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Rubber, vulcanized — Measurement of fatigue crack growth rate

Caoutchouc vulcanisé — Mesurage du taux de croissance des craquelures de fatigue

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Foreword

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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.

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ISO 27727 was prepared by Technical Committee ISO/TC 45, *Rubber and rubber products*, Subcommittee SC 2, *Testing and analysis*.

Rubber, vulcanized — Measurement of fatigue crack growth rate

1 Scope

This International Standard specifies a method for the determination of the fatigue crack growth rate of vulcanized rubber under repeated loading over an extended period of time. The crack starts from the tip of a cut made in the test piece before the test, and grows progressively until it finally becomes large enough for complete fracture to occur. Using a pure-shear test piece, measurements are made to monitor the crack growth under the cyclic loading in order to obtain the crack growth rate, i.e. the increase in crack length per cycle. Tests are carried out at various tearing energies by varying the strain energy density in the test piece. This is done by changing the strain amplitude.

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 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
strain energy density
W
elastic energy stored in unit volume of the test piece when in a state of strain and resulting from the work done in deforming the test piece

NOTE It is measured in joules per cubic metre.

3.2
tearing energy
T
amount of energy required to propagate a tear/crack in a test piece

NOTE The tearing energy is expressed as the ratio of the total work done to the surface area of the crack. It is measured in joules per square metre.

3.3
strain-range parameter
P_R
⟨test cycles in which the test piece is always in a strained state⟩ ratio of the minimum distance from the relaxed (zero strain) position to the maximum distance from the relaxed position in each cycle

NOTE The strain-range parameter is expressed as $P_R = d_{min}/d_{max}$, where d_{min} is the minimum distance from the relaxed position and d_{max} is the maximum distance from the relaxed position.

4 Principle

A pure-shear geometry test piece with a deliberately introduced cut is subjected to cyclic loading during which the length of the crack produced grows with the number of deformation cycles. The crack length is measured by means of an *in situ* monitoring device as a function of the number of cycles carried out, and the measured data are processed by digital analysis to establish the rate of crack growth. The crack growth rate is then interpreted in terms of the tearing energy of the test piece, determined from its strain energy density.

5 Apparatus

5.1 Fatigue crack growth rate test machine

A suitable test machine for measuring fatigue crack growth rate, which operates with constant displacement cycles, is shown in Figure 1. The grips hold the test piece in a temperature-controlled chamber, with the upper grip connected to the load cell fixed to a crosshead, and the lower grip connected to a servo-controlled drive. The height of the crosshead is fixed, using stop rings, at a predetermined distance from the lower grip and, if required, a stress-strain curve can be obtained by varying the position of the lower grips. The test piece is periodically subjected to rectilinear deformation at a frequency and amplitude controlled by the servo mechanism. The strain range can be controlled by adjusting a pre-straining device positioned above the upper grip.

5.2 Image-processing device

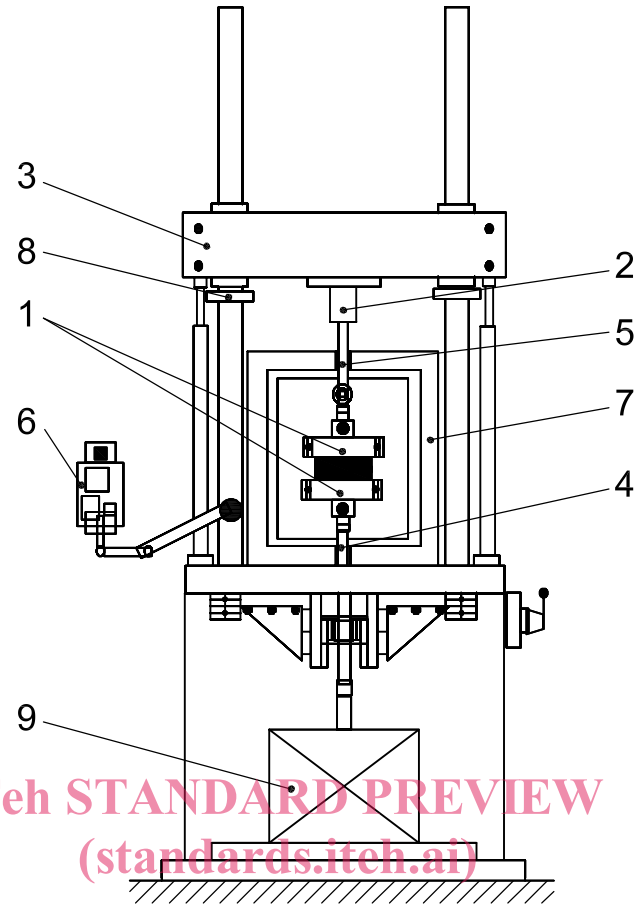
The growth of the crack in the test piece shall be monitored by means of an image-processing system equipped with a high-speed camera. Measurements shall be made to track the tip of the crack, and the length of the crack shall be recorded as a function of the number of strain cycles, thus providing the rate of fatigue crack growth.

5.3 Temperature-controlled chamber

When tests are made at a particular temperature, e.g. a standard laboratory temperature or another temperature specified in ISO 23529, a temperature-controlled chamber capable of maintaining the test piece at the temperature specified shall be used (see example in Figure 1). A temperature-sensing device shall be located within the chamber near or at the location of the test piece.

5.4 Thickness- and width-measurement instruments

Instruments for measuring the thickness and width of the test piece shall be in accordance with ISO 23529.



