



**GLOSSARY OF TERMS
FOR COMPOSITE MATERIALS**

PURPOSE This glossary is a tool used to assist all employees in understanding the most common terms used in composite material manufacturing. It is not an all inclusive list of terms. All terms found in this glossary are not necessarily used by Vermont Composites.

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A

Ablative - Describes a material that absorbs heat through a decomposition process called pyrolysis at or near the exposed surface.

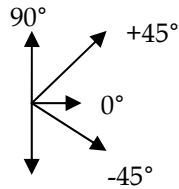
Accelerator - A chemical additive that hastens cure or chemical reaction (see also catalyst).

Additive - An ingredient mixed into resin to improve properties (e.g., plasticizers, initiators, light stabilizers and flame retardants).

Adhesive - Substance applied to mating surfaces to bond them together by surface attachment.

Adhesive film - A thin plastic film onto which premixed adhesives are cast.

Angle-ply laminate - Any balanced laminate consisting of plies at angles of plus and minus theta, where theta is an acute angle with the principal laminate axis.



Aramid - Aromatic polyamide fibers. (Often referred to as Kevlar, DuPont's trademark.)

Areal weight - Weight of a fiber reinforcement per unit area (width times length) of tape or fabric.

Aspect ratio - Ratio of the length to the diameter of a fiber.

Autoclave - Closed vessel for applying fluid pressure, with or without heat, to an enclosed object (see consolidation).



Autoclave molding - Molding technique in which an entire assembly (layup and tooling) is placed into an pressure vessel and subjected to heat and elevated pressure for consolidation and/or curing while removing entrapped air and volatiles.



B

B-stage - Intermediate stage in the polymerization reaction of some thermosets in which the material softens with heat and is plastic and fusible but does not entirely dissolve or fuse. The resin of an uncured prepreg or premix is usually in this state.

Bag molding - Molding technique in which the composite structure is placed in a rigid mold and covered with a flexible impermeable layer of film whose edges are sealed, followed by consolidation and/or curing with pressure applied by vacuum, autoclave, press or inflation of the bag.

Balanced laminate - Any laminate that contains one ply of minus theta orientation, with respect to the principal axis of the laminate, for every identical ply with a plus theta orientation (e.g., a laminate with a principle axis of 0° combined with an equal number of plies having -45° and $+45^\circ$ orientations. i.e. $0^\circ, 90^\circ, +45^\circ, -45^\circ$

Barcol hardness - A surface hardness value obtained by measuring the penetration resistance of a given material to a sharp steel point under a spring load. The Barcol Impressor is an instrument that measures hardness on a 0-100 scale. It can be used to determine the completeness of cure of the resin.

Bias fabric - Fabric in which warp and fill fibers are at an angle to the length. i.e. $60^\circ, 45^\circ$ etc. not 0° or 90° .

Biaxial fabric - Fabric with two non-interwoven layers - a unidirectional warp (0°) layer and a unidirectional weft (90°) layer - which are stitched or held together, usually by through-the-thickness stitching, to form a single sheet of fabric. (See also triaxial fabric, quadraxial fabric.)

Bidirectional laminate - Laminate with fibers oriented in more than one direction on the same plane.

Binder - The agent applied to glass mat or preforms to bond the fibers prior to laminating or molding. (see resin)



Bismaleimide (BMI) - Type of thermoset polyimide that cures by an additional reaction, thus avoiding formation of volatiles. Exhibits temperature capabilities between those of epoxy and polyimide.

Bleeder cloth - Layer of woven or nonwoven material, not intended to become a part of the composite that allows excess gas and resin to escape during cure.

Bleedout - Excess liquid resin appearing at the surface or edges of the composite structure, particularly during filament winding.

BMI - See *bismaleimide*.

Bond strength - The adhesion between bonded surfaces. As measured by load/bond area, the stress required to separate a layer of material from another material to which it is bonded.

Boron fiber - Fiber produced by chemical vapor deposition of boron onto a core material, usually a tungsten-filament. Because of the deposition process, a boron fiber is of a fairly large diameter, typically about 0.4 mils, and is thus often referred to as a wire. Rarely used as reinforcement fiber in prepreg.

Breakout - Separation or breakage of fibers when the edges of a composite part are drilled or cut. (undesirable)

Breather - Loosely woven material that does not come in contact with the resin but serves as a continuous vacuum path over a part in production.

Bridging - The undesirable effect caused by drawing pre-preg, fibers, or bagging material too taught across a radius in the mold. Bridging prevents the compaction of the laminate in the corner leading to weak structure, resin rich areas or bags bursting.

