INTERNATIONAL STANDARD

ISO 6502

Third edition
1999-12-01

Rubber — Guide to the use of curemeters

Caoutchouc — Guide pour l'emploi des rhéomètres

Contents

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 3.

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.

International Standard ISO 6502 was prepared by Technical Committee ISO/TC 45, *Rubber and rubber products*, Subcommittee SC 2, *Physical and degradation tests.*

This third edition cancels and replaces the second edition (ISO 6502:1991), which has been technically revised.

Annexes A, B and C of this International Standard are for information only.

Introduction

Whilst reviewing the previous edition of this International Standard, it became clear that a number of different curemeters were available and that significant developments had taken place, especially with the rotorless types. Rather than specify individual rotorless instruments, possibly restricting future developments, it was felt that a more general document was required. Accordingly, it was decided to provide guidance and assistance in the design and use of curemeters generally.

Rubber — Guide to the use of curemeters

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.

1 Scope

This International Standard provides guidance on the determination of vulcanization characteristics of rubber compounds by means of curemeters.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 1382:1996, *Rubber — Vocabulary.*

ISO 3417:1991, *Rubber — Measurement of vulcanization characteristics with the oscillating disc curemeter.*

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 1382 apply, plus the following:

3.1
ocscillating-disc curemeter
ODC
a curemeter consisting of a biconical disc oscillated within a temperature-controlled die cavity containing the test piece

3.2
rotorless curemeter
RCM
a curemeter consisting of two dies forming a temperature-controlled cavity, one of which is moved relative to the other to apply a stress or strain to the test piece

NOTE   Types of rotorless curemeter are listed in clause 5 and illustrated in Figures 3 to 7.

3.3
marching-modulus cure
a type of vulcanization during which the modulus does not reach a maximum value but, after a rapid rise, continues to rise slowly at the vulcanization temperature

3.4
vulcanization characteristics
characteristics which may be taken from a vulcanization curve (see Figure 1).

NOTE   More explanations are given in clause 4.

3.5
stiffness
a general term used for modulus or resistance to stress

NOTE   Force and torque have not been defined since they have a generally accepted scientific meaning.

4 Basic principles

The properties of a rubber compound change during the course of vulcanization, and the vulcanization characteristics can be determined by measuring properties as a function of time and temperature. Vulcanization characteristics are most commonly determined using instruments known as curemeters in which a cyclic stress or strain is applied to a test piece and the associated strain or force is measured. Normally, the test is carried out at a predetermined constant temperature and the measure of stiffness recorded continuously as a function of time.

The stiffness of the rubber increases as vulcanization proceeds. Vulcanization is complete when the recorded stiffness rises to a plateau value or to a maximum and then declines (see Figure 1). In the latter case, the decrease in stiffness is caused by reversion. In cases where the recorded stiffness continues to rise (marching-modulus cure), vulcanization is deemed to be complete after a specified time. The time required to obtain a vulcanization curve is a function of the test temperature and the characteristics of the rubber compound. Curves analogous to Figure 1 are obtained for a curemeter in which strain is measured.

The following vulcanization characteristics can be taken from the measure of stiffness against time curve (Figure 1):

|	
Minimum force or torque	F_L or M_L
Force or torque at a specified time t	F_t or M_t
Scorch time (time to incipient cure)	t_{sx}
Time to a percentage y of full cure from minimum force or torque	$t'_c(y)$
Plateau force or torque	F_{HF} or M_{HF}
Maximum force or torque (reverting cure)	F_{HR} or M_{HR}
Force or torque value attained after a specified time (marching-modulus cure)	F_H or M_H

The minimum force or torque F_L or M_L characterizes the stiffness of the unvulcanized compound at the curing temperature.

The scorch time (time to incipient cure) t_{sx} is a measure of the processing safety of the compound.

The time $t'_c(y)$ and the corresponding forces or torques give information on the progress of cure. The optimum cure is often taken as $t'_c(90)$.

The highest force or torque is a measure of the stiffness of the vulcanized rubber at the curing temperature.

NOTE   The term F denotes force, and the term M denotes torque.
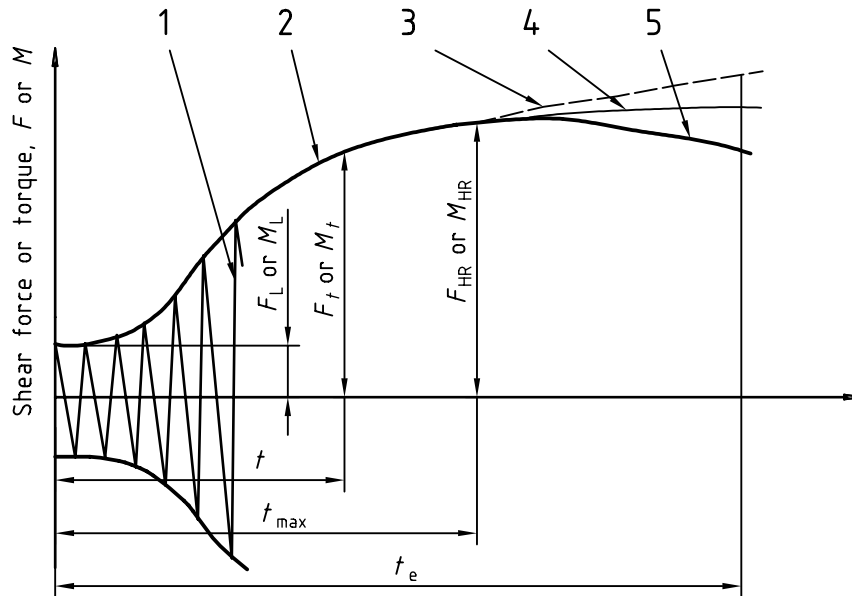
Key

