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Standard Terminology of Force, Deformation and Related Properties of Textiles[1]

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1. Scope

1.1 This terminology standard is a compilation of definitions of technical terms related to force and deformation properties when evaluating a stress-strain curve of a textile. (See Figs. X1.1 and X1.2.) A chart showing the relationship of the basic terms is shown in Table 1. Terms that are generally understood or adequately defined in other readily available sources are not included.

1.2 For other terms associated with textiles, refer to Terminology D 123.

2. Referenced Documents

2.1 *ASTM Standards:*

D 123 Terminology Relating to Textiles[2]

3. Terminology

breaking elongation—See **elongation at break**.

breaking force, *n*—the maximum force applied to a material carried to rupture. (Compare **breaking point, breaking strength.** *Syn.* **force-at-break**)

DISCUSSION—Materials that are brittle usually rupture at the maximum force. Materials that are ductile usually experience a maximum force before rupturing.

breaking load—deprecated term. Use the preferred term **breaking force**.

breaking point, *n—on a force-elongation curve, or stress-strain curve,* the point corresponding with the breaking force or the breaking stress in a tensile test. (Compare **breaking force**.)

breaking strength, *n*—strength expressed in terms of breaking force. (See also **breaking force** and **strength**. *Syn*., strength at break)

breaking tenacity, *n*—the tenacity at the breaking force. (See also **breaking force, tenacity**.)

breaking toughness, *n*—toughness up to the breaking force of a material.

DISCUSSION—Breaking toughness is represented by the area and the stress-strain curve from the origin to the breaking force per unit length, and, in textile strands, is expressed as work (joules) per unit of linear density of the material. In textile fabrics, the unit is joules per gram.

TABLE 1 Relationship of Force and Deformation Terms

Term	Symbol	Mathematical Expression	Unit
Length	L		mm (in.)
Extension	ΔL		mm (in.)
Strain		ΔL/L	
Elongation		ΔL/L × 100	%
Linear density	D_1[A]		tex (den)
Cross-sectional area	A		mm^2($in.^2$)
Force	F		N (lbf)
Tension	T		N (lbf)
Strength	S		N (lbf)
Tenacity		F/D_1[A]	mN/tex (lbf/den)[B]
Stress		F/A	N/m^2(lbf/yd^2)[B]

[A] In computers, this may be given as "LD" instead of "D_1".
[B] For fibers, these inch-pound units are usually gf/den and $gf/in.^2$

chord modulus, *n—in a stress-strain curve,* the ratio of the change in stress to the change in strain between two specified points on the curve.

compression, *n*—the act, process, or result of compacting, condensing, or concentrating.

compressive force, *n*—the perpendicular force applied to surface(s) of a material in compaction.

compression recovery, *n*—the degree to which a material returns to its original dimension(s) after removal of a compressive force.

compression resistance, *n*—the ability of a material to oppose deformation under a compressive force.

*corresponding elongation***—**See **elongation at specified force**.

corresponding force—See **force-at-specified-elongation.**

deformation, *n*—a change in shape of a material caused by forces of compression, shear, tension, or torsion.

DISCUSSION—Deformation may be immediate or delayed. Delayed deformation may be either recoverable or nonrecoverable.

deformation, permanent, *n*—the net long-term change in a dimension of a specimen after deformation and relaxation under specified conditions. (Syn. **permanent set, nonrecoverable deformation, and nonrecoverable stretch.**

DISCUSSION—Permanent deformation is usually expressed as a percentage of the original dimension.

delayed deformation, *n*—deformation which is time-dependload of a skein of yarn adjusted for the linear density of the yarn expressed in an indirect system.

[1] This terminology is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.58 on Yarn and Fiber Test Methods.

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[2] *Annual Book of ASTM Standards,* Vol 07.01.

DISCUSSION—Deformation may be recoverable or nonrecoverable following removal of the applied force.

elastic limit, *n*—*in mechanics*, the maximum stress which can be obtained in a material without causing permanent deformation of the material. (Compare *yield point*.)