Bromine - A fire retardant (halogen) used to reduce or eliminate a resin's tendency to burn.



Buckling - Failure mode usually characterized by unstable lateral deflection, rather than breakage, under compressive force.

Bundle - General term for a collection of essentially parallel filaments. Also called yarn.

Bulk molding compound (BMC) - A premixed blend of thermosetting resin, reinforcements, catalysts and fillers for use in compression-, transfer- or injection-molding processes.



C

CAD/CAM - Computer-aided design/computer-aided manufacturing.

Carbon fiber - Reinforcing fiber produced by the pyrolysis of an organic precursor fiber, such as PAN (polyacrylonitrile), rayon or pitch, in an inert atmosphere at temperatures above 982°C/1800°F. The term carbon is often used interchangeably with the term graphite, but the fibers differ. Carbon fibers are typically carbonized at about 1315°C/2400°F and contain 93 percent to 95 percent carbon. Carbon fibers can be converted to graphite fibers by graphitization at 1900°C to 2480°C (3450°F to 4500°F), after which they contain more than 99 percent elemental carbon. Carbon fibers are known for their light weight, high strength and high stiffness.

Cast polymer - A nonreinforced composite (resin used without reinforcing fibers) that combines polymers, fillers and additives as composites to meet specific application requirements.

Catalyst - Substance that promotes or controls curing of a compound without being consumed in the reaction. (See also hardener.)

Catalyzed resin - A resin mixture possibly still in the workable state, after it has been mixed with catalyst or hardener.

Caul plate - Plate or sheet the same size and shape as the composite layup with which it will be used. The caul plate is placed in immediate contact with the layup during curing to transmit normal pressure and provide a smooth surface on the finished part.

Centipoise (cps) - A unit of measure used to designate a fluid's viscosity (at 21°C/70°F, water is 1 cps; peanut butter is 250,000 cps).

Chopped strand - Continuous roving that is chopped into short lengths for use in mats, spray up or molding compounds.



Cloth - See *fabric*.

Cocured - Cured and simultaneously bonded to another prepared surface.

Coefficient of expansion (COE) - A measure of the change in length or volume of an object.

Coefficient of thermal expansion (CTE) - A material's fractional change in length for a given unit change of temperature.

Cohesion - Tendency of a single substance to adhere to itself. Also, the force holding a single substance together.

Coin tap - Tapping a laminate with a coin in different spots to detect a change in sound, indicating the presence of a defect void or Delamination that may require repair.

Composite - Three-dimensional combination of at least two materials differing in form or composition, with a distinct interface separating the components. Composite materials are usually manmade and created to obtain properties that cannot be achieved by any of the components acting alone.

Compression molding - Technique for molding thermoset composites in which the part is shaped and cured in the same step. Layered reinforcing fibers and resin paste (typically precombined in a leather-like, preimpregnated sheet) are placed into an open two-part mold cavity. The mold is closed and, with the application of both heat and pressure, the resin viscosity drops, the material is forcibly distributed throughout the mold cavity to take its final shape and the part is allowed to cure.

Compressive strength - Resistance to a crushing or buckling force; the maximum compressive load a specimen sustains divided by its original cross-sectional area.

Condensation - A polymerization reaction in which simple byproducts (e.g., water) are released.



Consolidation - A processing step in which a fiber and matrix are compressed to reduce voids and achieve a particular density.

Contaminant - An impurity or foreign substance that affects one or more properties of composite materials, particularly adhesion.

Core - In sandwich construction, the central component to which inner and outer skins are attached

Core crush - Compression damage of the core. Maybe cause for rejection of part

Core depression - A gouge or indentation in the core material.

Core orientation - Used on a honeycomb core to line up the ribbon direction, thickness of the cell depth, cell size and transverse direction.

Core separation - A breaking of honeycomb core cells.

Core splicing - Joining of two core segments by bonding them together.

Cowoven fabric - Reinforcement fabric woven with two different types of fibers in individual yarns (e.g., thermoplastic fibers woven side by side with carbon fibers).

Crazing - Region of ultrafine cracks that may develop on or under a resin surface.

Creep - Time-dependent dimensional change in a material under physical load.

Critical length - Minimum length of a fiber necessary for matrix shear loading to develop ultimate fiber strength.

Cross-laminated - Laminated with some of the layers oriented at one or more angles to the other layers with respect to the principal laminate axis. (See cross-ply laminate and fiber architecture.)



Crosslinking - Polymerization reactions that branch out from the main molecular chain to form a networked pattern of chemical links.

