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Standard Terminology for Composite Materials[1]

This standard is issued under the fixed designation D3878; 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 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. Referenced Documents

2.1 *ASTM Standards:*[2]
D123 Terminology Relating to Textiles

2.2 *Industry Standard:*[3]
CMH-17 Composite Materials Handbook

3. Terminology

3.1 *Definitions:*

±45° laminate—a balanced symmetric laminate composed of only +45° 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.

bond, *n*—the act of adhering one surface to another, with or without the use of an adhesive at the interface.

co-cure, cocure—see Cure.

co-bond, cobond, n—the act of curing (or consolidating) and bonding one semi-solid detail (e.g. uncured thermoset polymer or a thermoplastic polymer) to a solid detail in a single process through principal action of the matrix, possibly with the inclusion of a separate layer of adhesive at the interface.

secondary bond, n—the act of bonding two or more already-cured thermoset composite or other solid details, during which the only chemical or thermal reaction, or both, occurring is the curing of the adhesive layer at the interface.

DISCUSSION—For example, a previously cured composite or metal doubler bonded via an adhesive to a previously cured skin, or a previously cured face sheet bonded via an adhesive to a honeycomb core. Also applies to bonding metallic substrates such as aluminum face sheets onto aluminum honeycomb core.

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

breather string, *n*—a string, composed of a material such as glass, that provides a vacuum path from the laminate to a breather.

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.

caul, *n*—a flat or contoured tool used to distribute pressure and to define a surface for the top of the laminate during laminate consolidation or cure.

[1] This terminology is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.01 on Editorial and Resource Standards.

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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] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

co-fabrication, *n*—(*cofabrication*) a fabrication process where items such as inserts and other details are bonded into a composite structural component at the same time that the component is cured or consolidated.

composite:

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.

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.

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.

continuous filament yarn, *n*—two or more continuous filaments twisted into a single fiber bundle.

core, *n*—an inner layer of a multi-layer adherend assembly.

DISCUSSION—The core is usually of a relatively low density material. It separates the surface layers, and other possible layers, of a multi-layer construction, generally stabilizing and transmitting shear between them.

honeycomb core, n—a core material having a thin-walled cell structure made from a wide range of materials that can be formed into various cell configurations.

DISCUSSION—Honeycomb core materials are formed from sheet materials into configurations resembling honeycomb in appearance. Strictly speaking, the honeycomb cell configuration is hexagonal, but in practice, additional configurations are often referred to as "honeycomb," including, but not limited to, ox (over-expanded), flex, tube, and dovetail. Honeycomb core materials exhibit anisotropic behavior; therefore the following notation is used:

L = ribbon or longitudinal direction of core, parallel to the material used to construct the core;

W = expanded or transverse direction of core; and

T = core thickness or cell depth.

core shear instability, *n*—the core-dominated buckling of a sandwich construction dependent on the transverse shear stiffness of the core.

DISCUSSION—Core shear instability in a sandwich construction loaded under in-plane compression or shear, occurs through the depth (thickness) of the core, and may result in failure of the component by causing the face sheets to also fail locally due to reduction in support. This phenomenon is sometimes imprecisely referred to as "shear crimping."

crossply laminate—a laminate composed of only 0 and 90° plies. This is not necessarily symmetric.

cure, *n—in thermoset polymer composite materials*, the process resulting in the overall transformation of the polymeric matrix phase of the composite from a low molecular weight resin/hardener system to a cross-linked network by chemical reaction

co-cure, n—(cocure) the act of curing two semi-solid media (i.e. uncured thermoset polymers) in a single process, resulting in the two media being bonded through principal action of the matrix, possibly with the inclusion of a separate layer of adhesive at the interface.

dam, *n*—a solid material (such as silicone rubber, steel, or aluminum), used in processing composites, to contain the matrix material within defined boundaries or to prevent crowning of a processing bag.

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.

damage tolerance, *n—1*) *in structures and structure materials*, a measure of the relationship between damage size and type and the level of a performance parameter, such as stiffness or strength, at which the structure or structural material can operate for a particular loading condition; *2*) *in structural systems*, a measure of the ability of such systems to function at designated performance parameters (for example, magnitude, length of time, and type of loading(s)) without system failure in the presence of a particular or specified level of damage.

DISCUSSION—Damage tolerance involves, and can be provided by, a number of factors operating at a number of levels: structural material, structural, and overall system. These factors include *1*) basic material ability to operate with damage present (often referred to as the residual strength aspect), *2*) damage growth resistance and containment provided by material and structural considerations, and *3*) system inspection and maintenance plans which allow the damage to be detected and corrected and which depend upon material, structural, and operational considerations.

Damage tolerance increases as the damage size increases for a given level of a performance parameter. Damage tolerance increases as the level of the performance parameter increases for a given damage size. Damage tolerance depends upon the type of loading which is applied. For example, the damage tolerance for a compressive load can be, and generally is, different than for the same level of tensile load.

Damage resistance is often confused with damage tolerance. Damage tolerance is directly related only to the size and type of damage while being only indirectly related to how the damage was created (see *damage resistance*). Thus, damage tolerance is distinct from damage resistance.

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

debulk, *v*—to decrease voids between lamina before laminate consolidation through use of vacuum or by mechanical means.

Discussion—Laminae can be debulked at ambient or elevated temperatures.

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

denier, *n*—a direct numbering system for expressing linear density, equal to the mass in grams per 9000 metres of yarn, filament, fiber, or other textile strand.

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.

face sheets, facesheets, *n—in sandwich construction,* the outer structural layers on each face of the core. (Synonyms: face, skin, facing.)

Discussion—The face sheets are generally thin and of higher density relative to the core. The face sheets provide the primary ability to equilibrate the in-plane normal and shear forces from bending and torsion applied to the construction. If the face sheets are composite, then the entire composite laminate bonded to one side of the core constitutes a face sheet, as shown in Fig. 1.

FIG. 1 Sandwich Construction

face sheet dimpling, *n—in sandwich construction,(1)* the buckling of a face sheet into or out of the individual cells of a honeycomb core due to localized compressive or shear stresses, or both, or *(2)* the sagging of the face sheet into the individual honeycomb cells during curing of composite face sheets onto the core.

Discussion—Although described by the same phrase, these two phenomena are different in nature and in subsequent effects.

face sheet wrinkle, *n—in sandwich construction,* the localized elastic instability (buckling) of a face sheet into or away from the core as a result of in-plane compression forces.

Discussion—This stress-induced phenomenon generally progresses across the width of a sandwich panel and may result in panel failure. Not to be confused with fabrication-induced face sheet wrinkling, which is a distinctly different phenomenon.

fabrication, *n*—the process of manufacturing, forming, constructing, or assembling a product or component.

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.**)

TABLE 1 Fiber Forms

	Continuous Filaments		Discontinuous Filaments	
Twist	Twisted	Little or No Twist	Twisted	Little or No Twist
Tow,[A] strand, sliver	*[B]	P[C]	—[D]	—
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.