INTERNATIONAL STANDARD

ISO 4664-1

Second edition
2011-11-15

Rubber, vulcanized or thermoplastic — Determination of dynamic properties —

Part 1: General guidance

Caoutchouc vulcanisé ou thermoplastique — Détermination des propriétés dynamiques —

Partie 1: Lignes directrices

Reference number
ISO 4664-1:2011(E)

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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.

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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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 4664-1 was prepared by Technical Committee ISO/TC 45, *Rubber and rubber products*, Subcommittee SC 2, *Testing and analysis*.

This second edition cancels and replaces the first edition (ISO 4664-1:2005), which has been technically revised as follows:

— the test conditions given in Tables 2 and 3 have been modified;

— a number of equations and figures have been added for better comprehension of the text;

— the clause concerning calibration (Clause 7 in the previous edition) has been deleted.

ISO 4664 consists of the following parts, under the general title *Rubber, vulcanized or thermoplastic — Determination of dynamic properties*:

— *Part 1: General guidance*

— *Part 2: Torsion pendulum methods at low frequencies*

Rubber, vulcanized or thermoplastic — Determination of dynamic properties —

Part 1: General guidance

1 Scope

This part of ISO 4664 provides guidance on the determination of dynamic properties of vulcanized and thermoplastic rubbers. It includes both free- and forced-vibration methods carried out on both materials and products. It does not cover rebound resilience or cyclic tests in which the main objective is to fatigue the rubber.

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 815-1, *Rubber, vulcanized or thermoplastic — Determination of compression set — Part 1: At ambient or elevated temperatures*

ISO 7743:2011, *Rubber, vulcanized or thermoplastic — Determination of compression stress-strain properties*

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 Terms applying to any periodic deformation

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

NOTE Loops can be centred 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 in more than one way, but this fact is frequently ignored.

3.1.2
energy loss
energy per unit volume which is lost in each deformation cycle, i.e. the hysteresis loop area

NOTE It is expressed in J/m^3.

3.1.3
power loss
energy loss per unit time, per unit volume, which is transformed into heat through hysteresis, expressed as the product of energy loss and frequency

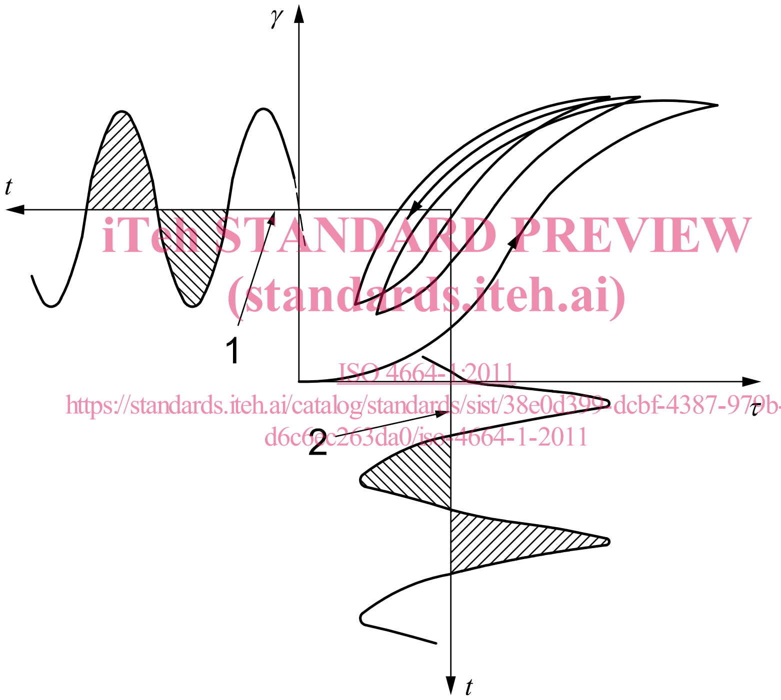
NOTE It is expressed in W/m^3.

3.1.4
mean load
average value of the load during a single complete hysteresis loop

NOTE It is expressed in N.

3.1.5
mean deflection
average value of the deflection during a single complete hysteresis loop (see Figure 1)

NOTE It is expressed in m.



Key

1 mean strain

2 mean stress

NOTE 1 Open initial loops are shown, as well as equilibrium mean strain and mean stress as time-averages of instantaneous strain and stress.