1   Sinusoidal curve
2   Envelope curve
3   Vulcanization curve with steady increase to F_H or M_H at time t_e at end of test (marching-modulus cure)
4   Vulcanization curve with plateau at F_{HF} or M_{HF} (plateau cure)
5   Vulcanization curve with maximum F_{HR} or M_{HR} at time t_{max} (reverting cure)

a) Vulcanization curve F or $M = f(t)$
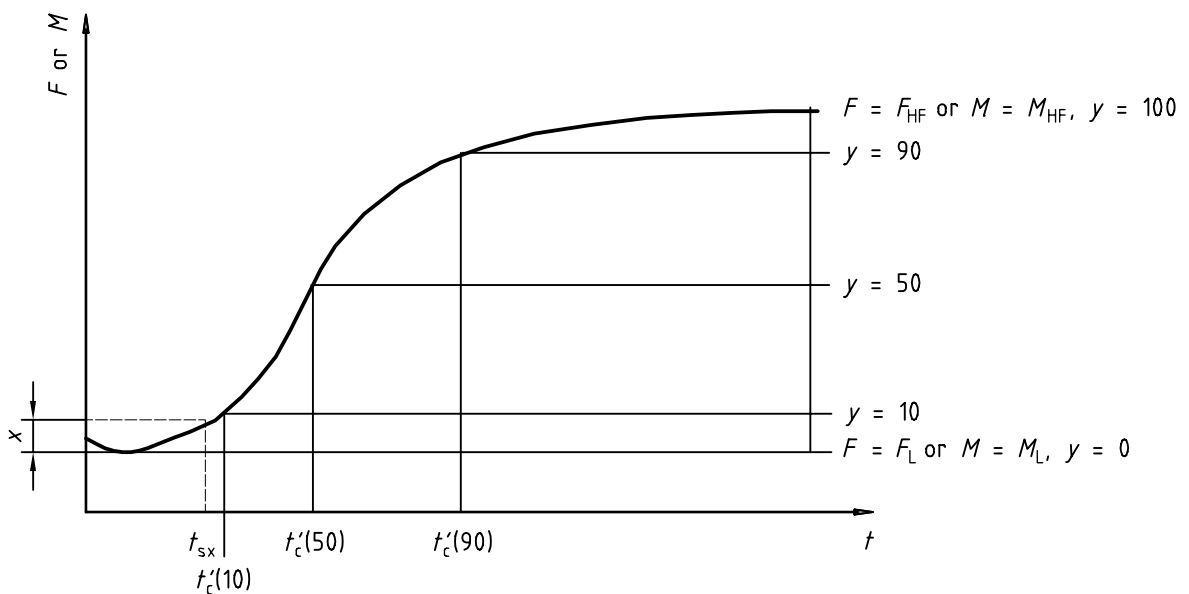
b) Method of evaluation

Figure 1 — Typical vulcanization curve and method of evaluation

5 Types of curemeter

Three types of curemeter have found widespread use:

— Oscillating-disc;

— Reciprocating-paddle;

— Rotorless.

The reciprocating-paddle type was popular, but is now much less used and is not considered further in this guide.

Rotorless curemeters can be subdivided into three forms:

— Reciprocating (linear strain);

— Oscillating (torsion) unsealed cavity;

— Oscillating (torsion) sealed cavity.

Oscillating types may have a biconical die, a flat-plate die or be of top-hat section.

Other geometries are possible, for example with a vibrating probe or needle.

The oscillating-disc curemeter has for many years been the most widely used type of instrument, but more recently the rotorless type of curemeter has increased greatly in popularity. The principal advantages of the rotorless type are that the specified temperature is reached in a shorter time after insertion of the test piece into the die cavity and there is better temperature distribution in the test piece (see annex A).

6 Apparatus

6.1 General

A curemeter consists of two heated dies with means of closing them under a specified force to form a die cavity containing the test piece, a means of oscillating a rotor within the cavity, or alternatively oscillating or reciprocating one of the dies relative to the other, and a means of measuring and recording the force or torque required to produce the relative movement, or the movement produced by a given applied force or torque. In addition, with sealed rotorless torsion systems, reaction torque on the stationary die opposite the moving die may be measured.

The general arrangements for oscillating-disc and rotorless curemeters are shown in Figures 2 to 7.

6.2 Die cavity

The dies should be manufactured from a non-deforming material. The surface of the dies should minimize the effect of contamination and be hard so as to prevent wear. A minimum Rockwell hardness of 50 HRC, or equivalent, is recommended. The tolerances necessary on the dimensions of the dies will depend on the particular design, but as a general guide the dimensions of the cavity should be controlled to $\pm 0,2$ %.

The top and bottom surfaces of the cavity should have a pattern of grooves of dimensions sufficient to prevent slippage of the rubber test piece.

Holes should be provided in both the upper and lower dies to accommodate temperature sensors. The positions of the sensors relative to the cavity should be controlled to ensure reproducible response.

In the case of oscillating-disc instruments, one die requires a central hole to allow insertion of the die stem. A seal of suitable low, constant friction should be provided in this hole to prevent material leaking from the cavity.

Suitable means should be employed by design of dies or otherwise to apply pressure to the test piece throughout the test to minimize slippage between the disc and the rubber. A positive pressure is also important to exclude air which may affect the cure of, for example, peroxide-cured rubbers and to prevent any tendency for the rubber to become porous.

The dimensions of the die cavity may be checked by measuring the dimensions of the vulcanized test piece. For biconical-die rotorless curemeters, particular attention should be paid to the thin central portion, the thickness of which depends on the die gap. For oscillating-disc curemeters, the vulcanized test piece should be cut in half and checked to see that it is symmetrical. Any asymmetry indicates that the rotor height has been set incorrectly.

The dimensions of the cavity and of the vulcanized test piece will not be identical because of the effect of mould shrinkage.

6.3 Die closure

The dies are closed and held closed during the test by, for example, a pneumatic cylinder.

A force of 11 kN ± 0,5 kN is recommended for oscillating-disc instruments with a mating-surface area between the dies of approximately 1 400 mm^2.

In unsealed rotorless instruments, the dies are not completely closed but a small clearance is left which should be between 0,05 mm and 0,2 mm. For sealed cavities, no gap should exist at the edges of the die cavity. The minimum closing force required depends on the clearance area. As a general guide, a minimum of 7 kN to 8 kN is recommended.