Cross-ply laminate - A laminate having plies oriented only at 0° and 90°. May or may not be symmetrical.

Crystalline - Having a molecular structure in which the atoms are arranged in an orderly, three-dimensional pattern.

CTE - See *coefficient of thermal expansion*.

Cure - Irreversible alteration of the molecular structure and physical properties of a thermosetting resin by chemical reaction, typically stimulated by heat and/or the presence of catalysts, with or without applied pressure. However, see ultraviolet (UV) cure.

Cure temperature - The temperature at which a material attains final cure.

Curing agent - Catalytic or reactive agent that brings about polymerization when added to a resin (also see accelerator, catalyst and hardener).



D

Damage tolerance - A measure of a structure's ability to retain load-carrying capability after exposure to sudden loads (for example, ballistic impact).

Damping - Diminishing the intensity of vibrations.

Debond - Deliberate separation of a bonded joint or interface, usually for repair or rework purposes. (See also disbond.)

Delamination - Separation of plies in a laminate due to adhesive failure. This may occur locally or involve a large area. Also includes the separation of layers of fabric from the core structure.

Demold - To remove a part from a tool or a tool from an intermediate model.

Denier - Numbering system for continuous yarn and continuous filaments in which the yarn number is equal to the weight in grams per 9,000 meters of yarn; the finer the yarn, the lower the denier. (engineering term)

Design allowable - A limiting value for a material property that can be used to design a structural or mechanical system to a specified level of performance with a specific level of statistical confidence.

Dielectric - Electrically nonconductive; the ability of a material to resist the flow of an electric current. Glass composites have high dielectric strength)

Dielectric strength - The voltage required to penetrate insulating material. Material with high dielectric strength offers excellent electrical insulating properties.

Disbond - Undesirable separation of bonded surfaces at the bond interface, due to adhesive or cohesive failure, occurring at any time during the life of the bonded structure and arising from any of a wide variety of causes. The term is also sometimes used to describe delamination. (Also see debond.)



Doubler - An extra layer of reinforcement, applied to increase stiffness or strength in portions of a laminate expected to incur abrupt load transfers.

Draft - The degree of taper designed into the sides of a mold so the part can be removed.

Draft angle - A mandrel's taper or tool's angle for ease of part removal.

Drape - The ability of fabric or prepreg to conform to a contoured surface.



E

E-glass - Abbreviation for "electrical glass," borosilicate glass fibers, which have high electrical resistivity. Most often used in conventional polymer matrix composites.

Elastic limit - The greatest stress a material is capable of sustaining without permanent strain remaining after complete release of the stress (see stress and strain).

Elasticity - The property of materials to recover immediately their original size and shape when load is removed after deformation.

Elongation - The fractional increase in length of a material loaded in tension. When expressed as a percentage of the original length, it is called percent elongation.

Engineering plastics - A general term covering all plastics, with or without fillers or reinforcements that have mechanical, chemical and thermal properties suited for use as construction materials or in components for machines and chemical processing equipment.

Epoxy - A thermosetting polymer containing one or more epoxide or oxirane groups, curable by reaction with amines or alcohols; used as a resin matrix in reinforced plastic products and as the primary component in certain structural adhesives. Cured epoxy resin is highly resistant to chemicals and water and its performance properties are relatively unaffected by extreme temperatures.

Exotherm - Heat released during a chemical reaction. Uncontrolled exotherm during cure of a composite component can lead to heat build up, which can result in part warpage and/or mold damage and, in extreme cases, could produce an explosion or fire.



F

Fabric - Planar textile. Also known as cloth.

Fabric, nonwoven - Planar textile constructed by bonding or interlocking but not interlacing fibers or yarns by mechanical, chemical, thermal or solvent means.

Fabric, woven - Planar textile constructed by interlacing fibers or yarns, using a weaving process.

Fabrication - Process of making a composite part or tool.

Fatigue - Failure or deterioration of a material's mechanical properties as a result of repeated cyclic loading or deformation over time.

Fatigue strength - Maximum cyclical stress withstood for a given number of cycles before a material fails. The residual strength after being subjected to fatigue loading.

FEA - See *finite-element analysis*.

Fiber - One or more filaments in an ordered assemblage.

Fiber architecture - The design of a fibrous preform or part in which the fibers are arranged in a particular way to achieve a desired result. Mats and braided, stitched and woven fabrics are common forms of fiber architecture.

Fiber bridging - Reinforcing fiber material bridging an inside radius of a pultruded product. The condition is caused by shrinkage stresses around such a radius during cure.

