



Standard Terminology for Composite Materials¹

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

1. Scope

1.1 These definitions cover generic terms, including terms of commercial importance, that appear in one or more standards on composites containing high-modulus (greater than 20-GPa (3×10^6 psi)) fibers.

1.2 The definitions cover, in most cases, special meanings used in the composites industry. No attempt has been made to include common meanings of the same terms as used outside the composites industry.

1.3 Definitions included have, in general, been approved as standard.

2. Terminology

2.1 Definitions:

$\pm 45^\circ$ laminate—a balanced symmetric laminate composed of only $+45^\circ$ plies and -45° plies.

angleply laminate—any balanced laminate consisting of plus and minus theta plies where theta is an acute angle with respect to a reference direction.

balanced laminate—any laminate that contains one ply of minus theta orientation with respect to the laminate principal axis for every identical ply with a plus theta orientation.

braided fabric—see *braided fabric* under **fabric**.

bundle—a general term for a collection of essentially parallel filaments.

carbon fiber precursor—a material from which carbon fiber is made by pyrolysis. Polyacrylonitrile, rayon or pitch fibers are commonly used precursors.

catenary:

filament catenary—the difference in length of the filaments in a specified length of tow, end, or strand as a result of unequal tension; the tendency of some filaments in a taut horizontal tow, end, or strand to sag lower than others.

roving catenary—the difference in length of the ends, tows, or strands in a specified length of roving as a result of unequal tension; the tendency of some ends, tows, or strands in a taut horizontal roving to sag lower than others.

composite:

¹ These definitions are under the jurisdiction of ASTM Committee D30 on High-Modulus Fibers and Their Composites and are the direct responsibilities of Subcommittee D30.01 on Editorial and Terminology.

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composite material—a substance consisting of two or more materials, insoluble in one another, which are combined to form a useful engineering material possessing certain properties not possessed by the constituents.

DISCUSSION—a composite material is inherently inhomogeneous on a microscopic scale but can often be assumed to be homogeneous on a macroscopic scale for certain engineering applications. The constituents of a composite retain their identities: they do not dissolve or otherwise merge completely into each other, although they act in concert.

damage, n —in *structures and structural mechanics*, a structural anomaly in material or structure created by manufacturing or service usage.

damage resistance, n —in *structures and structural mechanics*, a measure of the relationship between the force, energy, or other parameter(s) associated with an event or sequence of events and the resulting damage size and type.

DISCUSSION—Damage resistance increases as the force, energy, or other parameter increases for a given size or type of damage. Conversely, damage resistance increases as damage decreases, for a given applied force, energy, or other parameter. Damage resistance and damage tolerance are often confused. A material or structure with high damage resistance will incur less physical damage from a given event. Materials or structures with high damage tolerance may incur varying levels of physical damage but will have high amounts of remaining functionality. A damage-resistant material or structure may, or may not, be considered damage tolerant.

discontinuous fiber-reinforced composite—any composite material consisting of a matrix reinforced by discontinuous fibers. The fibers may be whiskers or chopped fibers.

fabric-reinforced composite—any composite material consisting of a matrix reinforced by fabric (woven, knitted, or braided assemblages of fibers).

fiber-reinforced composite—any composite material consisting of a matrix reinforced by continuous or discontinuous fibers.

filament count—number of filaments in the cross section of a fiber bundle.

filamentary composite—a composite material reinforced with continuous fibers.

unidirectional fiber-reinforced composite—any fiber-reinforced composite with all fibers aligned in a single direction.

crossply laminate—a laminate composed of only 0 and 90°

TABLE 1 Fiber Forms

Continuous Filaments			Discontinuous Filaments	
Twist	Twisted	Little or No Twist	Twisted	Little or No Twist
Tow, ^A	* ^B	P ^C	— ^D	—
strand, sliver				
Single yarn	P	*	P	—
Plied yarn	P	—	P	—
Roving ^E	*	P	—	—
end (generic term that can be applied to any of the above)				
Chopped fiber	—	—	—	P
Whisker	—	—	(single crystal)	

^A Small filament count.
^B *—Secondary/alternate definition.
^C P—primary/preferred definition.
^D —not applicable.
^E Large filament count.

plies. This is not necessarily symmetric.

debond—a deliberate separation of a bonded joint or interface, usually for repair or rework purposes.

delamination—separation of plies in a laminate. This may be local or may cover a large area in the laminate.

disbond—an area within a bonded interface between two adherents in which an adhesive or cohesive failure has occurred. It may occur at any time during the life of the structure and may arise from a wide variety of causes. It is sometimes used to describe an area of separation between two laminae in the finished laminate (the term “delamination” is preferred).

discontinuous fiber—a polycrystalline or amorphous fiber that is discontinuous within the sample or component or that has one or both ends inside of the stress field under consideration. The minimum diameter of a discontinuous fiber is not limited, but the maximum diameter may not exceed 0.25 mm (0.010 in.).

end, n—in fibrous composites, a general term for a continuous, ordered assembly of essentially parallel, collimated filaments, with or without twist.