6.4 Moving member

The disc in an oscillating-disc instrument should be manufactured from a non-deforming material having a minimum hardness of 50 HRC. Both the top and bottom surfaces should have a pattern of grooves to prevent slippage of the rubber test piece.

The disc should be biconical in shape to give an approximately uniform shear rate, and its diameter should be controlled to ±0,03 % and the cone angle to ±1,3 %.

The moving member in a rotorless instrument is one of the dies. The shape of the die cavity should be a plane disc for reciprocating types and either biconical, flat plate or "top hat" in the oscillating type to produce a substantially uniform shear rate.

The drive linkage should be sufficiently stiff to prevent significant deformation.

6.5 Movement

The frequency of oscillation or reciprocation should be between 0,05 Hz and 2 Hz, and tests may be made at two or more frequencies. If a single frequency is selected, 1,7 Hz ± 0,1 Hz is recommended.

Generally, greater sensitivity can be obtained with larger amplitudes, but the amplitude that can be used in practice is restricted by the possibility of slippage between the test pieces and the die surface or rotor.

For oscillating-disc curemeters, an amplitude of ±1° is recommended, but ±3° may be possible and advantageous in some circumstances.

For rotorless curemeters, the range may be between ±0,1° and ±2° or, for reciprocating types, between ±0,01 mm and ±0,1 mm.

The tolerance on amplitude should be ±2 % apart from the instruments considered in ISO 3417, and the drive should be sufficiently powerful and stiff to substantially maintain the amplitude under load.

6.6 Stiffness measurement

The means of measuring force or torque should be rigidly coupled to a die or rotor and be capable of measuring the resultant force or torque to an accuracy of ±1 % of the force or torque range. This tolerance should include any errors due to deformation of the measuring device and its coupling and of the output device.

The recorder to continuously monitor force or torque should have a response time for full-scale deflection of 1 s or less.

6.7 Heating and temperature control

The heating and temperature control system should be capable of producing a reproducible and evenly distributed temperature in the dies and permit rapid and reproducible temperature recovery after insertion of the test piece. Close control of these parameters is necessary for the precise measurement of vulcanization characteristics.

The temperature-measuring system should enable temperature to be measured to a resolution of $\pm0,1$ °C over the range 100 °C to 200 °C. The temperature controllers should enable the dies to be controlled to an accuracy of $\pm0,3$ °C at the steady state. The temperature of the dies should recover after insertion of a test piece at 23 °C $\pm$ 5 °C to within 0,3 °C within 3 min for biconical-die rotorless instruments. For flat-plate-die rotorless instruments, the recovery range should be ±1 °C within 1,5 min at the test temperature of 150 °C.

The effect of temperature distribution on measured cure rate is discussed in annex A.

6.8 Calibration

Calibration of curemeters should be carried out in accordance with the manufacturer's instructions. The force or torque should be determined at several points over the range(s) used but, additionally, it may be useful to have provision for making in-use checks.

Stable standard rubber compounds may also be tested periodically to check for consistent performance.

7 Test piece

The test piece should be homogeneous and as far as possible free from trapped air. The test piece volume should be slightly larger than the die cavity volume such that a small amount of material is extruded between all edges of the dies when they are closed. The optimum volume should be determined by preliminary tests, and test pieces of equal volume should be used to obtain reproducible results. Oversize test pieces may cool the cavity excessively during the early part of the test cycle.

The test piece should be punched from sheeted material by an appropriate device which ensures the production of test pieces of constant volume.

Normally one test piece is taken from each rubber sample, but if this may not be representative of the batch then further test pieces should be taken.

8 Vulcanization temperature

The vulcanization temperature is chosen as that appropriate for the rubber compound being tested and intended processing. The range of 100 °C to 200 °C is recommended.

9 Conditioning

The rubber sample should be conditioned at 23 °C $\pm$ 5 °C for a minimum of 3 h before testing.

10 Test procedure

10.1 Preparation for the test

The temperature of both dies should be brought to the test temperature with the cavity closed and, in the case of oscillating-disc curemeters, with the disc in place, and allowed to stabilize.

Any necessary zeroing and selection of range of the force- or torque-measuring device should be made before loading the test piece.

10.2 Loading the curemeter

The loading of the test piece and the closure of the dies should be carried out as quickly as possible. The dies should be closed immediately after insertion of the test piece. The whole cycle, from opening to closure, should not exceed 20 s.

The vulcanization time should be recorded from the instant the dies are fully closed. Oscillation of the movable die or disc should be started before or at the instant of die closure.

After removal of the cured test piece, a further sample may be inserted immediately if the temperature of the dies has remained within $\pm 0,3$ °C of the set value. If not, the dies should be closed and the temperature allowed to recover to the test value.

A deposit of material from the rubber compound may build up on the dies (and disc) which may affect the final torque values. The use of a standard compound may be used to detect this occurrence. If such contamination develops, it may be removed by very light blasting with a mild abrasive, ultrasonic cleaning or non-corrosive cleaning fluids. Great care should be taken with cleaning, and the manufacturer's advice followed. If fluids are used, the first two tests after cleaning should be rejected. Running a natural-rubber gum compound can be used to remove debris. In some cases, a protective film may be used to prevent contamination. For biconical-die rotorless curemeters of the sealed-cavity type, the use of protective film (polyester of thickness $< 0,03$ mm) is strongly recommended.

11 Expression of results

All or some of the cure characteristics given in clause 4 should be taken from the cure curve. Times should be given in minutes, force in newtons and torque in newton metres.

The scorch time t_{sx} is the time required for the force or torque to increase by x units from F_L. It may be convenient to define the scorch as a given percentage, e.g. 2 % or 5 %, of the total cure.

The time to a percentage of full cure from minimum force, $t'_c(y)$, is the time taken for the force (or torque) to reach

$$F_L + 0,01y\,(F_{HF} - F_L)$$

or

$$M_L + 0,01y\,(M_{HF} - M_L)$$

$t'_c(10)$ is a measure of the early stages of cure.