Key

1	upper and lower grips	4	cyclic shaft	7	temperature-controlled chamber
2	load cell	5	strain-range controller	8	stop ring
3	crosshead	6	high-speed CCD camera	9	servo-controlled drive

Figure 1 — Example of a fatigue crack growth rate test machine

6 Test pieces

6.1 Shape and dimensions

The test pieces shall be moulded strips of the shape shown in Figure 2. Each test piece shall have a smooth surface and be free from irregularities, and the thin section of the test piece shall be of uniform thickness. The recommended dimensions of the test piece are 200 mm long (L) and 20 mm wide (h_0). The length-to-width ratio L/h_0 shall be at least 10 in order to minimize edge effects. The thickness t_0 of the thin section shall be less than 2 mm and the thickness t of the thicker sections held in the upper and lower grips shall be greater than 5 mm.

6.2 Number of test pieces

At least three test pieces shall be used for each set of test conditions.

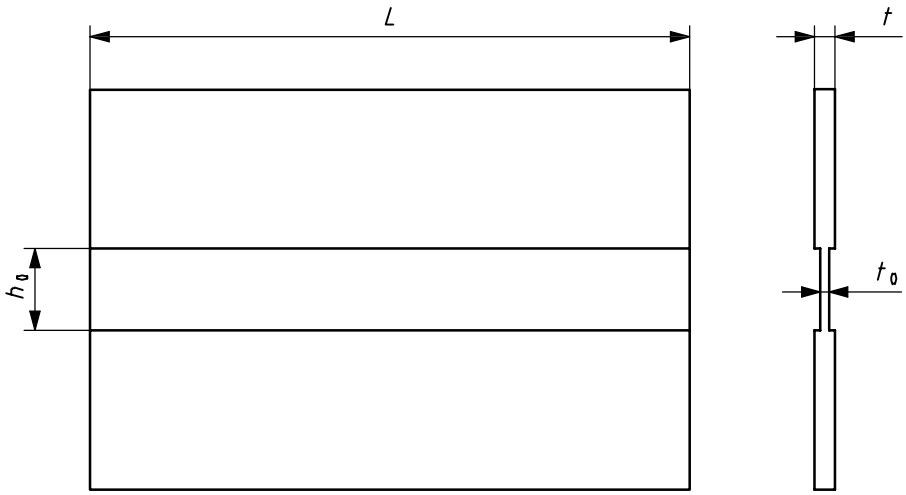


Figure 2 — Shape of pure-shear test piece for fatigue crack growth rate measurements

6.3 Time interval between moulding and testing

Unless otherwise specified for technical reasons, the following requirements shall be observed (see ISO 23529):

— For all test purposes, the minimum time between moulding and testing shall be 16 h.

— For non-product tests, the maximum time between vulcanization and testing shall be four weeks and, for evaluations intended to be comparable, the tests shall, as far as possible, be carried out after the same time interval.

— For product tests, whenever possible, the time between vulcanization and testing shall not exceed three months. In other cases, tests shall be made within two months of the date of receipt of the product by the customer.

6.4 Conditioning

Test pieces shall be protected from light as completely as possible during the interval between vulcanization and testing.

The test pieces shall be conditioned at standard laboratory temperature for at least 3 h immediately before being measured and tested.

If the test is to be carried out at a temperature other than a standard laboratory temperature, the test pieces shall, immediately prior to testing, be conditioned at the test temperature for a period sufficient to ensure that they have reached the test temperature (see ISO 23529).

6.5 Preparation of test pieces for testing

Each test piece shall be prepared by making a cut in it in order to eliminate the random nature of the tear initiation process. Before making the cut, strain the test piece three times to the highest strain to be applied in the test. Then, immediately before the test, make a cut about 30 mm long with a sharp razor blade at one end of the test piece.

7 Test conditions

7.1 Temperature

Measurements are normally carried out at a standard laboratory temperature as defined in ISO 23529. If tests are required at an elevated or subnormal temperature, the temperature shall be selected from those specified in ISO 23529.

7.2 Cycle frequency

The test piece shall be subjected to rectilinear-deformation cycles at a frequency normally in the range from 1 Hz to 10 Hz, but other frequencies may be used for special purposes. For tests intended to be comparable, the frequency used in each test shall be the same.

7.3 Strain amplitude

The strain amplitude shall be changed in order to vary the strain energy density in the test piece up to a maximum of 200 % elongation. The test piece shall return to zero strain, which is the fully relaxed state, during each cycle (see, however, 7.4).

7.4 Testing under non-relaxed conditions

If required, the test may be carried out under non-relaxed conditions, in which the minimum strain in each cycle is not zero, by varying the strain-range parameter r_R.

8 Procedure

8.1 Determination of strain energy density

The strain energy density W, which is the elastic energy released during crack growth, is represented by the area under the stress-strain curve. With unfilled rubbers, it is obtained by testing a pure-shear test piece without first making a cut in it, as shown in Figure 3 a), cycling under exactly the same conditions as with a test piece with a crack. Due to the pronounced hysteretic behaviour of filled rubber compounds, the stress-strain curve for such compounds is obtained from retractive-force/extension measurements, as shown in Figure 3 b). In either case, at least three test pieces shall be tested and the mean value of W calculated from the results.

8.2 Determination of tearing energy

In a pure-shear test piece, the tearing energy T is given by the equation:

$$T = W \times h_0$$

where h_0 is the unstrained width of the test piece.