International Standard ISO 4666/2

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Rubber, vulcanized — Determination of temperature rise and resistance to fatigue in flexometer testing — Part 2 : Rotary flexometer

Caoutchouc vulcanisé — Détermination de l'élévation de température et de la résistance à la fatigue dans les essais aux flexomètres — Partie 2 : Flexomètre à rotation

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 4666/2 was developed by Technical Committee ISO/TC 45, *Rubber and rubber products*, and was circulated to the member bodies in October 1979.

It has been approved by the member bodies of the following countries :

Austria	Germany, F. R.	Spain
Belgium	Hungary	Sweden
Bulgaria	India	Switzerland
China	Italy	United Kingdom
Czechoslovakia	Korea, Rep. of	USA
Denmark	Malaysia	USSR
Egypt, Arab Rep. of	Romania	
France	South Africa, Rep. of	

The member bodies of the following countries expressed disapproval of the document on technical grounds :

Brazil
Canada

Rubber, vulcanized — Determination of temperature rise and resistance to fatigue in flexometer testing — Part 2 : Rotary flexometer

1 Scope and field of application

This part of ISO 4666 specifies the rotary flexometer test for the determination of the temperature rise and resistance to fatigue of vulcanized rubbers under rotary shear loading. It allows the use of all four types of testing conditions described in ISO 4666/1.

It gives directions for carrying out measurements which make possible predictions regarding the durability of rubbers in finished articles (tyres, bearings, supports, V-belts, cable-pulley insert rings and similar products subject to dynamic flexing in service). However, owing to the wide variations in service conditions, no simple correlation between the accelerated tests described in this International Standard and service performance can be assumed.

2 References

ISO 4648, *Rubber, vulcanized — Determination of dimensions of test pieces and products for test purposes.*

ISO 4666/1, *Rubber, vulcanized — Determination of temperature rise and resistance to fatigue in flexometer testing — Part 1 : General principles.*

3 Definitions

For definitions of the terms and concepts used in connection with this test and in evaluating the test results, see ISO 4666/1.

4 Principle

A cylindrical test piece is compressed axially to a predetermined stress or strain (prestress or prestrain) between two chuck plates. One of the chuck plates is mounted on a freely rotating shaft while the other plate is mounted on a shaft which is driven by a motor. The shafts are displaced laterally relative to each other by a predetermined amount or by means of a predetermined force. The eccentricity of the two rotating plates produces a flexing of the rotating test piece, while it is under compression, resulting in a rise in temperature and ultimately fatigue breakdown. The rise in temperature is determined at the centre of the test piece by means of a needle probe. The fatigue life is also determined.

5 Test pieces

For general guidance as to number, preparation and conditioning of test pieces, see ISO 4666/1.

The test pieces shall be cylinders of height equal to their diameter. The dimensions shall be either 20 ± 0,2 mm or 38 ± 0,4 mm. The smaller test piece is preferred because it is usually more uniform in degree of vulcanization throughout the whole mass.

If test pieces are prepared by vulcanization in moulds, it is recommended that the mould cavities have a diameter and depth of 20,2 ± 0,05 mm or 38,2 ± 0,05 mm in order to allow for thermal shrinkage after vulcanization. If test pieces are prepared from finished parts by cutting, it is recommended that the circular die used for this purpose has an inside diameter of 20 ± 0,03 mm or 38 ± 0,03 mm.

6 Apparatus

6.1 Rotary flexometer (see figures 1 and 2)

The schematic illustration in figure 1 shows the important parts of the flexometer. The cylindrical test piece acts as a friction clutch between two chuck plates mounted on parallel shafts such that they can be rotated. The shaft carrying the right-hand chuck plate (see figure 1) shall be mounted on a movable bearing so that almost frictionless movement in the axial direction is possible. This is in order that the test piece can be subjected to axial compression by displacing the movable chuck plate by a predetermined amount (testing under constant pre-strain) or through the action of a predetermined force (testing under constant pre-stress), for example by means of a compression spring.