$t'_c(50)$ can be determined accurately providing the slope of the curve is greatest at this point.

$t'_c(90)$ is often used as an indicator of optimum press cure.

The cure rate index is the average slope of the rising curve and is given by

$$100/[t'_c(y) - t_{sx}]$$

12 Test report

The test report shall include the following information:

a) a reference to the International Standard concerned;

b) sample details:

   1) a full description of the sample and its origin,

   2) the method of preparation of the test pieces;

c) test details:

   1) type and identification of curemeter used,

   2) the amplitude of oscillation,

   3) the frequency of oscillation,

   4) the force or torque range used,

   5) the heating-up time,

   6) the curing temperature;

d) test results:

   1) the recorded vulcanization curve with force and time scales indicated, if required,

   2) the values of the parameters obtained from the vulcanization curve, as required;

e) the date of the test.
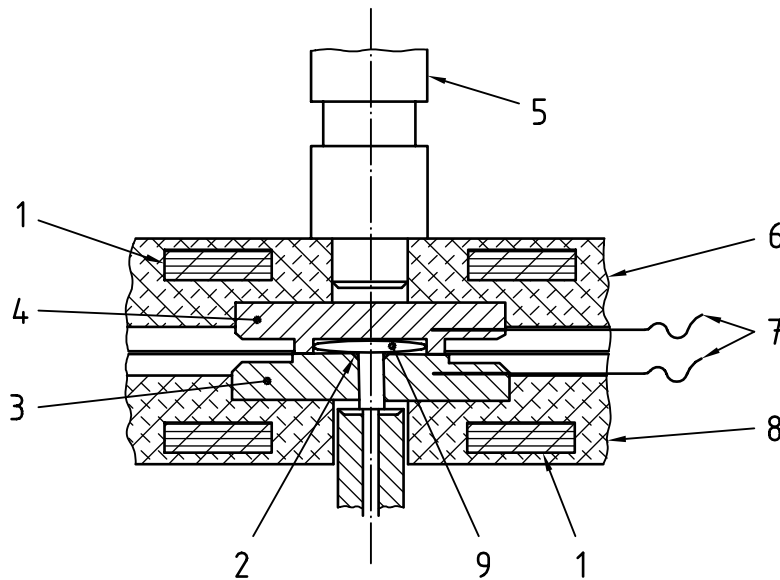
Key

1	Heater	6	Upper platen
2	Seal	7	Calibrated temperature sensors
3	Lower die	8	Lower platen
4	Upper die	9	Biconical disc
5	Cylinder rod		

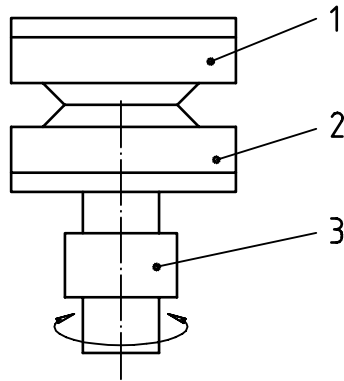**Figure 2 — Typical oscillating-disc curemeter**