DISCUSSION—Elastic limit is a property of a material whereas yield point is a specific point on a stress-strain curve.

elasticity, *n*—that property of a material by virtue of which it tends to recover its original size and shape immediately after removal of the force causing deformation.

elongation, *n*—the ratio of the extension of a material to the length of the material prior to stretching, expressed as a percent.

DISCUSSION—Elongation may be measured at any specified force or at rupture.

elongation at break, *n*—the elongation corresponding to the breaking force. (Compare **elongation at rupture**. See also **elongation**.) Syn. **breaking elongation**.

elongation at the breaking load, *n*—deprecated term. Use the preferred term **elongation at break**.

elongation at specified force, (EASF), *n*—the elongation associated with a specified force on the force-extension curve. (Syn. **corresponding elongation**).

elongation at rupture, *n*—the elongation corresponding to the force-at-rupture. (Compare **elongation at break**.)

DISCUSSION—The elongation at rupture for a brittle material is usually equal to the elongation at break; but for ductile materials this elongation may be greater.

extensibility, *n*—that property by virtue of which a material can undergo extension or elongation following the application of sufficient force.

extension, *n*—the change in length of a material due to stretching. (Compare **elongation**.)

DISCUSSION—Extension may be measured at any specified force or at rupture and is expressed in units of length, for example, millimetres and inches.

extension-recovery cycle, *n*—*in tension testing*, the continuous extension of a specimen, with a momentary hold at a specified extension, followed by a controlled rate of return to zero extension.

failure, *n*—an arbitrary point beyond which a material ceases to be functionally capable of its intended use. (Compare **rupture**.)

DISCUSSION—A material may be considered to have failed without having ruptured.

force, *n*—a physical influence exerted by one body on another which produces acceleration of bodies that are free to move and deformation of bodies that are not free to move. (Compare **strength**.)

DISCUSSION—Force is properly expressed in newtons (N) or multiples and submultiples of newtons, for example kilonewtons (kN) and millinewtons (mN). Force is also expressed as grams-force (gf), kilograms-force (kgf), or pounds-force (lbf), but the use of these terms is deprecated.

force at break, *n*—See **breaking force**.

force at rupture, *n*—the force applied to a material immediately preceding rupture. (Compare **breaking force**. See also **rupture**.)

DISCUSSION—Materials that are brittle usually rupture at the maximum force. Materials that are ductile usually experience a maximum force before rupturing.

force at specified elongation (FASE), *n*—the force associated with a specific elongation on the force-extension or force-elongation curve. (*Syn.* **corresponding force**.)

force-deformation curve, *n*—a graphical representation of the force and deformation relationship of a material under conditions of compression, shear, tension or torsion. (Compare **force-elongation curve, force-extension curve** and **stress-strain curve**.)

DISCUSSION—Force-deformation related curves include force-extension, force-compression, force-shear (displacement), force-torque and stress-strain curves. The shape of the force-extension curve of a material and the shape of the corresponding stress-strain curve are the same, only the units are different. Force is expressed in such units as newton, kilogram-force, pound force. In tension, shear or compression tests, deformation is expressed in such units of length as metre, millimetre or inches. In torsion tests, deformation is expressed in such units for plane angles as radians or degrees.

force-elongation curve, *n*—a graphical representation of the force and elongation relationship of a material under tension. (Compare **force-deformation curve, force-extension curve** and **stress-strain curve.)**

force-extension curve, *n*—a graphical representation of the force and extension relationship of a material under tension. (Compare **force-deformation curve, force-elongation curve** and **stress-strain curve**.)

immediate elastic recovery, *n*—recoverable deformation which is essentially independent of time, that is, occurring in (a time approaching) zero time and recoverable in (a time approaching) zero time after removal of the applied force. (Compare **delayed deformation** and **delayed elastic recovery**.)

initial modulus, *n*—*in a stress-strain curve*, the slope of the initial straight-line portion of the curve.

knot breaking force, *n*—*in tensile testing*, the breaking force of a strand having a specified knot configuration tied in the portion of the strand mounted between the clamps of a tensile testing machine. (Compare **knot breaking strength**. See also **breaking force**.)

knot breaking load, *n*—deprecated term. Use the preferred term, **knot breaking force**.

knot breaking strength, *n*—strength expressed in terms of knot breaking force. (See also **knot breaking force**.)

linear density, *n*—mass per unit length.

load—deprecated term. Use the preferred term, **force**.

load, *vt*—to apply a force.

