INTERNATIONAL

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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.

1.4 *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]

D123 Terminology Relating to Textiles

2.2 *Industry Standard:*[3]

CMH-17 Composite Materials Handbook

3. Terminology

3.1 *Definitions:*

±45°, *adj*—describing a laminate that is balanced, and that consists only of plies with ply orientations of +45° and −45°.

Discussion—A ±45° laminate is not necessarily symmetric.

angleply, *adj*—describing a laminate that is balanced, and that consists only of plies with ply orientations of plus theta and minus theta.

Discussion—An angleply laminate is not necessarily symmetric.

balanced, *adj*—describing a laminate that contains one ply with a ply orientation of minus theta for every ply of the same material and thickness with a ply orientation of plus theta, and any number of plies with a ply orientation of 0° or 90°.

Discussion—A ply with an orientation of 0° or 90° is balanced unto itself, and thus does not require another ply to balance it within a laminate.

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

Discussion—See **co-cure (cocure)**, **co-bond (cobond)** and **secondary bond** for associated terms.

braid, *n*—a textile process that interlaces, in a specific pattern, three or more yarns such that no two yarns are twisted around each other.

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

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

carbon fiber precursor, *n*—a material from which carbon fiber is made by pyrolysis.

Discussion—Polyacrylonitrile, rayon, and pitch fibers are commonly used precursors.

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.

co-bond, cobond, *n*—the act of curing (or consolidating) and bonding one semi-solid detail (for example, 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.

co-cure, cocure, *n*—the act of curing two semi-solid details (that is, uncured thermoset polymers) in a single process,

[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.

resulting in the two details being bonded through principal action of the matrix, possibly with the inclusion of a separate layer of adhesive at the interface.

co-fabrication, cofabrication, *n*—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 (material), *n*—a substance (material) 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.

Discussion—There are several types of composites as described by the means by which the matrix material is reinforced: discontinuous fiber-reinforced composite, fabric-reinforced composite, fiber-reinforced composite, filamentary composite.

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

core, *n—in sandwich construction*, an inner layer of a multi-layer adherend assembly, as shown in Fig. 1.

Discussion—The core is usually of a relatively low density material and is often substantially thicker than the other layers. It separates the surface layers (face sheets), and other possible layers, of a multi-layer sandwich construction, generally stabilizing the face sheets and transmitting shear between them.

Discussion—Core can also be used in non-sandwich configurations, such as tubular constructions, where it is usually the innermost material.

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, *adj*—describing a laminate that consists only of plies with ply orientations of 0° and 90°.

Discussion—A crossply laminate 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.

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.

FIG. 1 Sandwich Construction

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 structural 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.

Discussion—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 force can be, and generally is, different than for the same level of tensile force.

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

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

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

delamination, *n*—a separation of plies in a laminate.

Discussion—A delamination may be localized or may cover a large area within 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, *n*—an area within a bonded interface between two adherends in which an adhesion or cohesion failure has occurred.

Discussion—A disbond 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 plies in the finished laminate (the term "delamination" is preferred).

discontinuous fiber, *n*—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.

Discussion—The minimum diameter of a discontinuous fiber is not limited, but the maximum diameter may not exceed 0.25 mm (0.010 in.).

Discussion—With regard to reinforcement of a composite, these fibers may be whiskers or chopped fibers. See Table 1.

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 1.

fabric, *n*—a planar textile that may be constructed by various processes.

Discussion—Also referred to as "cloth". There are several types of fabric as described by the process of fabrication: braided fabric, knitted fabric, nonwoven fabric, woven fabric. See Fig. 2.

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

face sheets, facesheets, *n—in sandwich construction,* the outer structural layers on each face of the core, as shown in Fig. 1.

Discussion—Also referred to as "face", "skin", "facing".

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.

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.

face sheet dimpling, *n—in sandwich construction, (1)* the buckling of a face sheet into or out of the individual cells of a discontinuous core such as honeycomb due to localized compressive or shear stresses, or both; or *(2)* the deformation of the face sheet into the individual core 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. The phenomenon described by definition (*1*) is also sometimes referred to as "intracell buckling".

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.

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, *n*—the amount of fiber present in a composite or prepreg expressed either as percent by weight or percent by volume.

