INTERNATIONAL STANDARD

ISO 4664-1

Third edition
2022-07

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 4664-1:2022(E)

Contents

Page

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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

This third edition cancels and replaces the second edition (ISO 4664-1:2011), which has been technically revised.

The main changes are as follows:

— other types of deformation mode have been included in Table 2;

— descriptions of nonlinear behaviour have been added in 6.1.2;

— explanations regarding the forced resonant vibration type method have been added in 6.2;

— other shapes and dimensions of test pieces have been added in Table 4 (the former Table 3);

— test conditions (temperature, frequency, strain, etc.) have been expanded in Table 5 (the former Table 4);

— the derivation method for required viscoelastic parameters has been clarified in 9.5;

— test methods for free vibration and forced vibration resonant type have been detailed in Clauses 10 and 11.

A list of all parts in the ISO 4664 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Rubber, vulcanized or thermoplastic — Determination of dynamic properties —

Part 1:
General guidance

1 Scope

This document gives 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 documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Terms applying to any periodic deformation

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

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

Note 1 to entry: It is expressed in J/m^3.

3.1.3
power loss
energy loss (3.1.2) per unit time, per unit volume, which is transformed into heat through hysteresis, expressed as the product of energy loss and frequency

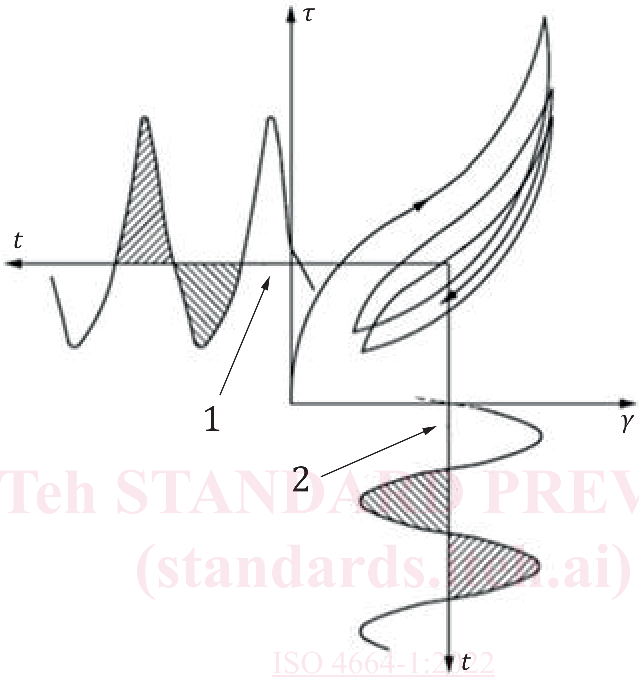
Note 1 to entry: It is expressed in W/m^3.

3.1.4
mean stress
average value of the stress during a single complete *hysteresis loop* (3.1.1)

Note 1 to entry: It is expressed in Pa.

Note 2 to entry: This is the static stress applied before starting dynamic motion.

Note 3 to entry: See Figure 1.



Key

1	mean stress	τ	stress
2	mean strain	γ	strain
		t	time

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 nonlinear 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

3.1.5
mean strain
average value of the strain during a single complete *hysteresis loop* (3.1.1)

Note 1 to entry: This is the static strain applied before starting dynamic motion.

Note 2 to entry: See Figure 1.

3.1.6
maximum load amplitude
F_0
maximum applied load, measured from the average value of the load during a single sinusoidal wave

Note 1 to entry: It is expressed in N.

3.1.7
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 1 to entry: It is expressed in Pa.

3.1.8
maximum deflection amplitude
x_0
maximum value of the deflection, measured from the average value of the deflection during a single sinusoidal wave

Note 1 to entry: It is expressed in m.

3.1.9
maximum strain amplitude
γ_0
maximum value of the strain, measured from the *mean strain* (3.1.5) (zero to peak on one side only)

3.1.10
Payne effect
phenomenon in which the dynamic modulus decreases as the strain increases, in dynamic testing of a filled rubber compound

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 1 to entry: 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 1 to entry: 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 1 to entry: 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

$$G^* = G' + iG''$$

Note 1 to entry: It is expressed in Pa.

3.2.5
absolute complex shear modulus
|*G**|
absolute value of the *complex shear modulus* (3.2.4)

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

Note 1 to entry: 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 1 to entry: 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

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

Note 1 to entry: 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

$$E^* = E' + iE''$$

Note 1 to entry: It is expressed in Pa.

3.2.9
absolute complex normal modulus
absolute value of the *complex normal modulus* (3.2.8)

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

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

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

Note 1 to entry: 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

$$K'' = \left|K^{*}\right| \sin\delta$$

Note 1 to entry: 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

$$K^{*} = K' + iK''$$

Note 1 to entry: It is expressed in N/m.

3.2.13
absolute complex spring constant
$|K^{*}|$
absolute value of the *complex spring constant* (3.2.12)

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

Note 1 to entry: 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 1 to entry: 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* (3.2.11) to the *storage spring constant* (3.2.10)

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

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

Note 1 to entry: It is expressed in rad.

3.3 Other terms applying to periodic motion

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

3.3.2
transmissibility
V_τ
ratio of the force transmitted to the force applied

4 Symbols

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

A	(m^2)	test piece cross-sectional area
a and b	(m)	width or side length of test piece
a_T		Williams, Landel, Ferry (WLF) shift factor
b_T		vertical shift factor
α	(rad)	angle of twist
C_p		heat capacity
γ		strain
γ_0		maximum strain amplitude
γ^*		complex strain
d	(m)	diameter of circular test piece
δ	(rad)	loss angle or phase difference
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 (loss Young's modulus)
E^*	(Pa)	complex normal modulus (complex Young's modulus)
$\|E^*\|$	(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
$\|G^*\|$	(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
$\|K^*\|$	(N/m)	absolute value of complex spring constant
k		numerical factor for shape factor correction
k_l		shape factor in torsion
L_f		loss factor
l	(m)	test piece length or distance between test piece holders
λ		extension ratio
Λ		logarithmic decrement
M'	(Pa)	in-phase or storage modulus
M''	(Pa)	out of phase or loss modulus
M^*	(Pa)	complex modulus
$\|M^*\|$	(Pa)	absolute value of complex modulus
m	(kg)	mass
Q	(N·m)	torque
S		shape factor
T	(K)	temperature (in kelvins)