Fiber content - The amount of fiber present in a composite expressed either as a percent by weight or percent by volume. Also sometimes stated as a fiber volume fraction or expressed in ratio to the matrix content (e.g., a 60:40 fiber-to-resin ratio denotes a composite with 60 percent fiber content and 40 percent resin content).



Fiber orientation - Direction of fiber alignment in a nonwoven or mat laminate wherein most of the fibers are placed in the same direction to afford greater strength in that direction.

Fiber placement - Continuous process for fabricating composite shapes with complex contours and/or cutouts by means of a device that lays pre-impregnated fibers (in tow form) onto a non-uniform mandrel or tool. Differs from filament winding in several ways: There is no limit on fiber angles; compaction takes place online via heat, pressure or both; and fibers can be added and dropped as necessary. The process can produce shapes with greater complexity and permits a faster putdown rate than filament winding.

Fiber-reinforced plastics (FRP) - General term for a polymer-matrix composite that is reinforced with cloth, mat, strands or any other fiber form. However, in practice, the term is most often used in reference to glass fiber-reinforced plastics.

Fiber wash - Dislocation or displacement of reinforcing fibers placed within a mold caused by the force of the resin flow, resulting in unintended fiber distribution within the finished part.

Fiber volume fraction - See *fiber content*.

Fiberglass - Reinforcing fiber made by drawing molten glass through bushings. The predominant reinforcement used with polymer matrix composites, it is known for its good strength, processability and low cost.

Filament - Polycrystalline or amorphous individual fiber unit with a length-to-diameter ratio greater than one. The minimum diameter of a filament is not limited, but the maximum diameter may not exceed 0.010 inches. Filaments greater than about 0.002 inches in diameter are often referred to as wires.

Filament count - Number of filaments in the cross-section of a fiber bundle.



Filament winding - An automated process in which continuous reinforcing fibers, either preimpregnated with resin or drawn through a resin bath, are wound under controlled tension around a rotating form to make a composite structure. (Also see winding and mandrel.)

Fill - The fiber bundles in a woven fabric that run transverse (at a 90° angle) to the warp yarns; also known as weft or woof.

Filler - A solid constituent, usually inert, added to a matrix to modify a composite's properties (e.g., increase viscosity, improve appearance or decrease density) or to decrease part material cost.

Filler ply - An additional patch used to fill in a depression in a repair or build up an edge.

Film adhesive - Adhesive in the form of a thin, dry resin film, with or without a carrier; commonly used for adhesion between laminate layers.

Finish - Material applied to textiles to improve the bond between the fiber and matrix; applied after sizing is removed. At VCI this could also mean any of the following processes; sand, fill, prime, paint anodize, alodine plate etc.

Finite element analysis - Process of selecting the optimum combination of materials in a composite, based on computer-based computational modeling and analysis.

Flexural modulus - Ratio, within the elastic limit, of the applied stress (=load [pounds/sq inch]) on a test sample in flexure to the corresponding strain(=elongation[inches/inch]) in the outermost fibers of the sample.

Flexural strength - Strength of a material in bending, usually expressed in force per unit area, as the stress of a bent test sample at the instant of failure.

Fracture - A rupture in the surface of a laminate due to external or internal forces; may or may not result in complete separation.



Fracture toughness - A measure of the damage tolerance of a material containing initial flaws or cracks.

FRP - See *fiber-reinforced plastics*.



G

Gel - To enter an initial jelly-like, semi-solid phase during a resin curing process. (Measurable increase in resin viscosity)

Gel coat - An unreinforced, clear or pigmented coating resin applied to the surface of a mold or part to provide a smooth, more impervious finish on the part exterior.

Gel time - The period of time from initial mixing of liquid reactants in a resin to the point when gelation occurs as defined by a specific test method.

Glass fiber - see *fiberglass*.

Glass transition - A reversible change in an amorphous polymer between a liquid condition and a hard, relatively solid condition.

Glass-transition temperature (Tg) - Approximate temperature at which increased molecular mobility results in significant changes in properties of a cured resin. The measured value of Tg can vary, depending on the test method.

Graphitization - Process of pyrolysis at very high temperatures (up to 2982°C/5400°F) that converts carbon to its crystalline allotropic form.

Graphite fibers - Carbon fibers that have been graphitized by heating and stretching at temperatures above 1649°C/3000°F.



H

Halogenated resin - A resin combined with chlorine or bromine to increase fire retardancy.