Dimensions in millimetres
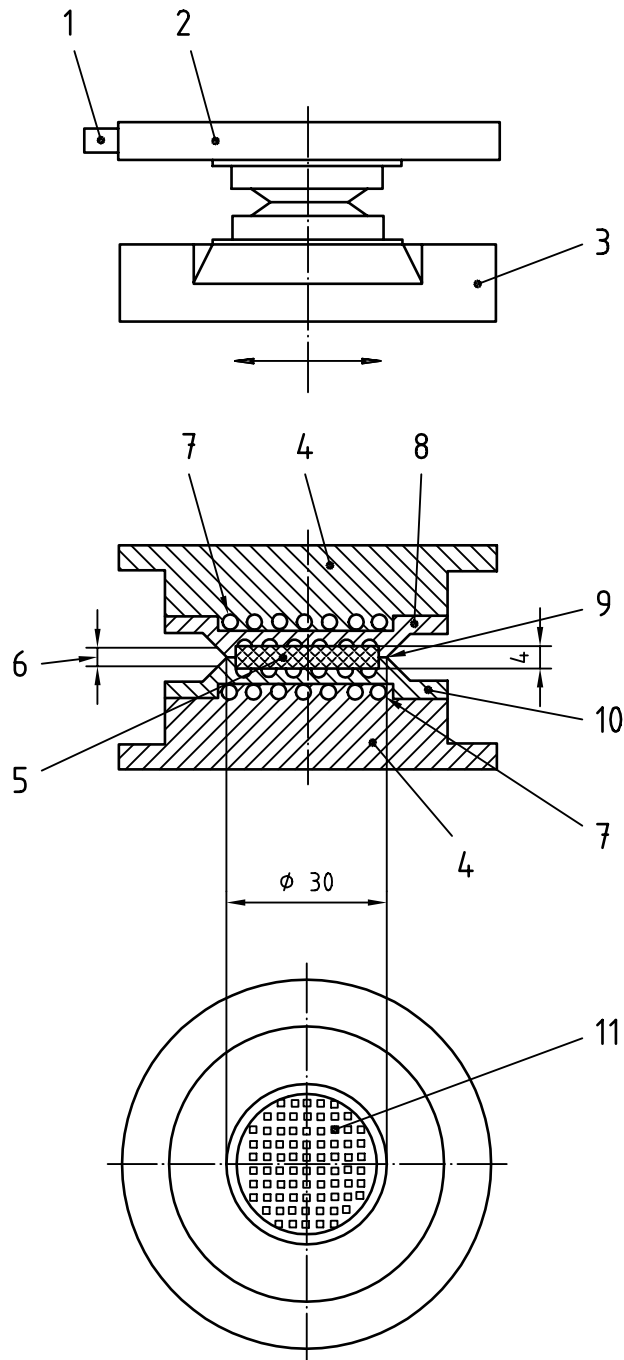
Key

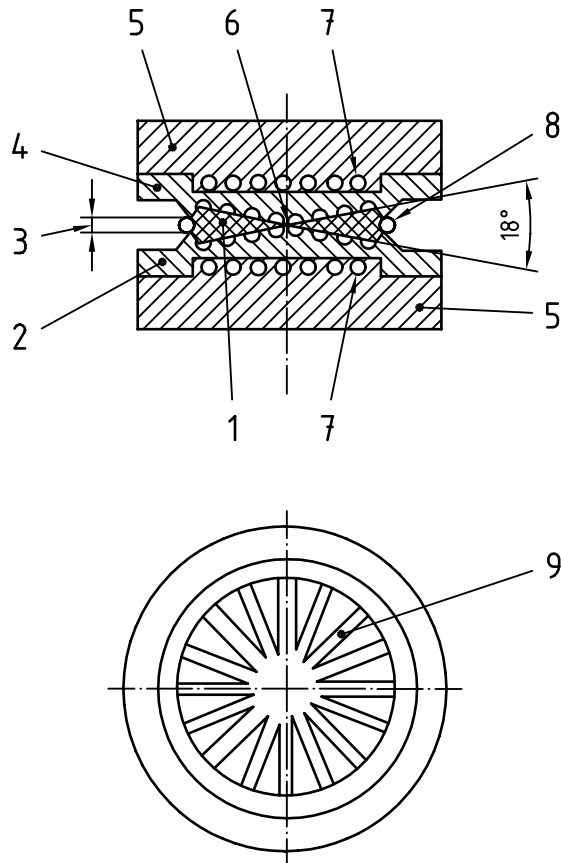|						
1	Force-measuring system	5	Test piece	9	Spew
2	Fixed die	6	Die gap	10	Lower die
3	Oscillating die	7	Heater	11	Grooves
4	Temperature sensor	8	Upper die		

Figure 3 — Typical linear-shear curemeter

Key

1　Fixed die
2　Oscillating die
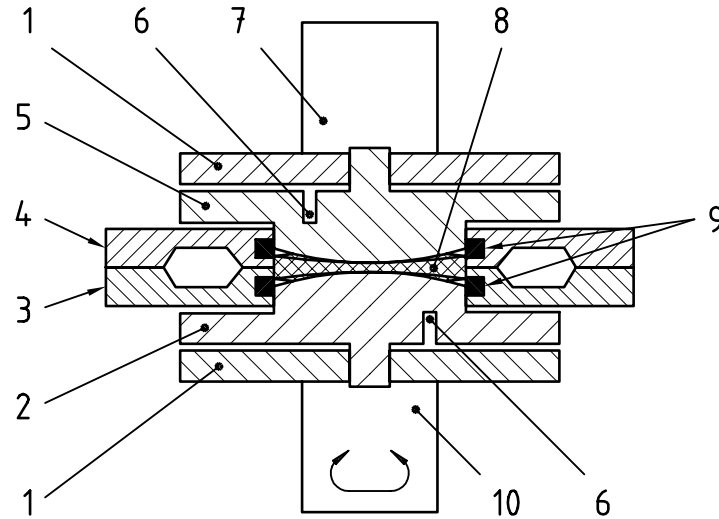3　Torque-measuring system

a) Measurement principle

Key

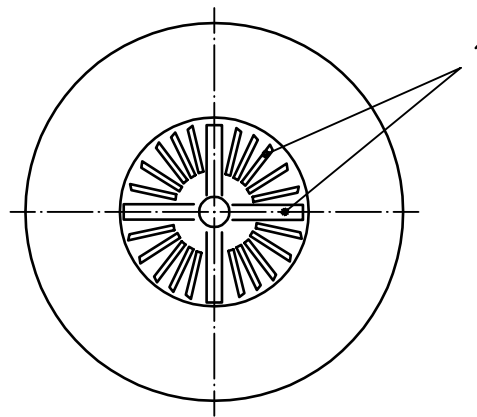|					
1	Test piece	4	Upper die	7	Heater
2	Lower die	5	Temperature sensor	8	Spew
3	Die gap	6	Die gap > 0,5 mm	9	Grooves

b) Details of dies

Figure 4 — Typical unsealed torsion-shear curemeter

Key

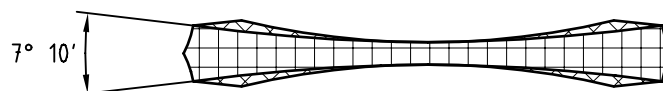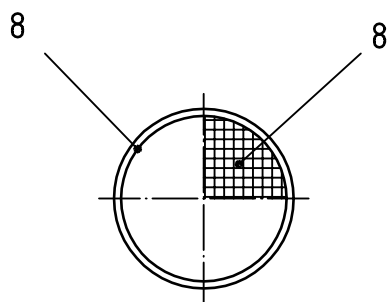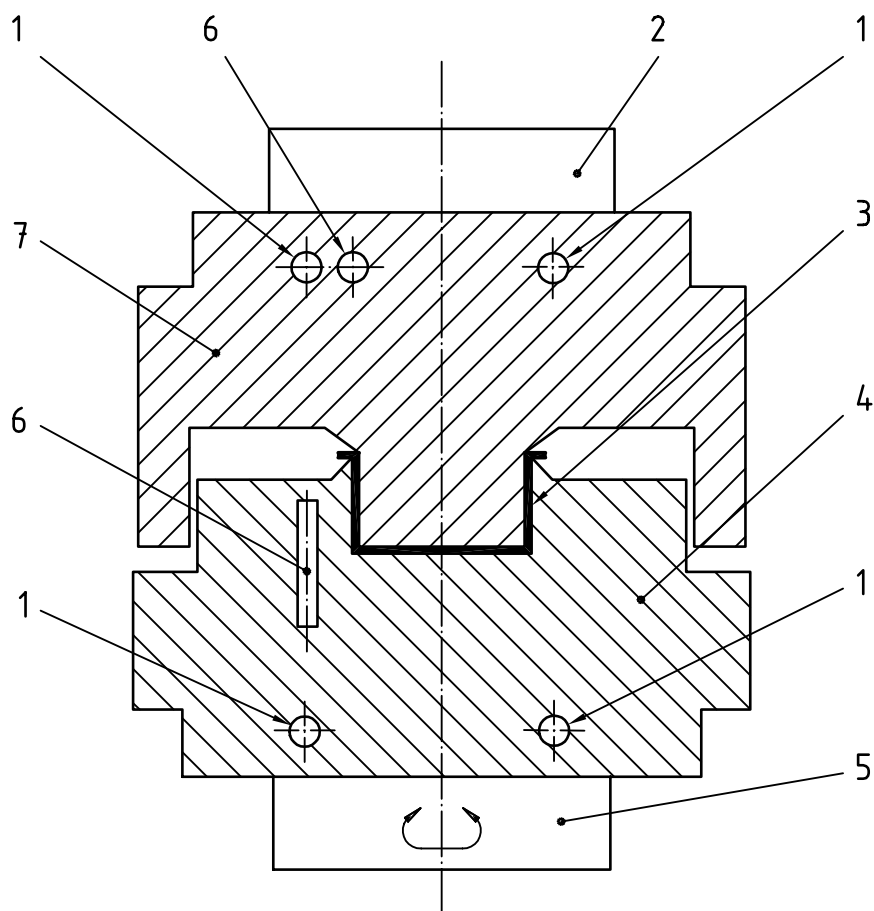|					
1	Heater	5	Upper die	9	Seals
2	Lower die	6	Temperature sensor	10	Oscillating-drive system
3	Lower seal plate	7	Torque-measuring system		
4	Upper seal plate	8	Test piece		

