 Tensile stress at yield

The tensile stress at yield, σ_{max}, is the ratio of the maximum measured force, F_{max}, to the initial cross-sectional area of the test piece, A_0.

NOTE: If the tensile testing of rubber is carried out at or above ambient temperature, force F_R is generally equal to force F_{max}.

2.3 Elongation at break

The elongation at break, ε_R, is the ratio of the change in length at break, $L_R - L_0$, to the initial gauge length of the test piece, L_0. For ring test pieces, L_0 is the internal circumferential length, and for dumb-bell test pieces, the distance between two gauge marks.

2.4 Stress

The stress at a given strain, σ_i, is the ratio of the tensile force applied to achieve a given elongation, F_i, to the initial cross-sectional area, A_0.

NOTE 1: Where ring test pieces are used, the elongation shall be referred to the initial mean circumferential length of the ring, U_m, not its internal circumferential length.

NOTE 2: The use of the term 'modulus' (e.g. modulus of elasticity) in this context is incorrect and should be avoided since it normally applies only to materials for which there is a proportional relationship between stress and strain, which is not the case for rubber, even where the strain is low.

NOTE 3: In addition to the stress as defined here, the elongation at a given stress, as specified in ISO/DIS 37, may be determined.

2.5 Force-extension curve

The force-extension curve represents the relationship between tensile force and extension of a test piece during tensile testing up to rupture.

3 Designation

Designation of a tensile test on rubber carried out as specified in this standard using an R 1 ring test piece:

Test DIN 53 504 – R 1

Continued on pages 2 to 7.

4 Apparatus

4.1 Instrument for measuring test piece thickness

For measuring the test piece thickness, a thickness gauge as specified in subclause 5.2 of DIN 53 534, May 1994 edition, shall be used.

4.2 Instruments for determining the initial cross section of ring test pieces

For determining the mean initial cross section of ring test pieces, a balance permitting the test pieces mass in air and in water to be established shall be used.

4.3 Tensile testing machine

The tensile testing machine shall conform to class 1 as specified in DIN 51 221. For tests to be carried out at other than ambient temperature, a controlled-atmosphere test chamber shall be used. The temperature in the chamber shall be measured in the vicinity of the test piece and shall be kept constant to within ± 2 °C during the test. For further details, see subclause 6.1.

For testing ring test pieces, the testing machine shall be equipped with one power-driven and one freely rotatable pulley. The distance traversed by the former shall be about 50 mm for one rotation. It shall be possible to move the pulleys close enough together to permit the test pieces to be fitted without undue strain.

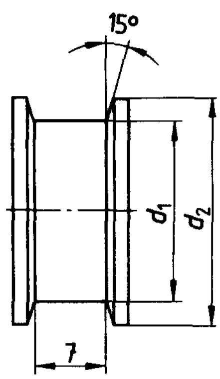

Figure 1: Testing machine pulley

Table 1: Pulley dimensions

Test piece	d_1	d_2	Spacing of pulley axes at start of test
R 1	22,3	26	35,0
R 2	18,3	22	28,7

For testing dumb-bell test pieces, the machine shall be equipped with two grips designed to enable the longitudinal axis of the test piece to be aligned to coincide with the strain axis of the machine at any time, which can be effected using a template. The test piece shall be held so as to prevent slip relative to the grips as far as possible. Suitable grips are those which maintain or even increase the pressure on the test piece as the stress increases. The grips shall not cause premature rupture of the test piece.

The testing machine shall permit both force-extension curves or stress-strain curves to be plotted. The extensometer shall be suitable for determining the change in gauge length of the test piece at any moment during the test and shall have as low an inertia as possible. When an extensometer attached to the test piece is used instead of a contact-free extensometer, there shall be no sign of damage to the test piece nor any slippage between the extensometer grips and the test piece.

5 Test pieces

5.1 Shape

Test results obtained for test pieces of different shape are not comparable.

5.1.1 Ring test pieces

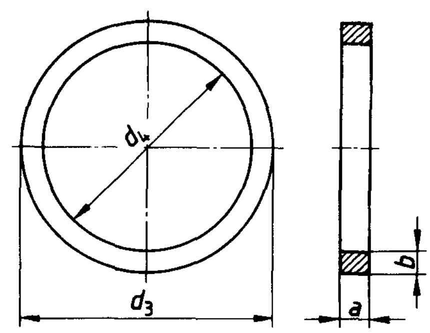

Figure 2: Ring test piece

Table 2: Dimensions of ring test pieces

		Ring	
		R 1	R 2
External diameter, d_3	$^{+0,05}_{0}$	52,6	44,6
Internal diameter, d_4	$^{+0,05}_{0}$	44,6	36,6
Width, $b = \frac{d_3 - d_4}{2}$	± 0,1	4,0	4,0
Thickness, a		4 ± 0,2 or 6,3 ± 0,3	4 ± 0,2 or 6,3 ± 0,3
Initial gauge length, L_0: a) internal circumferential length (for elongation at break): $U_i = \pi \cdot d_4$		140,1	115,0
b) mean circumferential length (for stress): $U_m = \pi \left(\frac{d_3 + d_4}{2}\right)$		152,7	127,5
Dimensions d_3 and d_4 relate to the dies. Type R 1 test pieces should preferably be used.			