Hand layup - A fabrication method in which reinforcement layers, preimpregnated or coated afterwards, are placed and arranged in a mold manually. (In contrast to sprayup or automated methods, such as fiber placement.)

HAPs - see *hazardous air pollutants*.

Hard tool - A tool made of metal or any "hard" material that is generally impervious to process-related damage (e.g., exothermic distortion) during normal molding operations (in contrast to soft tool). See tool.

Hardener - A substance that may be added to a resin to promote and/or control the curing process by participating in and being consumed by the cure reaction. (Also see accelerator, curing agent and catalyst.)

Hazardous air pollutants (HAPS) - Potentially airborne compounds determined to be hazardous to human health by the U.S. Environmental Protection Agency (EPA).

Heat - The term used colloquially to indicate any temperature above ambient (room) temperature to which a part or material is or will be subjected.

Heat-deflection temperature (HDT) - The temperature at which a standard plastic test bar deflects a specified distance under a stated load.

Helical - Describes ply laid onto a rotating mandrel at an angle, often at a 45° angle.

Helix angle - The angle at which continuous filaments are wound in relation to the longitudinal mandrel axis in the filament-winding process.

High-performance composites - Composites offering properties better than conventional structural metals, typically on a strength-to-weight or stiffness-to-weight basis. Such composites use continuous, oriented fibers in polymer, metal or ceramic matrices to achieve their superior properties.



Honeycomb - A lightweight cellular structure (typically hexagonal nested cells) used as core in composite sandwich structures. May be made from either metallic (e.g., aluminum) or nonmetallic (e.g., resin-impregnated paper or woven fabric) sheet materials. Rectangular sheets are adhesively bonded together in stacks, by means of parallel stripes of adhesive placed at regular intervals along one axis. Stacks are sliced across the transverse axis, and each sliced stack is expanded to form a honeycomb grid.

Hoop - Describes ply layed onto a rotating mandrel at a 90° angle to the long axis of the mandrel.

Hoop stress - Circumferential stress in a cylindrically shaped part as a result of internal or external pressure.

Hot-bond repair - Repair made on a hot-patch bonding machine to cure and monitor curing. Typically includes heat and vacuum source.

Hybrid composite - Composite containing at least two distinct types of matrix or reinforcement. The matrix or reinforcement types can be distinguished by their physical properties, mechanical properties, material form and/or chemical composition.

Hygroscopy - A material's readiness to absorb or retain moisture.



Impact strength - A material's ability to withstand shock loading as measured during a test in which a specimen is fractured.

Impregnate - To saturate the voids and interstices of a reinforcement with resin.

Impregnated fabric - See *prepreg*.

Inclusion - Physical and mechanical discontinuity occurring within a material or part (a foreign object is captured into a part- not desirable).

In situ - In the original position; in filament winding, designates a mandrel that remains in place after winding, as opposed to a mandrel that is removed after winding. In pipe repair, a type of repair that does not require pipe excavation; rather a composite sleeve is inserted into the existing pipe through a manhole.

Inhibitor - A chemical additive that slows or delays a cure cycle.

Injection molding - A method of forming a plastic to the desired shape by forcibly injecting the polymer into a mold.

Integral heating - System in which heating elements are built into a tool, forming part of the tool and usually eliminating the need for an oven or autoclave as a heat source.

Interface - The plane formed when two material surfaces make contact: in glass fibers, for instance, the area at which the glass and sizing meet; in a laminate, the area at which the reinforcement and laminating resin meet.

Interlaminar - Existing or occurring between two or more adjacent laminae in a laminate.

Interlaminar shear - Shearing force that produces displacement between two laminae along the plane of their interface.



Intralaminar - Existing or occurring within a single lamina in a laminate.

Intumescent - Capable of swelling or enlarging. In reference to fire-retardants, describes a layer or coating of material designed to swell or thicken in order to form a more effective barrier to heat and/or flame when exposed to either.

Isotropic - Fiber directionality with uniform properties in all directions, independent of the direction of applied load.

Isotropic laminate - A laminate in which the strength properties are equal in all directions, such as contact-molded laminates or metals.

A prescribed layup stack that balances several directions to achieve equal (strength) properties in all directions ie. 0,90,+45,-45 ...mirrored



K

Kevlar - Trademark of DuPont for high-performance para-aramid fibers used as reinforcements (see aramid).

Knit - Textile process that interlocks, in a specific pattern, loops of yarn by means of stitching process, using needles or wires.



L

Lamina - Subunit of a laminate consisting of one or more adjacent plies of the same material with identical orientation. (Plural: laminae.)

