International Standard 2856

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Elastomers — General requirements for dynamic testing

Élastomères — Spécifications générales pour essais dynamiques

Second edition — 1981-10-15

UDC 678.074 : 620.1 **Ref. No. ISO 2856-1981 (E)**

Descriptors : rubber, definitions, tests, testing conditions, test specimens, test equipment, elastic properties.

Price based on 14 pages

ISO 2856-1981 (E)

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 2856 was developed by Technical Committee ISO/TC 45, *Rubber and rubber products*.

The first edition (ISO 2856-1975) had been approved by the member bodies of the following countries :

Australia	Hungary	South Africa, Rep. of
Austria	India	Spain
Belgium	Italy	Sweden
Brazil	Mexico	Switzerland
Canada	Netherlands	Thailand
Czechoslovakia	New Zealand	United Kingdom
Egypt, Arab Rep. of	Poland	USA
France	Portugal	USSR
Germany, F. R.	Romania	

No member body had expressed disapproval of the document.

This second edition, which cancels and replaces ISO 2856-1975, incorporates draft amendment 1, which was circulated to the member bodies in December 1979 and has been approved by the member bodies of the following countries :

Austria	Hungary	Sri Lanka
Belgium	India	Switzerland
Canada	Italy	Thailand
China	Korea, Rep. of	Turkey
Czechoslovakia	Netherlands	United Kingdom
Denmark	Poland	USA
Egypt, Arab Rep. of	Romania	USSR
France	South Africa, Rep. of	
Germany, F. R.	Spain	

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

Malaysia
Sweden

Contents

Page

Elastomers — General requirements for dynamic testing

1 Scope and field of application

This International Standard gives definitions and specifies quantitative conditions and general requirements for test pieces, testing machines and test procedures for determining viscoelastic parameters of elastomers by application of cyclic forces or deformation of controlled form, frequency and amplitude, including impact forces or deformations. The term "dynamic properties" is here used to characterize the deformation behaviour of elastomers under conditions when both stress and strain vary periodically with time.

This International Standard is oriented towards the use of laboratory prepared test pieces but the same principles usually apply to tests on finished products or their models.

A summary of basic concepts and theory of dynamic properties of elastomers, with selected references, is included to clarify the definitions and interpretation of data.

2 References

ISO 471, *Rubber — Standard temperatures, humidities and times for the conditioning and testing of test pieces.*

ISO 1826, *Rubbers — Time-lapse between vulcanization and testing.*

ISO 3383, *Rubber — General directions for achieving elevated or sub-normal temperatures for tests.*

ISO 4661, *Rubber — Preparation of test pieces.*

3 Terms and relationships used to define dynamic properties of elastomers

Each of the following terms and relationships applies to linear models of elastomer behaviour.

It is recommended that the unqualified term "modulus" should not be used. The term "modulus" should be prefaced as in, for example, "elastic shear modulus". Bulk or hydrostatic compression modulus of elastomers is several orders of magnitude larger than the deformation moduli considered here, and is not dealt with in this International Standard. Shear and normal moduli are material properties of the rubber vulcanizate and are independent of the size and shape. In contrast, spring constant and damping constant are dependent upon geometry (shape and size) and are usually applied to whole products, such as bushings, mounts, and tyres.

Finally, the use of SI units in their basic form is recommended; these are accordingly given for the terms defined below.

3.1 Terms applying to any periodic motion

3.1.1 mechanical hysteresis loop : The closed curve representing successive stress-strain states of the material during a cyclic deformation.

NOTE — Loops may be centered around the origin of co-ordinates or more frequently displaced to various levels of strain or stress; in this case the shape of the loop becomes variously asymmetrical, but this fact is frequently disregarded.

3.1.2 energy loss (J/m^3) : The energy per unit volume which is lost in each deformation cycle. It is the hysteresis loop area, calculated with reference to co-ordinate scales.

3.1.3 power loss (W/m^3) : The power per unit volume which is transformed into heat through hysteresis. It is the product of energy loss and frequency.

3.1.4 mean stress (Pa) : The average value of the stress during a single complete hysteresis loop (see figure 1).