DISCUSSION—This term covers tow, strand, sliver, yarn, and roving. The relationship between fiber form terms is shown in Table X1.1.

fabric—a planar textile (Synonym: cdth)

braided fabric, n—a cloth constructed by a braiding process.

knitted fabric, n—a cloth constructed by a knitting process.

nonwoven fabric, n—a cloth constructed by bonding or interlocking, or both (but not interlacing) fiber by any combination of mechanical, chemical, thermal, or solvent means.

plied yarn, n—a yarn formed by twisting together two or more single yarns in one operation.

DISCUSSION—Plying, which is done in the opposite direction from the twist of each of the simple yarns, serves to counter the tendency of simple yarns to untwist.

woven fabric, n—a cloth constructed by a weaving process.
fiber, n—one or more filaments in an ordered assemblage.

DISCUSSION—There are a number of general and specific terms that define specific types of fiber forms. The relationship between fiber form terms is shown in Table 1.

fiber content—the amount of fiber present in a composite expressed either as percent by weight or percent by volume. This is sometimes stated as a fraction, that is, fiber volume fraction.

fiber volume fraction—see **fiber content**.

filament, n—a fibrous form of matter with an aspect ratio >10 and an effective diameter <1 mm. (See also **monofilament**.)

DISCUSSION—Filaments may be essentially continuous (aspect ratio on the order of 10⁵ or larger) or discontinuous. Whiskers are the special case of single crystal discontinuous filaments.

filler—in composite materials, a primarily inert solid constituent added to the matrix to modify the composite properties or to lower cost.

hybrid—(for composite materials) containing at least two distinct types of matrix or reinforcement. Each matrix or reinforcement type can be distinct because of its a) physical

or mechanical properties, or both, b) material form, or c) chemical composition.

interlaminar—describing objects (for example, voids), events (for example, fracture), or fields (for example, stress) between the laminae of a laminate.

intralaminar—describing objects (for example, voids), events (for example, fracture), or fields (for example, stress) within the laminae of a laminate.

knit—a textile process that interlocks, in a specific pattern loop of yarn by means of needles or wires.

knitted fabric—See *knitted fabric* under **fabric**.

lamina—a subunit of a laminate consisting of one or more adjacent plies of the same material with identical orientation.

lamina orientation—same as **ply orientation**.

laminated—any fiber- or fabric-reinforced composite consisting of laminae (plies) with one or more orientations with respect to some reference direction.

laminated coordinate axes—a set of coordinate axes, usually right-handed Cartesian, used as reference in describing the directional properties and geometrical structure of the laminate. Usually the x-axis and the y-axis lie in the plane of the laminate and the x-axis is the reference axis from which ply angle is measured.

laminated midplane—the plane that is equidistant from both surfaces of the laminate.

laminated principal axis—the laminated coordinate axis that coincides with the direction of maximum inplane Young’s modulus.

lay-up code—a designation system for abbreviating the stacking sequence of laminated composites.

mandrel—a form, fixture, or male mold used as the base for production of a part in processes such as lay-up or filament winding.

material form—the contour, arrangement, and structure of an unconsolidated composite material, especially with regard to the geometry and nature of the reinforcement. Factors considered part of the material form include, but are not limited to: reinforcement diameter, reinforcement length (for

discontinuous reinforcements), tow size or count, fabric areal weight, fabric style, reinforcement content, and ply thickness.

matrix content—the amount of matrix present in a composite expressed either as percent by weight or percent by volume. For polymer matrix composites this is resin content.

monofilament—a continuous filament strong enough to function as a yarn in commercial textile operations or as an entity in other operations.

nonwoven fabric—See *nonwoven fabric* under **fabric**.

off-axis laminate—a laminate whose principal axis is oriented at an angle θ other than 0 or 90° with respect to a reference direction, usually related to principal load or stress direction.