Lamina orientation - See *ply orientation*.

Laminate - To unite or bond two or more layers or laminae (often with the aid of pressure and/or heat). Any fiber- or fabric-reinforced composite consisting of laminae with one or more orientations with respect to some reference direction.

Laminate coordinate axes - Set of coordinate axes, usually right-handed Cartesian, used as a 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. The x-axis is often in the principal load direction of the laminate and/or in the direction of the laminate principal axis. (See principal axis, off-axis laminate and x-axis.)

Lap joint - A joint made by overlapping two parts and bonding them together. Also applies to lay-up of prepreg plies

Layup - To place or the process of placing layers of reinforcing material into position in or on a mold; also used to refer to the reinforcing materials as placed in the mold ("the layup").

Layup code - Designation system for abbreviating the stacking sequence of laminated composites.

Liner - The continuous, usually flexible, reinforced resin barrier on the inside surface of a plastic or thermoset laminate, used to protect the laminate from chemical attack or to prevent leakage under stress.

Liquid-crystal polymers (LCP) - High-performance melt-processible thermoplastics that develop high orientation in the melt and after molding, resulting in very high tensile strength and high-temperature capability.



Lot- is the designated batch of materials used to produce a product. This allows us full traceability of our products based on the materials used to make them

Low profile - Describes resin compounds formulated for low-to-zero shrinkage during molding.



M

MACT - Maximum Achievable Control Technology. A technology-based air pollution control standard developed by the U.S. Environmental Protection Agency (EPA) aimed at reducing emissions of hazardous air pollutants (HAPs) from U.S. manufacturing operations.

Mandrel - A form, fixture or male mold used as the base for production of a part in processes such as layup or filament winding.

Mat - An unwoven textile fabric made of fibrous reinforcing material, such as chopped filaments (to produce chopped strand mat) or swirled filaments (to produce continuous strand mat) with a binder applied to maintain form. Available in blankets of various widths, weights, thicknesses and lengths. May be oriented.

Matched metal molding - See compression molding.

Matrix - Material in which reinforcing fiber of a composite is embedded. Matrix materials include thermosetting and thermoplastic polymers, metals and ceramic compounds.

Matrix content - Amount of matrix present in a composite expressed either as a percent by weight or percent by volume. For polymer-matrix composites this is the resin content. (Also see fiber content.)

Metal-matrix composite (MMC) - Continuous carbon, silicon carbide, or ceramic fibers embedded in a metallic matrix material.

Midplane - Plane that is equidistant from both surfaces of the laminate.

Microcracking - Microscopic cracks formed in composites when thermal stresses locally exceed the strength of the matrix.

Mil - The unit used in measuring the diameter of glass fiber strands, wire and so forth (1 mil = 0.0254 mm/0.001 inch).



Milled fiber - Continuous glass or carbon strands hammer-milled into very short fibers.

MMC - See *metal-matrix composite*.

Modulus - The physical measure of a material's stiffness, equal to the ratio of applied load (stress) to the resulting deformation of a material. May be represented by a number or in descriptive terms as low, intermediate, high or ultrahigh. A higher modulus indicates greater stiffness. (See stiffness and Young's modulus.)

Moisture absorption - Pickup of water vapor from the air by a material. Refers to vapor withdrawn from the air only as distinguished from water absorption, which is weight gain due to the absorption of water by immersion.

Mold - An enclosed cavity or open form from which a composite component takes its shape, size and exterior surface appearance (also known as a tool).

Mold release agent - A lubricant used to prevent a part from sticking to a mold surface ie. Frekote type products.

Molding - The process of forming composite materials into a solid mass of prescribed shape and size, using a mold or tool.

Monomer - A single molecule that reacts with like or unlike molecules to form a polymer.

Monofilament - Single continuous filament strong enough to function as a fiber in textile or other operations.

Multifilament - Yarn or tow consisting of many continuous filaments (also see yarn and tow).



N

Naphtha - A petroleum distillate commonly used as a solvent for natural resins and rubber.

NDE, NDI, NDT - Nondestructive evaluation, nondestructive inspection, nondestructive testing. (See nondestructive inspection.)

Near-net shape - Describes a manufactured part or reinforcement preform fabricated to final dimensions that require minimal machining, cutting or other finishing.

Net shape - Fabricated to final dimensions that do not require machining or cutting.

Nomex - Trademark of DuPont for moderate-performance meta-aramid material that is often used in paper form with phenolic resin binder to make honeycomb core.