The movable bearing shall also be capable of being displaced transversely with respect to the axis of the test piece. This displacement can be obtained by movement of the bearing carrier or by means of a cross support arrangement. In this manner, a transverse deformation is imposed upon the test piece. The deflection may be by a predetermined amount (testing under constant cyclic strain) or under the action of a predetermined force (testing under constant cyclic stress).

The left-hand chuck plate shall be driven by a motor at a rotational frequency of 14,6 ± 0,1 Hz or 25,0 ± 0,2 Hz. The test piece transmits the rotation from the driven chuck plate to the displaceable chuck plate.

The rotation and simultaneous deflection subject the test piece to a sinusoidal form of shear deformation. Suitable devices such as dial gauges and electronic transducers shall be incorporated in order to determine all the deformations and loadings of the test piece. The devices for measuring the deformations shall have a precision of at least 0,01 mm. The precision of the force measuring devices shall be at least 0,1 N. The use of chart recorders for recording the transverse force or the transverse displacement is recommended. The measuring devices shall be mounted so that their pressure acts against the loading as shown in figure 1.

The chuck plates shall be made of steel. Caps made of plastics or other heat insulating materials having a conductivity of not more than 0,28 W/m·K may be placed over these for heat generation tests if considered necessary. The caps shall have a thickness of 10,0 ± 0,2 mm and shall lie in close contact with the metal plates over their entire surface. As an alternative to caps, discs of heat insulating material may be placed immediately behind the chuck plates.

To facilitate location of the cylindrical test piece between the chuck plates or caps, and in order to avoid sideways displacement during the test, the chuck plates and caps shall be provided with a centrally located recess to receive the test piece. The recess shall have the following dimensions :

- for small cylinders : diameter 20,2 ± 0,03 mm, depth 0,7 ± 0,03 mm;
- for large cylinders : diameter 38,4 ± 0,05 mm, depth 1,0 ± 0,05 mm.

6.2 Measuring gauge

The gauge for measuring the height and diameter of the test pieces shall conform to the requirements of ISO 4648. A dial gauge having a circular foot probe of diameter 10 mm and exerting a pressure of 22 ± 5 kPa is suitable.

6.3 Temperature measurement device

A temperature measurement device with a temperature sensing probe consisting of a needle of diameter not more than 1 mm should be used. The maximum allowable error shall be ± 0,5 °C.

6.4 Timer

The error of time measurement shall not be greater than 5,0 s.

7 Procedure

7.1 Preparation

When the small size test piece is used for the heat generation test, it is recommended that the insulating caps be fitted on the chuck plates. When using the larger size of test piece or when determining the fatigue resistance, the caps need not be fitted.

Measure the height of the test piece to within 0,05 mm in the unloaded condition before placing in the flexometer.

Before beginning the actual test, carry out a preliminary run of 15 min under test conditions, using a rubber of similar hardness to the test piece. In this way, the chuck plates (and caps when fitted) are warmed up and the apparatus is brought to normal conditions.

7.2 Test operation

With the device stationary, bring the two chucks into axial alignment and set up the test piece between them. Then compress the test piece axially by about 10 %; that is, to about 90 % of the original height. Switch on the motor and check that the test piece is properly located. If the test piece is not running centrally, remove and re-install it. Thereafter, i.e. at the beginning of the running of the test, compress the test piece to the desired deformation or apply the desired force by means of the compression spring or a weight. Directly thereafter, displace the right-hand (displaceable) bearing using the transverse spindle or by means of a transverse force perpendicular to the axis. The full deflection shall be reached within 10 s. The test duration begins after the required transverse deformation has been imposed.

7.2.1 Measurement of temperature rise

At the end of the specified test duration, switch off the motor, remove the transverse deformation and the axial deformation, and immediately measure the temperature at the centre of the test piece with the needle probe. The time between switching off the motor and the temperature measurement shall be 10 ± 2 s. The temperature measurement in the test piece can be carried out with the test piece in the apparatus or after its removal.

7.2.2 Determination of resistance to fatigue breakdown

Measure the period of time from the beginning of cyclic deformation to the beginning of breakdown in the interior of the test piece.