DISCUSSION—Although the terms *load* and *force* are frequently used interchangeably to denote the same phenomena, ASTM has adopted use of the technically correct term *force*.

load at specified elongation (LASE)—deprecated term. Use the

preferred term, **force at specified elongation (FASE)**.

load-deformation curve, *n*—deprecated term. Use the preferred term, **force-deformation curve**.

load-elongation curve, *n*—deprecated term. Use the preferred term, **force-elongation curve**.

loop breaking force, *n*—*in tensile testing*, the breaking force of a specimen consisting of two lengths of strand from the same supply looped together in a specified configuration and mounted between the clamps of a tensile testing machine. (Compare **loop breaking strength**. See also **breaking force**.)

loop breaking load, *n*—deprecated term. Use the preferred term, **loop breaking force**.

loop breaking strength, *n*—strength expressed in terms of loop breaking force. (See also **loop breaking force, strength**.)

modulus, *n*.—the property of a material representative of its resistance to deformation. (See also **chord modulus, initial modulus, tangent modulus, Young's modulus).**

pretension, *n*—the specified tension applied to a specimen preparatory to making a test.

DISCUSSION—Pretension may be used to establish a uniform baseline for a test. In tensile testing, the pretension is usually a low force designed to remove kinks, crimp or wrinkles and essentially straighten and align the specimen as it is being mounted in the testing machine.

recovery, delayed elastic—See **delayed elastic recovery**.

recovery immediate elastic—See **immediate elastic recovery**.

recovery tensile strain—See **tensile strain recovery**.

rupture, *n*—the breaking or tearing apart of a material. (Compare **failure**.)

DISCUSSION—As applied to tensile testing, rupture refers to the total separation of a material into two parts either all at once or in stages, or the development of a hole in some materials.

secant modules, *n*—deprecated term in textile terminology. Use the preferred term *chord modulus.*

single-strand breaking force, *n*—*in tensile testing*, the breaking force of one strand that follows a specified path, usually a straight line, between the clamps of a tensile testing machine. (Compare **breaking force**.)

single-strand strength, *n*—deprecated term. Use **single-strand breaking strength**.

skein break factor, *n*—the comparative breaking strength of a skein of yarn adjusted for the linear density of the yarn expressed in an indirect system; the product of the breaking strength of the skein and the yarn number expressed in an indirect system.

DISCUSSION—A statement of the break factor of the skein must indicate the number of wraps in the skein if this is not otherwise apparent; without information on the number of wraps, a statement of the break factor is meaningless. Break factor is frequently given other designations such as lea count constant, lea product, and breaking ratio.

skein breaking tenacity, *n*—the skein breaking strength divided by the product of the yarn number in direct numbering system and the number of strands placed under tension.

DISCUSSION—Observed breaking strength can be converted to breaking tenacity by dividing the breaking strength by the product of the yarn measured in a direct numbering system and the number of strands placed under tension (twice the number of wraps in the skein).

strain, *n*—deformation of a material caused by the application of an external force.

DISCUSSION—Strain is usually expressed as a ratio involving extension.

strength, *n*—the property of a material that resists deformation induced by external forces. (Compare **force**.)

DISCUSSION—Strength may be expressed in units of force for a specific material or units of stress. Traditionally, some have considered strength to be an average of individual values rather than the individual values.

strength at break, *n*—See **breaking strength**.

strength at rupture, *n*—strength expressed in terms of the force at rupture. (Compare **breaking strength**.)

stress, *n*—the resistance to deformation developed within a material subjected to an external force.

DISCUSSION—Stress is the result of strain and vice versa. In textiles, stress is expressed in units of force per unit cross-sectional area. Typical examples are tensile stress, shear stress, or compressive stress.

stress decay, *n*—*in mechanics*, the reduction in force to hold a material at a fixed deformation over a period of time.