3.1.5 mean strain (dimensionless) : The average value of the strain during a single complete hysteresis loop (see figure 1).

3.1.6 mean modulus (Pa) : The ratio of mean stress to mean strain.

3.1.7 stress amplitude (Pa) : The ratio of the maximum applied force, measured from the mean force, to the cross-sectional area of the unstressed test piece (zero to peak on one side only).

3.1.8 root-mean-square stress (Pa) : The square root of the mean value of the square of the stress averaged over one cycle of deformation. For a symmetrical sinusoidal stress the root-mean-square stress equals the stress amplitude divided by $\sqrt{2}$.

3.1.9 strain amplitude (dimensionless) : The ratio of the maximum deformation, measured from the mean deformation, to the free length of unstrained test piece (zero to peak on one side only).

3.1.10 root-mean-square strain (dimensionless) : The square root of the mean value of the square of the strain averaged over one cycle of deformation. For a symmetrical sinusoidal strain the root-mean-square strain equals the strain amplitude divided by $\sqrt{2}$.

3.2 Terms applying to sinusoidal motion

Sinusoidal motion implies hysteresis loops which are or can be considered to be elliptical. The term "incremental" may be used to designate dynamic response to sinusoidal motion about various levels of mean stress or mean strain (for example, incremental spring constant, incremental elastic shear modulus).

For large sinusoidal deformation, the hysteresis loop will deviate from an ellipse since the stress-strain relationship of rubber is non-linear and the motion is no longer sinusoidal.