If breakdown does not occur after 30 minutes, the test shall be stopped, unless a longer running test is specified. In this case, the fatigue deformability or fatigue stress shall be reported instead of the limiting fatigue deformability or limiting fatigue stress (see 9.2.2).

The onset of breakdown is indicated by changes in the transverse force or transverse displacement. The criterion for determining the onset of breakdown shall be the same for all comparative tests.

After termination of the test, the test piece shall be sectioned by cutting in an axial plane and examined visually to ensure that the level of damage (indicated by the presence of fine pores, cracks or degradation of the rubber in the centre of the test piece) is comparable. In the case of rubbers in which the beginning of breakdown is difficult to detect, several test pieces shall be subjected to the test to ensure correct assessment.

8 Test conditions

8.1 General

Tests shall be conducted at standard laboratory temperatures, i.e. at 23 ± 2 °C or 27 ± 2 °C.

The forces produced by the dial gauges or strain gauges shall be taken into account.

8.2 Measurement of temperature rise

After a running time of 20 ± 0,5 min, after which temperature equilibrium is generally reached, the temperature rise shall be measured.

Recommended loadings are the forces or deformations given under "normal" in table 1. If the resulting temperature rise is too small to allow a meaningful comparison, the "increased" values can be used.

8.3 Determination of resistance to fatigue breakdown

If the fatigue life has only to be determined for one loading, or for preliminary investigations to determine the appropriate loading ranges for plotting the fatigue life curve, the test conditions normally recommended are those given under "normal" in table 2. If the resulting duration of the test is too short, the "reduced" values can be used.

Table 1 — Loading conditions for measurement of temperature rise

Test conditions	Test piece dimensions mm	Normal		Increased	
		Axial	Transverse	Axial	Transverse
Constant pre-stress and cyclic stress amplitude	20 × 20 38 × 38	300 ± 2 N 1 000 ± 5 N	30 ± 0,2 N 100 ± 0,5 N	500 ± 2 N 1 400 ± 5 N	40 ± 0,2 N 200 ± 1 N
Constant pre-strain and cyclic strain amplitude	20 × 20 38 × 38	6 ± 0,02 mm 10 ± 0,04 mm	2,8 ± 0,02 mm 3,0 ± 0,04 mm	— —	— —

Table 2 — Loading conditions for determination of resistance to fatigue breakdown

Test conditions	Test piece dimensions mm	Normal		Reduced	
		Axial	Transverse	Axial	Transverse
Constant pre-stress and cyclic stress amplitude	20 × 20 38 × 38	500 ± 2 N 1 700 ± 5 N	80 ± 0,2 N 270 ± 2 N	500 ± 2 N 1 700 ± 5 N	50 ± 0,2 N 150 ± 1 N
Constant pre-strain and cyclic strain amplitude	20 × 20 38 × 38	6 ± 0,02 mm 10 ± 0,04 mm	6,5 ± 0,02 mm 10 ± 0,04 mm	6 ± 0,02 mm 10 ± 0,04 mm	3,5 ± 0,02 mm 5,0 ± 0,04 mm

9 Evaluation of test data

9.1 Temperature rise

Measure the rise in temperature above ambient temperature of the centre of the test piece.

9.2 Resistance to fatigue breakdown

9.2.1 Fatigue life

The fatigue life is the number of loading cycles to failure, N, which can be calculated by the product of the time, in seconds, to failure and the test frequency, in hertz, or can be measured directly.

9.2.2 Fatigue life curves

The resistance to fatigue breakdown is best presented graphically. The values for the fatigue life N (number of cycles to breakdown) and the loading amplitudes are plotted on a graph with a logarithmically scaled abscissa (number of cycles) and a linearly scaled ordinate (loading). Figure 3 shows an example of an evaluation of the testing of cylindrical test pieces 20 mm in height and 20 mm in diameter under conditions of predetermined cyclic deformation.

The cyclic strain amplitude or cyclic stress amplitude at which the fatigue life curve becomes essentially parallel to the log N axis is taken as the limiting fatigue deformability γ_∞ or limiting fatigue stress τ_∞.