NOTE 2 A sinusoidal response to a sinusoidal motion implies hysteresis loops which are or can be considered to be elliptical.

NOTE 3 For large sinusoidal deformations, the hysteresis loop will deviate from an ellipse since, for rubber, the stress-strain relationship is non-linear and the response is therefore not sinusoidal.

NOTE 4 The term “incremental” may be used to designate a dynamic response to sinusoidal deformation about various levels of mean stress or mean strain (for example, incremental spring constant, incremental elastic shear modulus).

Figure 1 — Heavily distorted hysteresis loop obtained under forced pulsating sinusoidal strain

3.1.6
mean stress
average value of the stress during a single complete hysteresis loop (see Figure 1)

NOTE It is expressed in Pa.

3.1.7
mean strain
average value of the strain during a single complete hysteresis loop (see Figure 1)

3.1.8
mean modulus
ratio of the mean stress to the mean strain

NOTE It is expressed in Pa.

3.1.9
maximum load amplitude
F_0
maximum applied load, measured from the mean load (zero to peak on one side only)

NOTE It is expressed in N.

3.1.10
maximum stress amplitude
τ_0
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)

NOTE It is expressed in Pa.

3.1.11
root-mean-square stress
square root of the mean value of the square of the stress averaged over one cycle of deformation

NOTE 1 For a symmetrical sinusoidal stress, the root-mean-square stress equals the stress amplitude divided by $\sqrt{2}$.

NOTE 2 It is expressed in Pa.

3.1.12
maximum deflection amplitude
x_0
maximum deflection, measured from the mean deflection (zero to peak on one side only)

NOTE It is expressed in m.

3.1.13
maximum strain amplitude
γ_0
maximum strain, measured from the mean strain (zero to peak on one side only)

3.1.14
root-mean-square strain
square root of the mean value of the square of the strain averaged over one cycle of deformation

NOTE 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

3.2.1
spring constant
K
component of the applied load which is in phase with the deflection, divided by the deflection

NOTE It is expressed in N/m.

3.2.2
elastic shear modulus
storage shear modulus
G'
component of the applied shear stress which is in phase with the shear strain, divided by the strain

$$G' = \left| G^* \right| \cos \delta$$

NOTE It is expressed in Pa.

3.2.3
loss shear modulus
G''
component of the applied shear stress which is in quadrature with the shear strain, divided by the strain

$$G'' = \left| G^* \right| \sin \delta$$

NOTE It is expressed in Pa.

3.2.4
complex shear modulus
G^*

ratio of the shear stress to the shear strain, where each is a vector which can be represented by a complex number

$$G^* = G' + \mathrm{i}G''$$

NOTE It is expressed in Pa.

3.2.5
absolute complex shear modulus
$\left| G^* \right|$
absolute value of the complex shear modulus

$$\left| G^* \right| = \sqrt{G'^2 + G''^2}$$

NOTE It is expressed in Pa.

3.2.6
elastic normal modulus
storage normal modulus
elastic Young's modulus
E'
component of the applied normal stress which is in phase with the normal strain, divided by the strain

$$E' = \left| E^* \right| \cos \delta$$

NOTE It is expressed in Pa.

3.2.7
loss normal modulus
loss Young's modulus
E''
component of the applied normal stress which is in quadrature with the normal strain, divided by the strain

$$E'' = |E^*| \sin\delta$$

NOTE It is expressed in Pa.

3.2.8
complex normal modulus
complex Young's modulus
E^*
ratio of the normal stress to the normal strain, where each is a vector which can be represented by a complex number

$$E^* = E' + \mathrm{i}E''$$

NOTE It is expressed in Pa.

3.2.9
absolute normal modulus
absolute value of the complex normal modulus

$$|E^*| = \sqrt{E'^2 + E''^2}$$

3.2.10
storage spring constant
dynamic spring constant
K'
component of the applied load which is in phase with the deflection, divided by the deflection

$$K' = |K^*| \cos\delta$$

NOTE It is expressed in N/m.

3.2.11
loss spring constant
K''
component of the applied load which is in quadrature with the deflection, divided by the deflection

$$K'' = |K^*| \sin\delta$$

NOTE It is expressed in N/m.