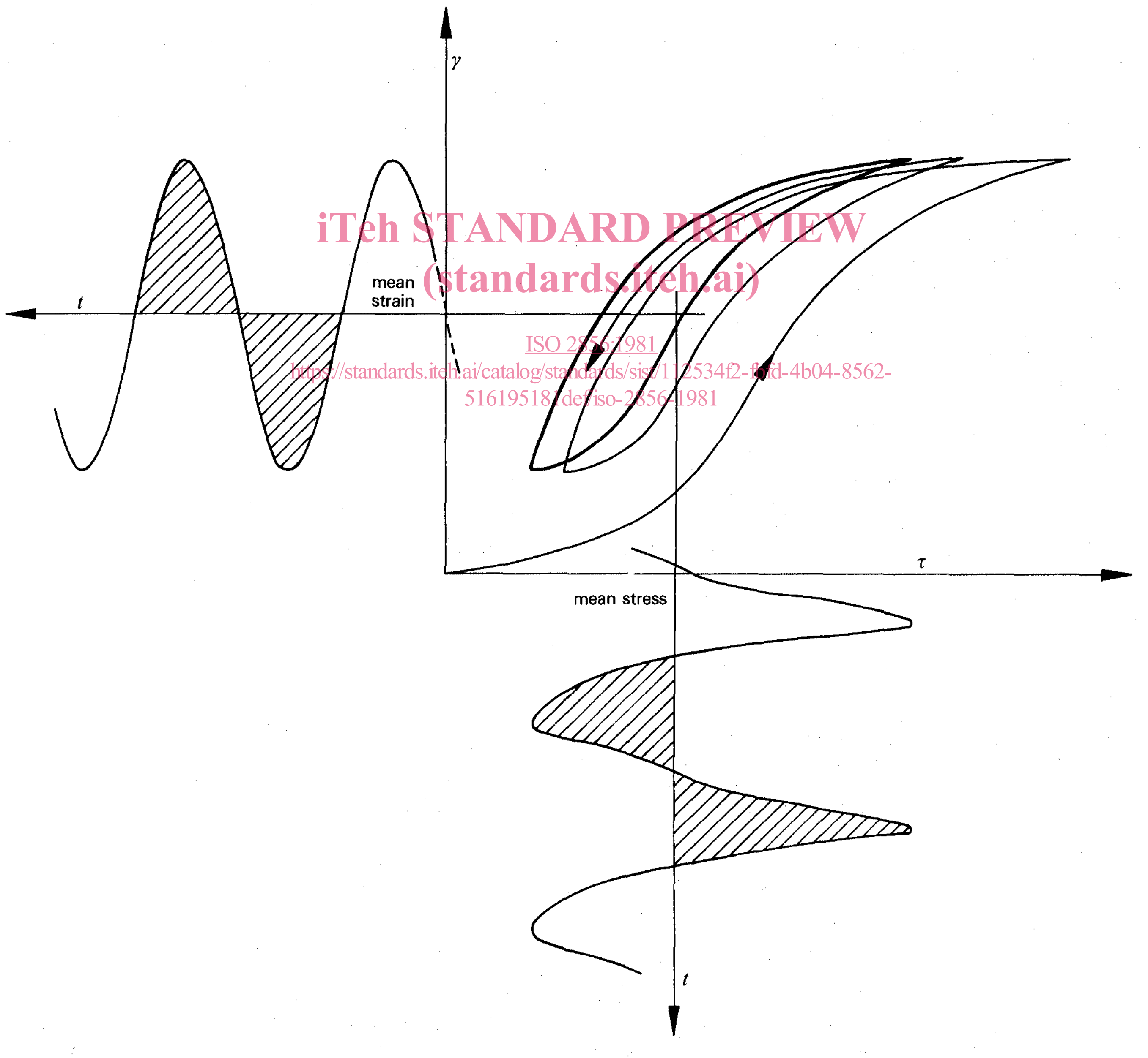

Figure 1 — Heavily distorted hysteresis loop obtained under forced pulsating sinusoidal strain. Open initial loops are shown as well as equilibrium mean strain and mean stress as time-averages of instantaneous strain and stress

3.2.1 spring constant k (N/m) : The component of applied force which is in phase with the deformation, divided by the deformation.

3.2.2 elastic shear modulus (storage shear modulus) G' (Pa) : The component of applied shear stress which is in phase with the shear strain, divided by the strain.

3.2.3 elastic normal modulus (storage normal modulus; elastic Young's modulus) E' (Pa) : The component of applied normal stress which is in phase with the normal strain, divided by the strain.

3.2.4 damping constant c (N·s/m) : The component of applied force which is in quadrature with the deformation, divided by the velocity of deformation.

3.2.5 loss shear modulus G'' (Pa) : The component of applied shear stress which is in quadrature with the shear strain, divided by the strain.

3.2.6 loss normal modulus (loss Young's modulus) E'' (Pa) : The component of applied normal stress which is in quadrature with the normal strain, divided by the strain.

3.2.7 complex shear modulus $G^* = G' + jG''$ (Pa) : The ratio of the shear stress to the shear strain, where each is a vector which may be represented by a complex number.

3.2.8 complex normal modulus (complex Young's modulus) $E^* = E' + jE''$ (Pa) : The ratio of the normal stress to the normal strain, where each is a vector which may be represented by a complex number.

3.2.9 absolute (value of) complex shear modulus $G^* = |G^*| = \sqrt{G'^2 + G''^2}$ (Pa) : The magnitude of the complex shear modulus.

3.2.10 loss factor tan δ (dimensionless) : The ratio of loss modulus to elastic modulus. For shear stresses, $\tan \delta = G''/G'$ and for normals stresses, $\tan \delta = E''/E'$.

3.2.11 loss angle δ (rad) : The phase angle between stress and strain, the tangent of which is the loss factor.

3.3 Terms applying to other motion

3.3.1 logarithmic decrement Λ (dimensionless) : The natural (naperian) logarithm of the ratio between successive amplitudes of the same sign of a damped oscillation.

3.3.2 damping ratio u (dimensionless) : The ratio of actual to critical damping where critical damping is that required for the borderline condition between oscillatory and non-oscillatory behaviour. Damping ratio is a function of the logarithmic decrement :

$$u = \frac{\Lambda/2\pi}{\sqrt{1 + (\Lambda/2\pi)^2}} = \sin \arctan (\Lambda/2\pi)$$

For small values of Λ it is : $u = \Lambda/2\pi$

3.3.3 rebound resilience R (dimensionless) : After a succession of impacts, when steady state is reached, the ratio of the output to the input energy of a moving mass which impacts the test piece.