DISCUSSION—This is a generic definition. Stress is already defined. The stress decay is due to adsorption of energy.

stress-strain curve, *n*—a graphical representation of the stress and strain relationship of a material under conditions of compression, shear, tension, or torsion. (Compare **force-deformation curve, force-elongation curve**, and **force-extension curve**.)

DISCUSSION—In tension tests of textile materials, the stress may be expressed either in (1) units of force per unit cross-sectional area, or (2) units of force per unit linear density of the original specimen, and the strain may be expressed either as a fraction or as a percentage of the original specimen length.

tangent modulus, *n*—*in a stress strain curve*, the ratio of the change in stress to the change in strain derived from the tangent at any point on the curve.

tenacity, *n*—*in a tensile test*, the force exerted on the specimen based on the linear density of the unstrained material.

DISCUSSION—Tenacity is commonly expressed as millinewtons per tex (mN/tex), grams-force per denier (gf/den), or pounds-force per denier (lbf/den). Tenacity in millinewtons/tex is numerically equal to tenacity in grams-force/denier times 88.29.

tenacity-as-specified-elongation (TASE), *n*—the tenacity of a material at its force-at-specified-elongation. (Compare **breaking tenacity**.)

tenacity at rupture, *n*—the tenacity at the force-at-rupture. (See also **force at rupture, rupture, tenacity**.)

tensile, *adj*—relating to tension in, or on, a material.

tensile hysteresis, *n*—*in mechanics*, hysteresis resulting from the extension of a material. (See *hysteresis*.)

tensile strain, *n*—the strain on a material subjected to tension.

tensile strain recovery, *n*—the percent of recoverable extension to the total extension impressed on a fiber under specified conditions.

tensile strength, *n*—the strength of a material under tension as distinct from compression, torsion or shear.

DISCUSSION—Technically, strength is a characteristic that is expressed in terms of force. Historically, however, tensile strength has been commonly expressed in terms of force per unit base, for example, the cross-sectional area of the unstrained material. Some common units are newtons per square metre (N/m^2) and pounds-force per square in. (psi).

tensile stress, *n*—the stress within a material subjected to tension.

DISCUSSION—"Tensile stress" is usually referred to as "tensile strength" in fabrics and as "tenacity" in fibers and yarns.

tensile test, *n—in textiles*, a test in which a specimen is extended in one direction to determine one or more of its force-extension, or stress-strain, characteristics; for example, breaking force, elongation-at-break.

DISCUSSION—Other ASTM committees consider tensile tests as defined above to be "tension tests." The tearing test is not regarded as a tensile test.

tension, *n*—a uniaxial force tending to cause the stretching of a material.

tension test, *n—in textiles*, a test designed to measure the tautness in a textile strand or fabric. (See also **tensile test**.)

DISCUSSION—Tension tests on textile strands are specifically designed to avoid deformation or rupture of the strand.

textile modulus, *n*—deprecated term. Use the preferred term **Young's modulus.**

torque, *n*—a moment (of forces) which produces or tends to produce rotation or torsion.

toughness, *n*—the capacity of a material to absorb energy (Compare work to break, work to rupture).

toughness at rupture, *n*—toughness of a material to breaking or tearing apart.

weigh, *vt*—to determine the mass of a material.

weight, *n—in textile testing*, an object, having a known mass, used in such procedures as weighing, calibrating, and applying a force.

work, *n*—the energy expended in displacing a body; mathematically, force times distance.

work recovery, *n*—the percent of recoverable work to the total work required to strain a fiber a specified amount under specified conditions.

work to break, *n*—the energy expended up to the breaking force. (See **work-to-rupture**. Compare**toughness**.)

DISCUSSION—Work-to-break is proportional to the area under the stress-strain curve from the origin to the breaking force.

work to rupture, *n*—the energy expended to tear apart a material. (See **work to break**. Compare **toughness**.)

yield point, *n—in a stress-strain curve*, the point beyond which work is not completely recoverable and permanent deformation takes place. (Compare **elastic limit)**

DISCUSSION—*In textile fibers*, an exact proportionality does not exist between force and extension and there is not a true yield point. The point on the force extension curve beyond which the force-extension ratio changes from that existing during the first essentially straight line portion of the curve is frequently called the yield point of a textile strand or fiber. With animal fibers, permanent deformation does not occur until the extension reaches about 30 %, or when the rate of extension is extremely slow or the fiber is held under tension for a long time. In fact, if animal fiber is stretched in water, or at high humidity conditions, to as much as 30 % of the original length and allowed to relax for 24 h, the original force extension curves may be reproduced.