Nondestructive inspection (NDI) - Determining material or part characteristics without permanently altering the test object. Nondestructive testing (NDT) and nondestructive evaluation (NDE) are broadly considered synonymous with NDI.

Nonwoven roving - A form of fiber reinforcement composed of continuous fiber strands loosely gathered together.

Nylon - The generic name, by common usage, for all synthetic polyamides.



O

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

One-off - Denotes a fabrication process in which a single part is produced.

One-part resin system - A resin system (often used in resin transfer molding) in which the neat resin and catalyst are mixed together by the materials supplier as part of the resin production process.

Original equipment manufacturer (OEM) - Describes a company that designs and builds products bearing its name; for example, Boeing 777 aircraft or Prince tennis racquets.

Out-time - Period of time in which a prepreg retains desirable handling characteristics and performance properties outside a specified storage environment (such as a freezer, in the case of thermoset prepreps). Can be as little as 3 days and as much as 30 days.

Outgassing - The release of solvents and moisture from composite parts under a vacuum.



P

PAN - See *polyacrylonitrile*.

Part consolidation - A design-and-fabrication process in which a number of previously discrete parts are combined in a single component to reduce or eliminate assembly operations and associated costs.

Parting film - A layer of thin plastic that prevents bagging materials from sticking to a part. It may be perforated to vent excess resin. It is removed after cure.

PBO - See *poly p-phenylene-2,6-bisoxazole*.

Peel ply - A layer of material that, when applied to a layup surface, can be removed from the cured laminate prior to bonding operations, leaving a clean, resin-rich surface suitable for bonding.

Peel strength - Strength of an adhesive bond between sheet materials; determined by applying parting stress at a right angle (perpendicular) to the plane of the adhesive interface.

Phenolic resin - A thermosetting resin produced by a condensation reaction of an aromatic alcohol with an aldehyde (usually phenol with formaldehyde).

Pin holes - Small voids open to and visible on the surface of a cured composite part.

Pitch - Residual petroleum product used as a precursor in the manufacture of certain carbon fibers.

Planar winding - Filament winding method in which the filament path lays on a plane that intersects the winding surface.

Plastic - General term for a range of high-molecular-weight thermoplastic or thermosetting polymers that have characteristics and properties that make them suitable for use in molding, casting, extruding or laminating processes.

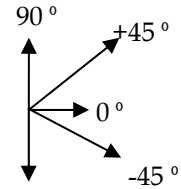
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Plied yarn - Two or more yarns collected together, with or without twist.

Ply - A single layer (or lamina) used to fabricate a laminate. Also, the number of single yarns twisted together to form a plied yarn.

Ply orientation - Acute angle (theta) - 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 schedule - A prescribed sequence for laying up individual plies or layers to form a laminate, indicating the arrangement of plies by material type and other characteristics, such as fiber orientation.

Poisson's ratio - When a material is stretched, its cross-sectional area changes as well as its length. Poisson's ratio is the constant relating these changes in dimensions, and is defined as the ratio of the change in width per unit width to the change in length per unit length.

Polar winding - Filament winding in which the filament path passes tangent to the polar opening at one end of the chamber and tangent to the opposite side of the polar opening at the other end of the chamber.

Polyacrylonitrile (PAN) - Polymer base material that is spun into a fiber form and used as a precursor in the manufacture of certain carbon fibers.

Polyester - Thermosetting resins produced by dissolving unsaturated, generally linear, alkyd resins in a vinyl-type active monomer, such as styrene. The resins are usually furnished in solution form, but powdered solids are also available.



Polyetherimide (PEI) - A high-performance thermoplastic resin with repeating aromatic imide and ether molecular units. Characterized by high strength and rigidity over a wide range of temperatures, as well as long-term heat resistance, highly stable dimensional properties and broad chemical resistance.

Polyimide (PI) - Highly heat-resistant thermoplastic polymer resin.

Polymer - Large organic molecule formed by combining many smaller molecules (monomers) in a regular pattern.

Polymer alloy (or polymer blend) - A blend of polymers, copolymers or elastomers.

Polymerization - Chemical reaction that links monomers to form polymers.

Poly p-phenylene-2,6-benzobisoxazole (PBO) - A relatively new polymer fiber, with a modulus and tensile strength almost double that of aramid fiber and a decomposition temperature almost 100°C/212°F higher.

Porosity - The presence of voids open to the surface of a solid material into which air or liquids may pass.

Postcure - Exposure of a molded component to elevated temperature after initial in-mold curing, performed for the purpose of improving the component's mechanical properties. Postcure may occur after demolding (free standing) and is often done without the use of pressure.