If required, a plot of fatigue life against cyclic strain amplitude or cyclic stress amplitude may be used to calculate the fatigue deformability or fatigue stress for a given fatigue life. In this case, it is not necessary to undertake tests at cyclic strain amplitudes or cyclic stress amplitudes where the fatigue life approaches infinity.

The values selected in accordance with 8.3 for the cyclic loading amplitudes are used together with the nominal dimensions of the test piece to calculate the cyclic strain amplitude, γ, and cyclic stress amplitude, τ, in megapascals, using the formulae

$$\gamma = \frac{s}{h} = \frac{s}{h_o - h_r}$$

where

s is the transverse deformation, in millimetres;

h_o is the height of the test piece, in millimetres (20 or 38);

h_r is the static compression, in millimetres.

and

$$\tau = \frac{Q}{A}$$

where

Q is the transverse force, in newtons;

A is the cross-sectional area, in square millimetres, of the test piece.

This simplified evaluation method is applicable, since the permitted tolerances for the dimensions of the test piece are fixed very closely. The method makes possible the direct plotting of the fatigue life curve from values of Q, in newtons, and s, in millimetres.

10 Test report

The test report shall include the following particulars :

a) a reference to this International Standard;

b) the nature of the rubber;

c) the test piece dimensions;

d) the test conditions, i.e. the following parameters as appropriate :

— pre-strain (or static axial compression, in millimetres),

— pre-stress in megapascals (or static axial force, in newtons),

— cyclic strain amplitude (or cyclic transverse deformation, in millimetres),

— cyclic stress amplitude, in megapascals (or cyclic force, in newtons);

e) the rotational frequency, in hertz;

f) the type of chucks or caps;

g) in the measurement of temperature rise : the individual values of the measured temperature rises, in degrees Celsius, and arithmetical averages calculated therefrom;

h) in the determination of resistance to fatigue breakdown :

— for determinations of fatigue life : the individual values of the measured number of cycles to breakdown, N, and arithmetical averages calculated therefrom,

— the confidence limits of the mean values, if an adequate number of test pieces have been tested,

— if a fatigue life curve has been plotted : the fatigue deformability or limiting fatigue deformability; the fatigue stress or limiting fatigue stress, as appropriate;

j) any departures from the procedures specified in this International Standard;

k) the date of the test.