Discussion—This is sometimes stated as a fraction, that is, **fiber weight fraction** or **fiber volume fraction**.

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

fiber weight fraction—see **fiber content.**

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

Discussion—Filaments may be essentially continuous (aspect ratio on the order of 10^5 or larger) or discontinuous. Whiskers are the special case of single crystal discontinuous filaments. See Table 1. See also **monofilament**.

filament catenary, *n—(1)* the difference in length of the filaments in a specified length of tow, end, or strand as a result of unequal tension; *(2)* the tendency of some filaments in a taut horizontal tow, end, or strand to sag lower than others.

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

fill, *n—in a woven fabric*, the yarn running from selvage to selvage at right angles to the warp.

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

float, *n—in woven fabric*, the portion of a warp (or fill) yarn that extends unbound over two or more fill (or warp) yarns.

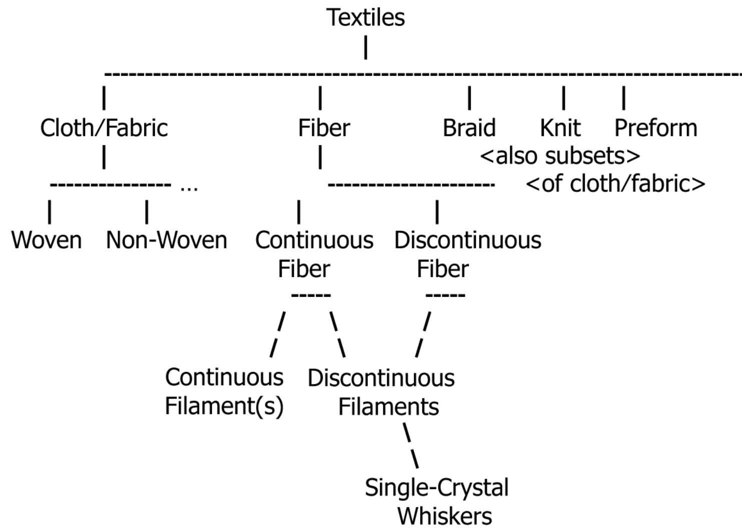

FIG. 2 Illustration of Textile Relationships

gel time, *n—in thermosetting polymers*, the period of time from a predetermined starting point to the onset of gelation as determined by a specific test method.

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.

Discussion—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.

hybrid, *n—for composite materials*, containing at least two distinct types of matrix or reinforcement.

Discussion—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.

in-plane, *adj*—referring to the plane of the laminate or ply.

Discussion—The specifics of this with regard to a laminate and to a ply are described within the definitions of **laminate coordinate axes** and **ply coordinate axes**, respectively.

insert, *n—in sandwich and composite construction,* an item bonded into the composite, either during fabrication or via a secondary operation, to distribute attachment stresses such as concentrated in-plane or pull-through forces.

Discussion—Previously also referred to as "hard points."

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

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

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

lamina, *n—in laminated* ***composites***, a subunit of a laminate consisting of one or more adjacent plies of the same material with identical ply orientation.

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

laminate, *n*—any fiber- or fabric-reinforced composite consisting of plies (laminae) with ply orientations of one or more values.

laminate coordinate axes, *n*—a set of coordinate axes, usually right-handed Cartesian, used as reference in describing the directional properties and geometrical structure of the laminate.

Discussion—In the use of a set of right-handed Cartesian axes, the axes are normally labeled *x*, *y*, *z*; or 1, 2, 3; or some other common corresponding notation. In such cases, the *x(or 1)*-axis and the *y(or 2)*-axis usually lie in the plane of the laminate with the *x(or 1)*-axis being the reference axis from which ply orientation is measured. The third axis, *z (or 3)*, would be through the thickness of the laminate.

laminate midplane, *n*—the plane that is equidistant from both surfaces of the laminate.

laminate principal axis, *n*—the laminate coordinate axis that coincides with the direction of maximum in-plane Young's modulus.

lay-up, *n—(1)* the stack of plies in specified sequence and **ply orientation** before cure or consolidation; *(2)* the complete stack of plies, bagging material, breather material, and so on before cure or consolidation; *(3)* a description of the component materials, geometry, and so on of a laminate; and *(4)*