4 General information about testing machines

Testing machines may provide impacts or cyclic oscillations in various ranges of stress or strain amplitudes, frequencies, and temperatures[6] [19]. Machines which operate at frequencies above 500 Hz or with which distributed vibrations occur are not considered here. Often two or more types of machine will be needed to cover the desired range of operating conditions.

Testing machines may be classified as follows :

1) Type of motion

— Cyclic resonant oscillations

— Cyclic non-resonant oscillations

— Rolling, pulsed deflection

— Free, damped oscillation

— Impact

2) Imposed quantity

— Strain

— Stress

— Energy

3) Frequency range covered

— Static and low frequency < 1 Hz

— Medium frequency 1 to 100 Hz

— High frequency > 100 Hz

5 Testing machine requirements

Only general requirements for dynamic testing machines are considered here. Construction shall, of course, be sturdy and precise. Response shall be unaffected by machine resonances within the test frequency range, or spurious vibrations of either internal or external origin. The imposed amplitude and frequency shall be constant and, where necessary, adjustable.

Readings or recordings, whether by mechanical, optical or electrical means, shall have adequate sensitivity, linearity and absence of effects due to such extraneous variables as temperature. If measurements are to be made at other than ambient temperature, an adequately thermostatted housing operating in accordance with ISO 3383 shall be provided for at least the test piece holder. A temperature measuring system shall be provided and properly operated. For adequate description of test piece temperature, this may involve transducers such as internal and external thermocouples or thermistors with appropriate indicating or recording devices.

6 Recommended standard test values

Because of the complex viscoelastic behaviour of elastomers, results of dynamic measurements are highly sensitive to test conditions such as temperature, frequency, and amplitude of applied force or deformation (see annex D). Test piece shape is also important (see clause 7).

Either stress or strain amplitude must be specified, and also either mean stress or mean strain.

Conditions for standard tests shall agree with those given in this clause.

6.1 Temperature (°C)

Nominal temperatures shall be selected from the following (°C) :

−70	+ 70
−55	+ 85
−40	+100
−25	+125
−10	+150
0	+175
+23	+200
+27	+225
+40	+250
+55	

The actual temperature anywhere in the test piece shall not differ from the nominal value by more than a set tolerance. This is normally ± 2 °C but may be narrowed to ± 0,5 °C near a transition temperature, or widened when high frequencies or high amplitudes are involved. The tolerance shall be stated in the test report (see clause 10).

6.2 Form and type of impressed strain and stress

The preferred form of impressed strain or stress is sinusoidal. Shear strains and stresses are preferable but normal ones are acceptable if reasonably homogenous (see 7.2). Sinusoidal strain or stress shall be impressed on the test piece with harmonic distortion as low as possible, and in no case greater than 10 %. Dynamic stress or strain may be superposed on any level of mean stress or strain, including zero.

Other acceptable forms of impressed strain or stress are free damped oscillations with a logarithmic decrement less than 1,0, periodic half-sinusoidal cycles, and impacts.

6.3 Frequency and amplitudes

Frequency, strain amplitude and stress amplitude ranges may include only a few points or up to several decades, depending on test objectives. It is recommended that these experimental parameters be varied in a logarithmic manner. The following scales, given by way of example, may be extended at either end through multiplication by appropriate negative or positive powers of 10.

Scale A : 1; 10

Scale B : 1; 3; 10

Scale C : 1; 2; 5; 10

Scale D : 1; 1,5; 2; 3; 5; 7; 10

6.3.1 Frequency (Hz)

Frequency tolerance shall be ± 2 % of the nominal value. No frequency higher than 500 Hz is considered here.

6.3.2 Strain amplitude (dimensionless)

Strain amplitude tolerance shall be ± 5 % of the nominal value.

6.3.3 Stress amplitude (Pa)

Stress amplitude tolerance shall be ± 5 % of the nominal value.

6.4 Mean strain or stress (pre-loading)

The direction of pre-loading is not restricted to that of the alternating strains or stresses. Values and tolerances shall be selected as for the alternating values.