3.2.12
complex spring constant
K^*
ratio of the load to the deflection, where each is a vector which can be represented by a complex number

$$K^* = K' + \mathrm{i}K''$$

NOTE It is expressed in N/m.

3.2.13
absolute complex spring constant
$|K^*|$
absolute value of the complex spring constant

$$|K^*| = \sqrt{K'^2 + K''^2}$$

NOTE It is expressed in N/m.

3.2.14
tangent of the loss angle
$\tan\delta$
ratio of the loss modulus to the elastic modulus

NOTE For shear stresses, $\tan\delta = \frac{G''}{G'}$ and for normal stresses $\tan\delta = \frac{E''}{E'}$.

3.2.15
loss factor
L_f
ratio of the loss spring constant to the storage spring constant

$$L_f = \frac{K''}{K'}$$

3.2.16
loss angle
δ
phase angle between the stress and the strain

NOTE It is expressed in rad.

3.3 Other terms applying to periodic motion

3.3.1
logarithmic decrement
natural (Napierian) logarithm of the ratio between successive amplitudes of the same sign of a damped oscillation

3.3.2
damping ratio
u
ratio of actual to critical damping, where critical damping is that required for the borderline condition between oscillatory and non-oscillatory behaviour

NOTE The damping ratio is a function of the logarithmic decrement:

$$u = \frac{\frac{\Lambda}{2\pi}}{\sqrt{1+\left(\frac{\Lambda}{2\pi}\right)^2}} = \sin\tan^{-1}\left(\frac{\Lambda}{2\pi}\right)$$

3.3.3
damping coefficient
damping constant
C

$$C = \frac{1}{\omega}\left|K^*\right|\sin\delta$$

where $\omega = 2\pi f$

NOTE It is expressed in N·s/m.

3.3.4
transmissibility
V_τ

$$V_\tau = \sqrt{\frac{1+(\tan\delta)^2}{\left[1-\left(\frac{\omega}{\omega_n}\right)^2\right]^2+(\tan\delta)^2}}$$

where ω_n is the natural angular frequency of the undamped vibrator, given by

$$\omega_n = \sqrt{\frac{K'}{m}}$$

and

$$K' = \left|K^*\right|\cos\delta$$

4 Symbols

For the purposes of this document, the following symbols apply:

A	(m^2)	test piece cross-sectional area
$a(T)$		Williams, Landel, Ferry (WLF) shift factor
α	(rad)	angle of twist
b	(m)	test piece width
C		damping coefficient (damping constant)
C_p		heat capacity
γ		strain
γ_0		maximum strain amplitude
δ	(rad)	loss angle
E	(Pa)	Young's modulus
E_c	(Pa)	effective Young's modulus
E'	(Pa)	elastic normal modulus (storage normal modulus)

E''	(Pa)	loss normal modulus
E^*	(Pa)	complex normal modulus (complex Young's modulus)
$\lvert E^* \rvert$	(Pa)	absolute value of complex normal modulus
F	(N)	load
F_0	(N)	maximum load amplitude
f	(Hz)	frequency
G	(Pa)	shear modulus
G'	(Pa)	elastic shear modulus (storage shear modulus)
G''	(Pa)	loss shear modulus
G^*	(Pa)	complex shear modulus
$\lvert G^* \rvert$	(Pa)	absolute value of complex shear modulus
h	(m)	test piece thickness
K	(N/m)	spring constant
K'	(N/m)	storage spring constant (dynamic spring constant)
K''	(N/m)	loss spring constant
K^*	(N/m)	complex spring constant
$\lvert K^* \rvert$	(N/m)	absolute value of complex spring constant
k		numerical factor
k_l		shape factor in torsion
L_f		loss factor
l	(m)	test piece length
λ		extension ratio
Λ		logarithmic decrement
M'	(Pa)	in-phase or storage modulus
M''	(Pa)	loss modulus
M^*	(Pa)	complex modulus
$\lvert M^* \rvert$	(Pa)	absolute value of complex modulus
m	(kg)	mass
ρ	(kg/m^3)	rubber density
Q	(N·m)	torque
S		shape factor
T	(K)	temperature (in kelvins)
T_g	(K)	low-frequency glass transition temperature
T_0	(K)	reference temperature