a) Measurement principle

Key

1   Grooves

b) Die (upper and lower)

c) Test piece

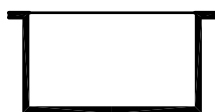**Figure 5 — Typical sealed torsion-shear rotorless curemeter with biconical-die structure**

Key

1	Heater	4	Lower die	7	Upper die
2	Torque-measuring system	5	Oscillating-drive system	8	Grooves
3	Test piece	6	Temperature sensor		

a) Details of dies

b) Test piece

Figure 6 — Typical top-hat-section rotorless curemeter

Dimensions in millimetres
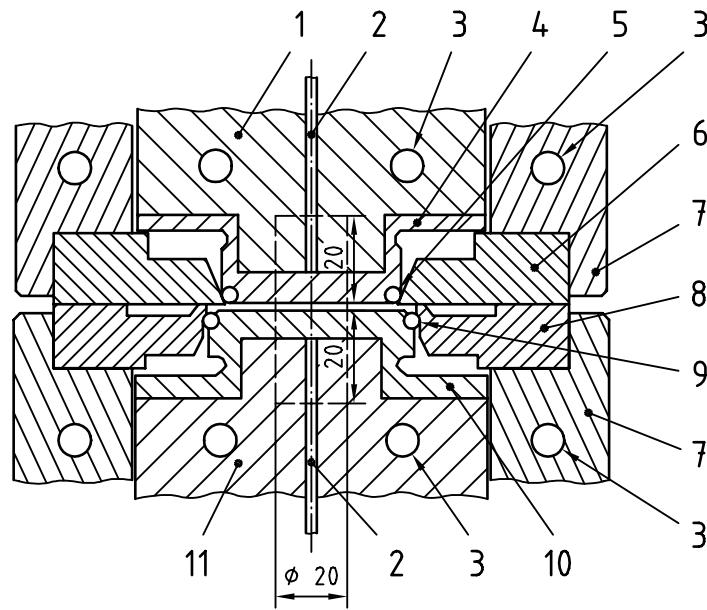
Key

1	Shaft of torque-measuring system	5	Upper seal	9	Lower seal
2	Temperature sensor	6	Upper seal plate	10	Lower die
3	Heater	7	Platen	11	Drive shaft
4	Upper die	8	Lower seal plate		

Dimensions in millimetres
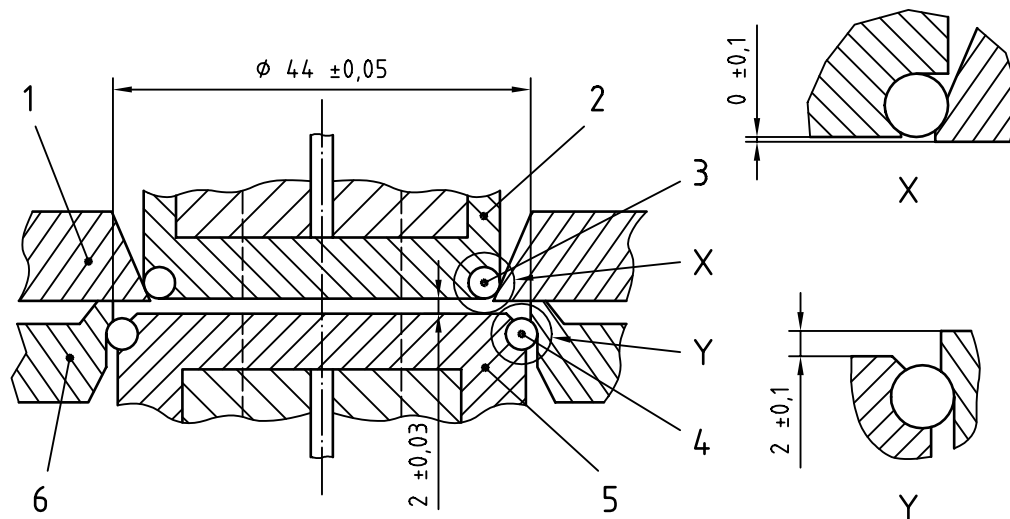
Key

1	Upper seal plate	4	Lower seal
2	Upper die	5	Lower die
3	Upper seal	6	Lower seal plate

Figure 7 — Typical sealed torsion-shear flat-plate-die rotorless curemeter *(continued on following page)*

Dimensions in millimetres

Figure 7 *(concluded)*

Annex A

(informative)