6.5 Single reference value

If, for reference purposes, a single set of parameters is required, this set shall be :

temperature :	70 °C
form and type of impressed strain :	sinusoidal shear
frequency :	10 Hz
strain amplitude :	0,06
mean :	zero

7 Test pieces

Although the overall size of the test piece will affect the internal temperature rise during test, this is also influenced by other factors (see 8.4), and hence absolute dimensions are not specified.

However, the test piece shape and the way in which the force is applied directly affect the stress distribution and hence the modulus values obtained experimentally. Both of these are specified (see 7.2.3).

7.1 Test piece preparation

Test pieces shall be prepared in general accordance with ISO 4661.

Preferably, test pieces shall be suitably moulded and vulcanized. Metal end pieces shall be attached with vulcanizing bonding agents. Care shall be taken to obtain very uniform vulcanization, especially with thick test pieces.

Alternatively, test pieces may be obtained from finished articles by cutting and buffing. Suitable cold-setting cement shall be used for bonding such test pieces to metal end pieces.

7.2 Shape of test piece and type of strain

An ideal test piece will give a homogeneous distribution of stress and strain. In practice, however, this is rarely the case. Hence, suitable analytical or empirical analyses shall be used to correct the results obtained experimentally.

7.2.1 Analysis of deformation

Unless otherwise stated, analysis of test piece deformation shall follow a first approximation statistical or phenomenological theory of rubber elasticity. The following expressions relate to the elastic component of the modulus. Analogous expressions for the loss component can be derived by references to annexes B and C.

For sheared test pieces, equation (1) shall be used.

$$\tau = \Phi_s G \gamma \qquad \ldots (1)$$

where

τ is the shear stress;

G is the shear modulus;

γ is the shear strain;

Φ_s is a shape factor.

For extended or compressed pieces, equation (2) shall be used :

$$\sigma \approx \Phi_s E (\lambda - 1) \qquad \ldots (2)$$

where

σ is the normal stress referred to initial section;

λ is the extension ratio (actual length/initial length).

This approximate relation is true only if λ is near unity, certainly not outside the range 0,8 to 1,2.

If a more accurate deformation analysis such as that in annex B is used, this shall be stated in the test report.

7.2.2 Non-homogeneous deformation shape factors

Any non-homogeneity of deformation shall be recognized by using suitable shape factors or functions[24].

Preference shall be given to expressions not containing, explicitly or implicitly, the moduli or other quantities to be determined.

7.2.3 Recommended shapes and shape factors

7.2.3.1 Sheared square prism

The base side b shall be four times the height h. Shear force shall be applied to the bases and parallel to one of the base sides.

Use equation (1) (see 7.2.1) with a shape factor $\Phi_s = 1{,}0$ so that

$$\tau = G \gamma$$

7.2.3.2 Sheared circular cylinder

The radius r shall equal the height h. Shear force shall be applied to the circular faces parallel to a diameter.

Use equation (1) (see 7.2.1) with a shape factor $\Phi_s = 0{,}9$ so that

$$\tau = 0{,}9\, G \gamma$$

7.2.3.3 Normally strained square prism

The base side b shall be twice the height h. Normal force shall be applied to the bases and parallel to the height.

Use equation (2) (see 7.2.1), with the stated limitations on λ, with a shape factor $\Phi_s = 1{,}5$ so that

$$\sigma \approx 1{,}5\, E (\lambda - 1)$$

7.2.3.4 Normally strained circular cylinder

The radius r shall equal one-half the height h. Normal force shall be applied to the bases parallel to the height.

Use equation (2) (see 7.2.1), with the stated limitations on λ, with a shape factor $\Phi_s = 1{,}1$ so that

$$\sigma \approx 1{,}1\, E (\lambda - 1)$$

7.2.3.5 Torus

The torus[15], having pseudotrapezoidal section, shall be bounded internally by a cylindrical surface of radius r_i and externally by a cylindrical surface of radius $r_e = 1{,}2\, r_i$ and thickness $h_e = r_e/6$. The lateral surface shall be hyperboloidal and defined by the relation :

$$r^2 h = r_e^2 h_e = \text{constant}$$

where r and h are any corresponding radius and thickness. Axial torque shall be applied to the cylindrical surfaces.