Young's modulus, *n—in a stress-strain curve for an elastic material*, the ratio of change in stress to change in strain within the elastic region of the material.

DISCUSSION—The ratio is calculated from the stress expressed in force per unit cross-sectional area and the strain is expressed as a fraction of the original length.

APPENDIXES

(Nonmandatory Information)

X1. INITIAL MODULUS

X1.1 In the case of a yarn exhibiting a region that obeys Hooke's law (Fig. X1.1), a continuation of the linear region of the curve is constructed through the zero-stress axis. This intersection point B is the zero-strain point from which strain is measured.

X1.1.1 The initial modulus can be determined by dividing the stress at any point along the line BD (or its extension) by the strain at the same point (measured form point B, defined as zero strain). Point C, the point where line BD first touches the stress-strain curve is the tangent point.

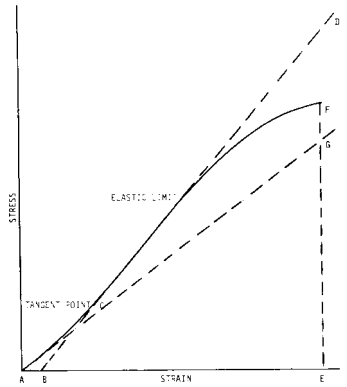

FIG. X1.1 Material with Hookean Region

X1.2 In the case of a yarn that does not exhibit any linear region (Fig. X1.2), a tangent K′B′ is constructed to the maximum slope and its extension intersecting the zero-stress axis at point B′. This intersection point B′ is the zero point

from which strain is measured. Point C′, the point where line K′B′ first touches the stress-strain curve, is the tangent point.

X1.2.1 The initial modulus may be determined by dividing the stress at any point along line B′K′ (or its extension) by the strain at the same point (measured from point B′, defined as zero strain).

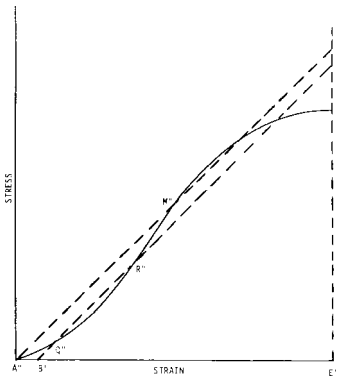

FIG. X1.2 Material with no Hookean Region

X2. CHORD MODULUS

X2.1 In a typical stress-strain curve (Fig. X2.1), a straight line is constructed through the zero-stress axis, such as zero strain point A″ and a second point, such as 10 % strain, point M″. The intersection point A″ is the zero strain point from which strain is measured.

X2.1.1 The chord modulus may be determined by dividing the stress at any point along line A″M″ (or its extension) by the strain at the same point (measured from point A″, defined as zero strain).

X2.1.2 Fig. X2.1 also represents a straight line constructed through any two specified points, point Q″ and point R″, other than zero and 10 % strain. In this case, the line extends through the zero stress axis at point B″. This intersection is the zero strain point from which strain is measured. The chord modulus can be determined by dividing the stress at any point along line Q″R″ (or itsextension) by the strain at the same point (measured from point B″, defined as zero strain).

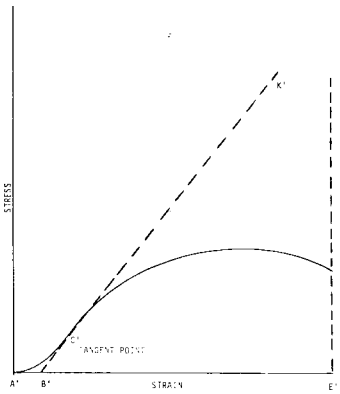

FIG. X2.1 Construction for Chord Modulus