
**Rubber, vulcanized or thermoplastic —
Determination of dynamic properties —**

**Part 1:
General guidance**

*Caoutchouc vulcanisé ou thermoplastique — Détermination des
propriétés dynamiques*

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Partie 1: Lignes directrices

ISO 4664-1:2005

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

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

It cancels and replaces ISO 4664:1998, which has been technically revised.

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

- iTeh STANDARD PREVIEW**
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- ISO 4664-1:2005
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- *Part 1: General guidance*
 - *Part 2: Torsion pendulum method at low frequencies*

Rubber, vulcanized or thermoplastic — Determination of dynamic properties —

Part 1: General guidance

WARNING — Persons using this part of ISO 4664 should be familiar with normal laboratory practice. This part of ISO 4664 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 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 (standards.iteh.ai)

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. <https://www.iso.org/standard/4664-1-2005>

ISO 815, *Rubber, vulcanized or thermoplastic — Determination of compression set at ambient, elevated or low temperatures*

ISO 4663, *Rubber — Determination of dynamic behaviour of vulcanizates at low frequencies — Torsion pendulum method*

ISO 5893, *Rubber and plastics test equipment — Tensile, flexural and compression types (constant rate of traverse) — Specification*

ISO 7743:2004, *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 may 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, the hysteresis loop area, calculated with reference to coordinate scales

NOTE It is expressed in J/m^3 .

3.1.3 power loss

power per unit volume in each deformation cycle 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

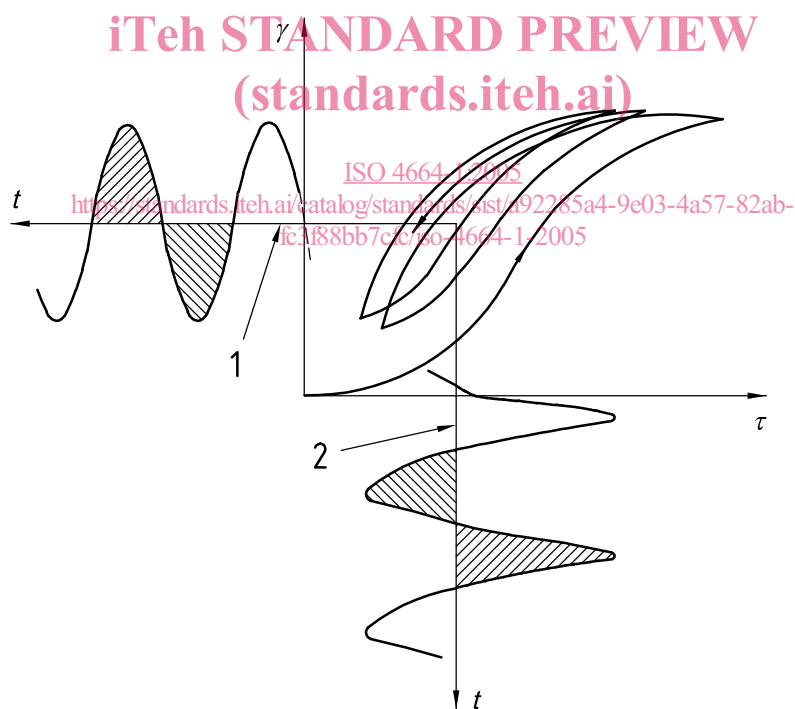
average value of the load during a single complete hysteresis loop

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. The term “incremental” may be used to designate 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

ratio of the 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

ratio of the 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

ratio of the 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

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

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

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

NOTE It is expressed in Pa.

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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 It is expressed in Pa.

3.2.5

absolute complex shear modulus

$|G^*|$
absolute value of the complex shear modulus

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

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

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

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

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

NOTE It is expressed in Pa.

3.2.9**absolute normal modulus**

absolute value of the complex normal modulus

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

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3.2.10**storage spring constant
dynamic spring constant** K'

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

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

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

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

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

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3.2.16
loss angle

δ
phase angle between the stress and the strain, the tangent of which is the tangent of the loss angle

NOTE It is expressed in rad.

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

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

NOTE 2 For large sinusoidal deformations, the hysteresis loop will deviate from an ellipse since the stress-strain relationship of rubber is non-linear and the response is no longer sinusoidal (see Figure 1).

3.3.3 damping coefficient damping constant

C

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

where $\omega = 2\pi f$

NOTE It is expressed in N-s/m.

3.3.4 transmissibility

V_T

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

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

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

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and

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

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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 |

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| | | |
|-----------|----------------------|---------------------------------------------------|
| E' | (Pa) | elastic normal modulus (storage normal modulus) |
| E'' | (Pa) | loss normal modulus |
| E^* | (Pa) | complex normal modulus (complex Young's modulus) |
| $ E^* $ | (Pa) | absolute value of complex normal modulus |
| F | (N) | load |
| 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 |
| k_l | | shape factor in torsion |
| L_f | | loss factor |
| l | (m) | test piece length |
| λ | | extension ratio |
| Δ | | logarithmic decrement |
| M' | (Pa) | in phase or storage modulus |
| M'' | (Pa) | loss modulus |
| M^* | (Pa) | complex modulus |
| $ M^* $ | (Pa) | absolute value of complex modulus |
| m | (kg) | mass |
| ρ | (kg/m ³) | rubber density |