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Standard Terminology for Plastics: Dynamic Mechanical Properties[1]

This standard is issued under the fixed designation D4092; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This terminology is a compilation of definitions and descriptions of technical terms used in dynamic mechanical property measurements on polymeric materials, including solutions, melts, and solids. Terms that are generally understood or defined adequately in other readily available sources are either not included or sources identified.

1.2 A definition is a single sentence with additional information included in notes. It is reviewed every five years and the year of the last review or revision is appended.

1.3 Definitions identical to those published by another standards organization or ASTM committee are identified with the abbreviation of the name of the organization or the ASTM committee.

1.4 Descriptions of terms specific to dynamic mechanical measurements are identified with an italicized introductory phrase.

NOTE 1—This terminology standard is similar to ISO 6721–1 however, the ISO document cites fewer terms.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D883 Terminology Relating to Plastics

D2231 Practice for Rubber Properties in Forced Vibration (Withdrawn 1998)[3]

E6 Terminology Relating to Methods of Mechanical Testing

2.2 *ISO Standards:*[4]

ISO 472: 1988 (E/F) Definitions

ISO 6721–1 1994 (E) Plastics-Determination of Dynamic Mechanical Properties, Part 1, General Principles

3. Terminology Definitions and Descriptions

alpha (α) loss peak (*in dynamic mechanical measurement*)**—**the first peak in the damping curve below the melt, in order of decreasing temperature or increasing frequency. (1981)

beta (β) loss peak (*in dynamic mechanical measurement*)**—**the second peak in the damping curve below the melt, in order of decreasing temperature or increasing frequency. (1981)

complex modulus, *E, *K**, or *G*—***the ratio of the stress to strain where each is a vector that may be represented by a complex number.

$$E^* = E' + iE''$$
$$G^* = G' + iG''$$
$$K^* = K' + iK''$$

where:

E^* = complex modulus, measured in tension or flexure,
E' = storage modulus, measured in tension or flexure,
E'' = loss modulus, measured in tension or flexure,

G^* = complex modulus, measured in shear,
G' = storage modulus, measured in shear,
G'' = loss modulus, measured in shear,

K^* = complex modulus, measured in compression,
K' = storage modulus, measured in compression
K'' = loss modulus, measured in compression, and
i = $\sqrt{-1}$, measured in compression.

DISCUSSION—The complex modulus may be measured in tension (E^*), compression (K^*), flexure (E^*), or in shear (G^*). (1981)

complex shear compliance, *J*—*the reciprocal of complex shear modulus. (1981)

[1] This terminology is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.10 on Mechanical Properties.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

*A Summary of Changes section appears at the end of this standard

$$J^* = \frac{1}{G^*}$$

complex tensile compliance, *D**—the reciprocal of complex tensile modulus. (1981)

$$D^* = \frac{1}{E^*}$$

critical damping (*in dynamic mechanical measurement*)**—**that damping required for the borderline condition between oscillatory and nonoscillatory behavior. (1983).

damping—the loss in energy, dissipated as heat, that results when a material or material system is subjected to an oscillatory load or displacement. (1981)

*dissipation factor***—** see **tan delta**.

dynamic mechanical measurement—a technique in which either the modulus or damping, or both, of a substance under oscillatory load or displacement is measured as a function of temperature, frequency, or time, or combination thereof. (1981)

*dynamic modulus***—**see **complex modulus**.

elasticity—that property of materials that causes them to return to their original form or condition after the applied force is removed. (1981)

*elastic modulus***—**see **complex modulus and storage modulus**.

energy loss—the energy per unit volume that is lost in each deformation cycle. (ISO) (1983)

Discussion—Energy loss is the hysteresis loop area, calculated with reference to coordinate scales.

frequency profile , *n*—a plot of the dynamic properties of a material, at a constant temperature, as a function of test frequency. (1981)

gamma (γ) loss peak , *n*—the third peak in the damping curve below the melt, in the order of decreasing temperature or increasing frequency. (1981)

glass transition—the reversible change in amorphous polymer, or in amorphous regions of a partially crystalline polymer, from (or to) a viscous or rubbery condition to (or from) a hard and relatively brittle one.

Discussion—The glass transition generally occurs over a relatively narrow temperature region and is similar to the solidification of a liquid to a glassy state; it is not a phase transition. Not only do hardness and brittleness undergo rapid changes in this temperature region, but other properties, such as coefficient of thermal expansion and specific heat, also change rapidly. This phenomenon has been called second-order transition, rubber transition, and rubbery transition. The word transformation has also been used instead of transition. When more than one amorphous transition occurs in a polymer, the one associated with segmental motions of the polymer backbone chain, or accompanied by the largest change in properties, is usually considered to be the glass transition. (D20) (1981)

glass transition temperature, T_g —the approximate midpoint of the temperature range over which the glass transition takes place.

Discussion—The glass transition temperature can be determined readily only by observing the temperature at which a significant change takes place in a specific electrical, mechanical, or other physical property. Moreover, the observed temperature can vary significantly, depending on the specific property chosen for observation and on details of the experimental technique (for example, rate of heating, frequency). Therefore, the observed T_g should be considered only an estimate. The most reliable estimates are normally obtained from the loss peak observed in dynamic mechanical tests or from dilatometric data. (D20) (1981)

hysteresis loop (*in dynamic mechanical measurement*)**—**the closed curve representing successive stress-strain status of the material during a cyclic deformation. (ISO) (1983)

Discussion—Hysteresis loops may be centered around the origin of coordinates 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.

logarithmic decrement, Δ (*in dynamic mechanical measurement*)**—**the natural logarithm of the ratio of any two (or more) successive amplitudes of like sign, in the decay of single frequency oscillation:

$$\Delta = \frac{1}{k} \quad \ln\frac{A_n}{A_{n+k}}$$

where: A_n and A_{n+k} are amplitudes (in radians of rotation) of two oscillations, and k is the number of oscillations separating the two amplitude measurements. (1981)

*loss angle, δ***—** see **phase angle**.

*loss factor***—**see **tan δ**.

loss modulus—*M*"(Pa)—[loss compliance O" (Pa^{-1})]: the imaginary part of the complex modulus (compliance).

Discussion—It is a measure of the energy lost (dissipated during a loading cycle). (See also **complex modulus** and **complex compliance**.) (See ISO 6721–1.)

*loss tangent***—**see **tan delta**.

mean modulus—the ratio of mean stress to mean strain. (ISO) (1983)

mean strain—the average value of strain during a single complete hysteresis loop of cyclic deformation. (ISO) (1983)

mean stress—the average value of the stress during a single complete hysteresis loop of cyclic deformation. (ISO) (1983)

*modulus, complex***—**see **complex modulus**.

*modulus, elastic***—**see **complex modulus and storage modulus**.

*modulus, loss***—**see **complex modulus and loss modulus**.

*modulus, storage***—**see **complex modulus and storage modulus**.

*modulus of elasticity***—** see **complex modulus and storage modulus**.

nonresonant forced and vibration technique , *n*—a technique for performing dynamic mechanical measurements, in which the sample is oscillated mechanically at a fixed frequency.

Discussion—Storage modulus and damping are calculated from the applied strain and the resultant stress and shift in phase angle. (1981)

normal stress, s—the stress component perpendicular to a plane on which the forces act. (E28) (1981)