5.1.2 Dumb-bell test pieces

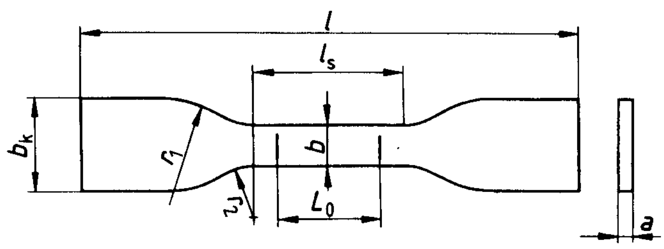

Figure 3: Dumb-bell test piece

Table 3: Dimensions of dumb-bell test pieces

	Test piece type S 1	S 2	S 3	S 3A
Minimum overall length, l	115	75	35	50
Width of ends, b_k	25	12,5	6	8,5
Length of narrow parallel portion, l_s	33	25	12	16
Width of narrow parallel portion, b (± 0,05)	6	4	2	4
Small radius, r_1	25	12,5	3	10
Large radius, r_2	14	8	3	7,5
Thickness, a	2 ± 0,2	2 ± 0,2	1 ± 0,1	2 ± 0,2
Initial gauge length, L_0	25	20	10	10
The dimensions given relate to the cutters. Although the width of the ends of dumb-bells and the small and large radii may deviate from the dimensions specified, the symmetry shall be maintained. S 2 dumb-bell test pieces shall preferably be used.				

5.2 Preparation of test pieces

Where test pieces are prepared separately, choose the sheet form. The thickness of the sheets shall be equal to the thickness of the final test pieces.

If the test pieces cannot be cut directly from finished components, cut out sheets of appropriate thickness so that test pieces can be taken from these.

Remove any unevenness by grinding.

The test piece thickness shall not deviate by more than ± 2,5 % from the median from three individual measurements.

Prepare the test pieces as described in ISO 4661-1, preferably using a circular cutter in the case of ring test pieces.

It should be noted that test results obtained for test pieces of a thickness other than specified in tables 2 and 3 (e.g. where the test pieces are to be taken from finished components) cannot be simply compared with those obtained for test pieces whose thickness lies within the specified range. The former results are to be identified in the test report.

5.3 Number of test pieces

Use at least three test pieces, or at least seven in arbitration cases. For dumb-bell pieces, take three (or seven) test pieces each from two directions at right angles to each other, choosing the directions parallel and perpendicular to the grain of the material if the latter can be established.

5.4 Reference marks

When using non-contact extensometers to measure the elongation of dumb-bell test pieces, make reference marks on the test pieces to define the gauge length, taking care that the marks and the marker used do not adversely affect the material to be tested. The marker lines shall be as narrow as possible and approximately equidistant from the centre. Determine the distance between them to within 1 % or less.

6 Procedure

6.1 General

Carry out the test at (23 ± 2) °C ('ambient temperature', for short) or, subject to agreement, at one of the following temperatures (cf. ISO 471: 1983): −70, −55, −40, −25, −10, 0, 40, 55, 70, 85, 100, 125, 150, 175, 200, 225, or 250 °C.

Prior to the test, condition the test pieces for a least 20 minutes at the test temperature. Testing shall not be carried out less than 16 hours, and in arbitration cases, less than 72 hours, after vulcanization.

NOTE: When testing ring test pieces below ambient temperature, replace the steel pulleys by those made of a material with a low coefficient of friction (e.g. tetrafluoroethylene) to ensure a uniform distribution of stresses in the ring.

6.2 Determination of test piece dimensions

Prior to testing, measure the test piece thickness at ambient temperature at not less than three points, that of dumb-bell test pieces within L_0, preferably at the two ends and in the centre. Calculate the initial cross-sectional area from the mean thickness and the width of the narrow portion (distance between the cutting edges) of the die. In arbitration cases, measure the width of the narrow portion.

The initial cross-sectional area of ring test pieces may alternatively be determined from the density using Archimedes' principle by weighing the sample in air and in water.

Calculate A_0 using equation (1):

$$A_0 = \frac{W_1}{\varrho \cdot \pi \cdot (d_3 + d_4)/2} \qquad (1)$$

where

- W_1 is the mass of the test piece, in g;
- ϱ is the density of the test piece, in g/cm^3;
- d_3 is the external diameter of a type R 1 test piece, in mm;
- d_4 is the internal circumferential length of a type R 1 test piece, in mm.