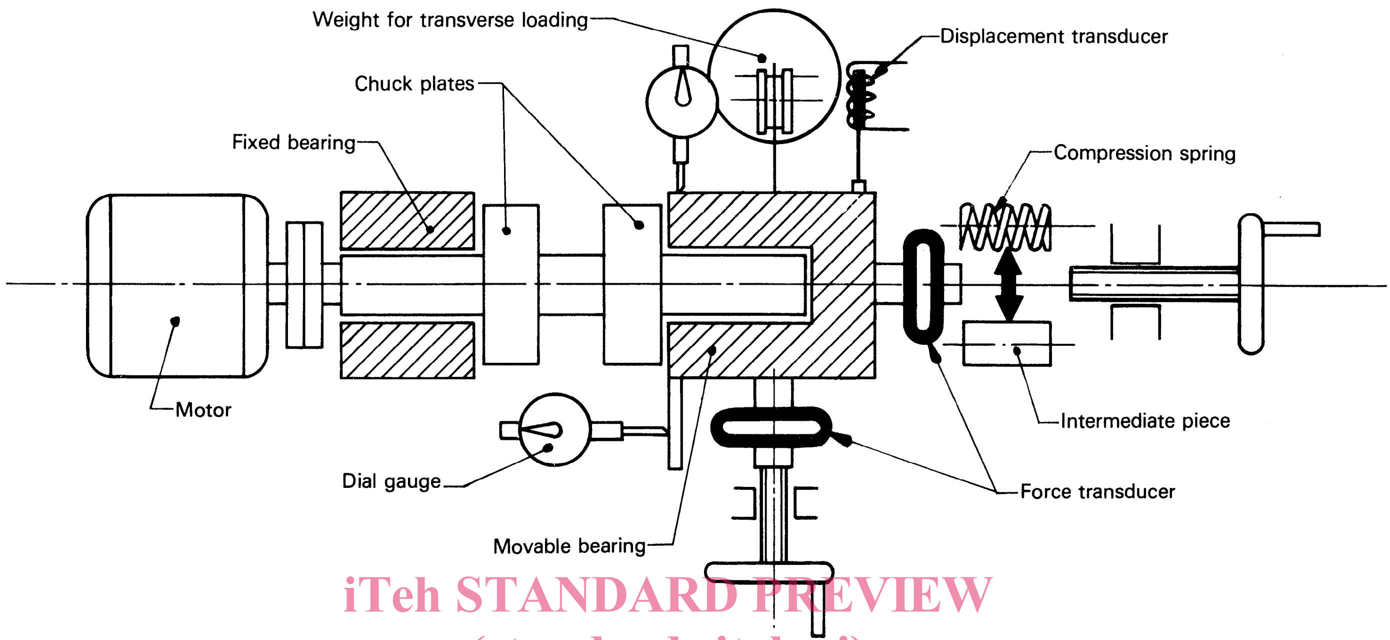

Figure 1 — Rotary flexometer before application of force

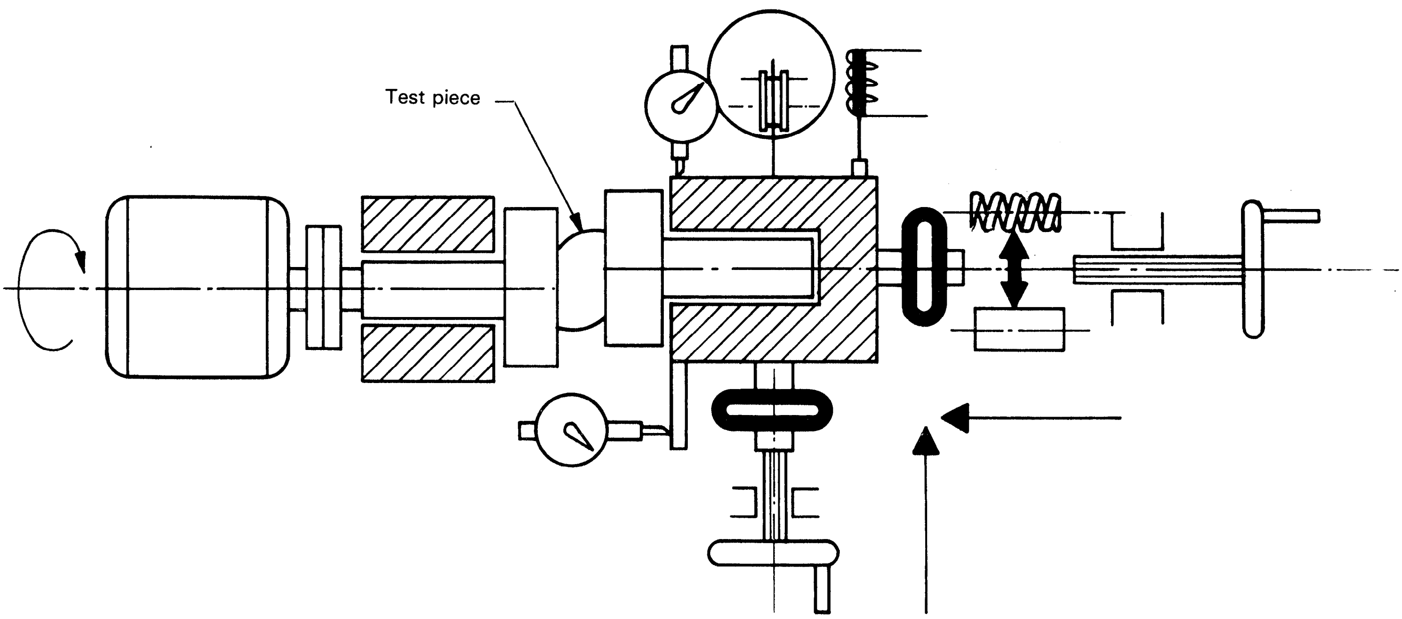

Figure 2 — Rotary flexometer after application of force

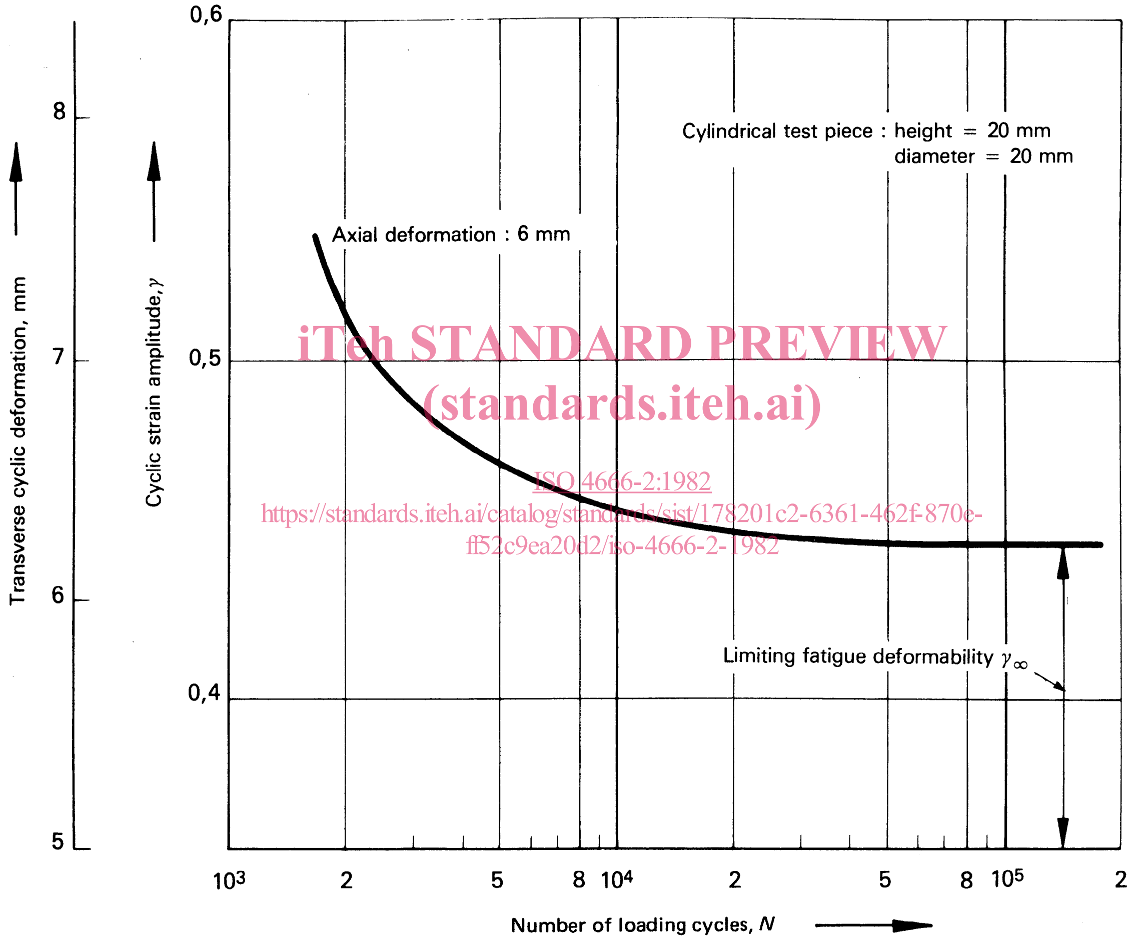

Figure 3 — Example of fatigue life curve with predetermined cyclic deformation

Bibliography

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[2] KAINRADL, P., WOLF, F., and ECKER, H., Variations in testing procedures on the rotary flexometer, *Rubber Chemistry and Technology*, **49** (1976), pp. 258-277.