orthotropic material—a material in which a property of interest, at a given point, possesses three mutually perpendicular planes of symmetry, which taken together define the principal material coordinate system.

pigment—a substance, generally in the form of fine particles, that is substantially insoluble in the matrix and is used because of its color or decorative properties.

plied yarn—See *plied yarn* under **yarn**.

ply—(in laminar composites) the constituent single layer as used in fabricating, or occurring within a composite structure.

ply coordinate axes—a set of Cartesian coordinates two of which lie within the plane of the ply, one axis of which is parallel to the principal fiber direction and the other axis perpendicular to the principal fiber direction (the third axis is through the ply's thickness).

ply orientation—the acute angle (θ) including 90° between a reference direction and the ply principal axis. The ply orientation is positive if measured counterclockwise from the reference direction and negative if measured clockwise.

ply principal axis—the ply coordinate axis that coincides with the direction of maximum inplane Young's modulus. For balanced weave fabric either warp or fill direction may be chosen.

preform, n —a preshaped fibrous reinforcement, normally without matrix, but often containing a binder to facilitate manufacture, formed by distribution of fibers to the approximate contour and thickness of the finished part.

prepreg—the admixture of fibrous reinforcement and polymeric matrix used to fabricate composite materials. Its form may be sheet, tape, or tow. For thermosetting matrices, it has been partially cured to a controlled viscosity called "B stage."

quasi-isotropic laminate—a balanced and symmetric laminate for which a constitutive property of interest, at a given point, displays isotropic behavior in the plane of the laminate. Common quasi-isotropic laminates are $(0/\pm 60)_s$ and $(0/\pm 45/90)_s$.

DISCUSSION—Usually a quasi-isotropic laminate refers to elastic properties, for which case, the laminate contains equal numbers of identical plies at k orientations such that the angles between the plies are $180i/k$ ($i = 0, 1 \dots k - 1$); $k \geq 3$. Other material properties may follow different rules. For example, thermal conductivity becomes

quasi-isotropic for $k \geq 2$, while strength properties generally are not capable of true quasi-isotropy, only approximating this behavior.

resin—a solid or pseudosolid organic material often of high molecular weight, which exhibits a tendency to flow when subjected to stress, usually has a softening or melting range, and usually fractures conchoidally.

resin content—see **matrix content**.

roving, n —*in fibrous composites*, large filament count tow. (See also **tow** and **filament count**.)

single yarn—See *single yarn* under **yarn**.

stacking sequence—the arrangement of ply orientations and material components in a laminate specified with respect to some reference direction.

staple, n —a collection of short filaments of spinnable length that are natural, manufactured directly in a short length, or cut from continuous filaments.

strand—*in fibrous composites*, Synonym for tow.

symmetric laminate—a laminate in which the stacking sequence for the plies located on one side of the geometric midplane are the mirror image of the stacking sequence on the other side of the midplane.

thermoplastic—a plastic that repeatedly can be softened by heating and hardened by cooling through a temperature range characteristic of the plastic, and that in the softened state can be shaped by flow into articles by molding or extrusion.

thermoset—a class of polymers that, when cured using heat, chemical, or other means, changes into a substantially infusible and insoluble material.

tow—*in fibrous composites*, a continuous, ordered assembly of essentially parallel, collimated filaments, normally without twist and of continuous filaments (Synonyms: strand and silver).

twist, n —*in fibrous composites*, a measure of the number of turns per unit length a fiber bundle makes around its axis.

DISCUSSION—Twist is noted as being either 'S'-twist or 'Z'-twist, where the shape of the letters are used as a mnemonic to describe the direction of the twist. Following the right-hand rule along the axis of the fiber bundle, 'Z'-twist is a positive twist and 'S'-twist is a negative twist. In addition, 'U' is often used to represent no twist (untwisted) and 'N' no twist (never twisted).

void—any pocket of enclosed gas or air within a composite.

weave—a planar textile process that interlaces, in a specific pattern, strands or yarns oriented in two directions in a specific pattern.

winding—a process in which continuous material is applied under controlled tension to a form in a predetermined geometric relationship to make a structure. A matrix material to bind the fibers together may be added before, during or after winding. Filament winding is the most common type.

woven fabric—See *woven fabric* under **fabric**.

yarn—*in fibrous composites*, a continuous, ordered assembly of essentially parallel, collimated filaments, normally with twist, and of either discontinuous or continuous filaments.

single yarn, n —an end in which each filament follows the same twist.

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