Effect of thermal parameters on measured cure properties

A.1 General

Curing (vulcanization) is the basic product-forming process in the rubber industry. In order to calculate the cure profile in an article, and hence the optimum cure schedule, it is necessary to know the relationship between cure, time and temperature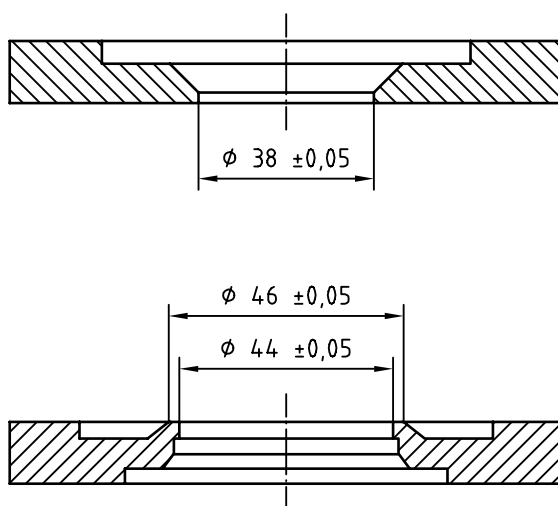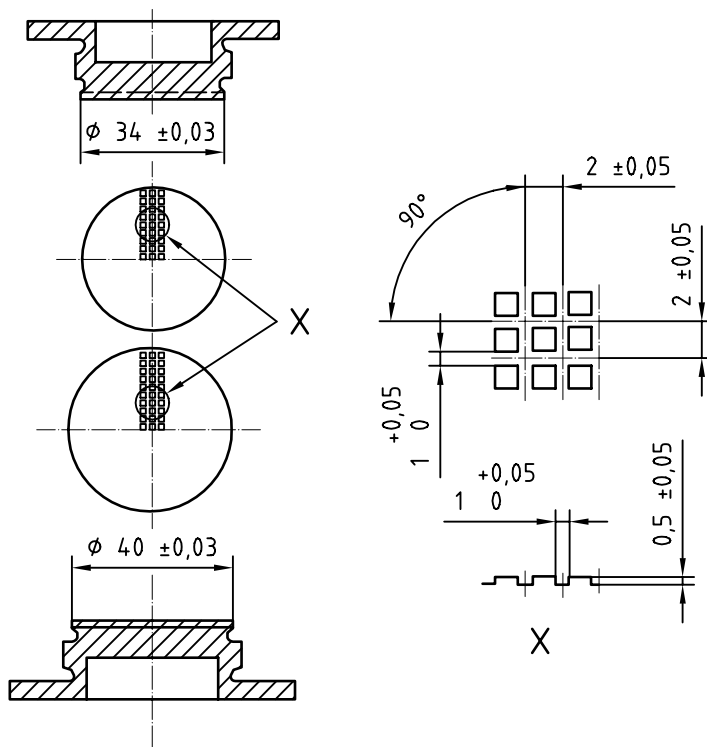 for the rubber compound under isothermal conditions. In current industrial practice, the basic cure parameters for rubber are determined from measurements made on curemeters. These instruments measure a property, which can be called stiffness, which is approximately proportional to the hot-shear modulus. The sample has a stiffness before any crosslinking takes place, and stiffness increases from this minimum value to a maximum during the course of the curing reaction, giving rise to the familiar S-shaped curve. The cure time at a given temperature is the time taken to reach 90 %, say, of this stiffness change. The material should be characterized by making measurements at different temperatures.

A.2 Deviation from isothermal conditions

The majority of curemeters do not operate under isothermal conditions. In any instrument, this deviation is a result of the finite time required for the sample to reach thermal equilibrium. During this heating-up period, the stiffness decreases [see Figure 1 b)]. As a rule of thumb, a 1-mm-thick sheet heated from both surfaces would take about 6 s to heat up. Time increases as the square of the thickness, and a 6-mm-thick sheet would take about 4 min. The heating-up time for a particular curemeter thus depends on the thickness of the test piece. It becomes more important at higher temperatures because the time needed to heat the sample is a larger fraction of the cure time.

There is an additional problem with curemeters with a rotor. Heat is lost continuously by conduction from the rotor down the drive shaft, causing the rotor to be cooler than the platens. The average temperature of the test piece is, therefore, less than the set temperature, and the curing process is slower.

The gap between the platens in a rotorless curemeter should be set so that the test piece remains under a positive pressure during the measurement. This is not only to eliminate problems with porosity, but also because it has been reported that lack of pressure gives cure times which are too long (see reference [1]). Pressure may have a direct effect on the curing-reaction rate, or it may affect the heat transfer between the platen surfaces and the test piece.

If the curemeters are only being used for quality control, the above considerations may not matter, unless results from different types of instrument are being compared. To accommodate this, the following action may be carried out. To obtain vulcanization characteristics comparable with those obtained with the oscillating-disc curemeter described in ISO 3417, the heater of the rotorless curemeter should be adjusted so as to heat the test piece to the specified temperature in 6 min. This has given comparable results with a number of compounds of medium filler content of the most important rubber types. This procedure should only be adopted with extreme caution.

If, on the other hand, curemeter results are to be used for calculating cure times, operators should be aware of the size and effect of any deviations from isothermal conditions (see reference [2]). For example, at 150 °C an oscillating-disc curemeter can overestimate the cure time by a factor of about two (see references [3] and [4]). The factor increases at higher temperatures. The relationship is not linear and should be determined experimentally.

A.3   Calculating cure times

Having obtained as near to isothermal cure data as the curemeter will allow at different temperatures, two types of information are then required for calculating the cure level at any point in an article. First, it is necessary to measure or to calculate the temperature within the article as it varies with time. Second, it is necessary to have a model of the curing process.

For economy, the heating and cooling cycles should be kept as short as possible, but for uniformity in the finished product the temperature variation within an article should be minimized by increasing the cycle time. These conflicting requirements become much more serious with large articles since the heating-up time for the centre is proportional to the square of the thickness. The same applies to small articles when cured at very high temperatures.

A thick article not only takes longer to heat up but also takes longer to cool down after removal from the mould and, in some cases, over half the total cure at the centre can take place during cooling. This should be taken into account in any cure calculation (see reference [5]). It is also necessary to ensure that the cure level at the centre at the end of the heating phase is sufficient to prevent porosity when the pressure is released (see reference [6]), and at the same time to ensure that overcure at the surface is not excessive.

The following table gives the approximate heating times for the centre of a slab to reach the same temperature as the surface when heated from both sides as in compression moulding. When the article is removed from the mould, the cooling times will be longer because the surface conditions are different.

Thickness	Time
1 mm	6 s
6 mm	3,6 min
12 mm	14,4 min
18 mm	32,4 min

For applications which are not critical, rules of thumb are often used to estimate cure times. A factor is added to the result from the curemeter for a given increase in thickness. Merely adding the heating-up time to the curemeter time would result in an overcured product. The factor obviously depends on the curemeter time and on any inherent errors in the curemeter, and also takes into account the cure which occurs during the cooling phase. If the curemeter is changed for one of a different type, a new rule of thumb should be developed.

For more demanding applications, the temperature distribution should be calculated. Assuming that the thermal diffusivity of the rubber compound is known, the temperature distribution can be calculated by using the published analytical solutions (see reference [7]) to the general heat equation, or by using a numerical method on a computer. The latter is more versatile and can be applied to a wider range of shapes (see references [8] and [9]).

During injection moulding the rubber enters the mould hot, and less time is required to achieve a uniform temperature distribution. However, because the process is more complicated than compression moulding the analysis of injection moulding is best done by computer simulation (see references [10] and [11]).

The cure rate at any instant in the curing reaction is a function of the temperature and the instantaneous cure level. Computer software packages are available which analyse data from isothermal curemeters to obtain a pragmatic form for this function. This can then be combined with the temperature history of any point in the article to give the cure at that point (see references [12] and [13]).

If a computer package is not available, the usual approach is to separate the effects of cure level and temperature on the cure rate. However, the form of the function for the cure level dependence is not generally known. The usual way round this difficulty is to work in terms of an equivalent cure time at an arbitrary reference temperature. The form of the function then becomes unimportant.

The temperature dependence can be represented by an activation energy or by a temperature coefficient. The temperature coefficient method is easier to use and is often more accurate. It is defined as the ratio of the cure times for a 10 °C change in the cure temperature. The rule-of-thumb value for the temperature coefficient is 2. The actual value can be obtained from a graph of log isothermal-cure time against temperature. The activation energy can be obtained from a graph of log isothermal-cure time against the reciprocal of the absolute temperature. Equivalent cure at, say, the centre can then be compared with the cure at the surface and with the ideal cure from the curemeter (see reference [14]).

A.4   References

[1]   NORMAN, R.H.: *Polymer testing*, **1**, (4), p. 247 (1980).

[2]   MICHAELI, W.,TIETZ, W., HARMS, R., and KALWA, M.: *Kaut. u. Gummi Kunst.*, **43** (10), p. 899 (1990).

[3]   HANDS, D., NORMAN, R.H., and STEVENS, P.: *Kaut. u. Gummi Kunst.*, **39** (4), p. 330 (1986).

[4]   SEZNA, J.A.: *Rubber World*, **205** (4), p. 21 (1992).

[5]   KHOUIDER, A., and VERGNAUD, J.M.: *J. Appl. Polym. Sci.*, **32** (6), p. 5301 (1986).

[6]   FLETCHER, W.: J.I.R.I, **5** (6), p. 249 (1971).

[7]   CARSLAW, H.S., and JAEGER, J.C.: *Conduction of Heat in Solids*, 2nd Edition, Oxford (1959).

[8]   HANDS, D., and HORSFALL, F.: ACS Rubb. Div., 124th meeting, Oct. 1983, paper 11.

[9]   HAERTEL, V., and STEINMETZ, G.: *Kaut. u. Gummi Kunst.*, **38** (1), p. 34 (1985).

[10] THOMAS, M.D.H., HORSFALL, F., and DOLBEY, P.C.: *Computer simulation of Thermoset, Thermoplastic and Rubber Injection Moulding*, Plastics Injection Moulding in the 1990s, Conf., Rapra Technology Ltd, Nov. 1990.

[11] KREHWINKEL, T., and SCHNEIDER, C.: *Kaut. u. Gummi Kunst.*, **41** (2), p. 164 (1988).

[12] DENG, J.S.: ACS Rubb. Div., 140th meeting, Oct. 1991, paper 55.

[13] KREHWINKEL, T., and SCHNEIDER, C.: *Kaut. u. Gummi Kunst.*, **41** (6), p. 564 (1988).

[14] HILLS, D.A.: *Heat Transfer and Vulcanization of Rubber*, Elsevier (1971).

Annex B
(informative)

Particular requirements for oscillating-disc curemeters

Particular requirements for oscillating-disc curemeters are given in ISO 3417.

Annex C
(informative)

Particular requirements for rotorless curemeters

C.1   Die cavity

The volume of the die cavity should be not greater than 5 cm^3. A volume between 1,5 cm^3 and 2,5 cm^3 is recommended for biconical-die types to attain near-isothermal conditions.

Typical dimensions are diameter 30 mm and height 4 mm for reciprocating instruments, diameter 40 mm, angle 7° to 18° and gap height at the centre ⩾ 0,5 mm for oscillating biconical instruments, diameter 44 mm and thickness 2 mm for oscillating flat-plate instruments and outside diameter 25 mm, height 15 mm and die gap 0,5 mm for oscillating "top hat" section instruments.

C.2   Heating and temperature control

A facility should be provided for inserting a temperature sensor into the test area to check the temperature distribution.

The apparatus should be capable of heating the test area to the specified curing temperature within 1,5 min of closing the die cavity, and the temperature distribution within the test area should not be greater than ±1 °C. Some instruments may allow the test area to reach the test temperature within 0,5 min. The difference between the reference temperature measured in the dies and the average test area temperature should not exceed 2 °C.

ICS 83.060

Price based on 19 pages