Pot life - Length of time in which a catalyzed thermosetting resin retains sufficiently low viscosity for processing.

Precure - Full or partial hardening of a resin or adhesive before pressure is applied. (Useful for cores and secondary bonding of skins)

Precursor - Material from which carbon fibers are made by pyrolysis. Common precursors are polyacrylonitrile (PAN), rayon and pitch.

Preform - Pre-shaped fibrous reinforcement, supplied without matrix, but often containing a binder to facilitate manufacture and maintain shape. A preform's fiber components are distributed or arranged, typically on a mandrel



or mock-up, to approximate the contours and thickness of the finished part, saving time and labor during the molding process.

Prepreg - Fibrous reinforcement (sheet, tape, tow, fabric or mat) preimpregnated with resin and capable of storage for later use. For thermosetting matrices the resin is usually partially cured or otherwise brought to a controlled viscosity, called B-stage. Additives (e.g., catalysts, inhibitors and flame retardants) are used to obtain specific end-use properties and/or improve processing, storage and handling characteristics.

Primary structure - An aerospace critical load-bearing structure; if damaged the aircraft or space vehicle cannot operate safely.

Prime contractors - Referred to as "primes"; companies that are awarded government contracts and usually work with subcontractors (or "subs") who provide individual and specific components or systems relevant to the contract. Primes often team on contracts, sharing portions of the contract funding.

Principal axis - Laminate coordinate axis that coincides with the direction of maximum inplane Young's modulus. Within a ply, for a balanced weave fabric either warp or fill direction may be chosen. (See also laminate coordinate axes and x-axis.)

Promoter - A chemical which hastens the reaction between a catalyst and a resin (also known as an accelerator).

Prototype - A test part not intended for commercial release, which establishes design, material and fabrication parameters for a new product. Also, to fabricate such a test part (a process that can entail multiple iterations to arrive at final/commercial part design).

Puckers - Local areas on prepreg where material has blistered and pulled away from the separator film or release paper.



Pultrusion - Continuous process for manufacturing composite rods, tubes and other linear structures that have constant cross-sections. The process involves drawing continuous reinforcement through a resin-impregnation bath (or an alternative resin-impregnation method is used), then pulling the wetout material through a heated shaping die, where cure takes place, securing the desired cross-section before the laminate departs from the die.

Puncture - A break in the composite skin of a sandwich structure that may or may not go through to the core material or completely through the part thickness.

Pyrolysis - The decomposition or other transformation of a compound caused by exposure to heat.



Q

Quadraxial fabric - Fabric with four non-interwoven layers $+45^\circ$, -45° , 0° and 90° - which are bonded together, usually by through-the-thickness stitching, to form a single sheet of fabric. (See also biaxial fabric, triaxial fabric.)

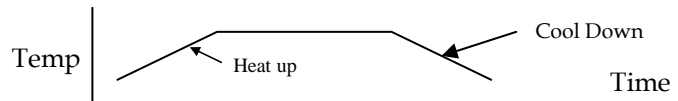
Quasi-isotropic - Approximates isotropy by orientation of plies in multiple directions. $+45^\circ$, -45° , 0° and 90°

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R

Ramping - A programmed gradual increase/ decrease in temperature and/or pressure to control cure or cooling of composite parts.



Rate tools - Tools designed to be used repeatedly in a production setting to fabricate many parts rather than a single prototype or small number of demonstration parts.

Reagent - A substance used in a chemical reaction to produce other substances.

Regrind - Scrap composites (thermoset or thermoplastic) collected in-plant or from post-consumer sources and reground into pellets or fine powder for reuse in molding new parts, either as a new base material or in combination with virgin materials.

Reinforced reaction injection molding (RRIM) - A closed molding process that mixes two highly reactive resin components for cure. Reinforcement, generally flake glass or milled fibers, is added to one of the resin components to add strength and reduce thermal expansion.

Reinforcement - The key element added to a matrix to provide the required properties (primarily strength).

Reinforcement forms range from individual short fibers to complex braided, woven or stitched textile forms. One of two parts of the composite –fiber/binder.

Release agent - An specially formulated material placed between the mold and uncured resin/fiber (usually sprayed or painted on the mold surface) to prevent permanent bonding between the two during cure and facilitates demolding after cure.

Release film - A release agent made from an impermeable film that does not form a bond with the composite material during cure.

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Resin - A solid or pseudo-solid polymeric 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. As composite matrices, resins bind together reinforcement fibers and work with them to produce specified performance properties.

Resin content - See matrix content.

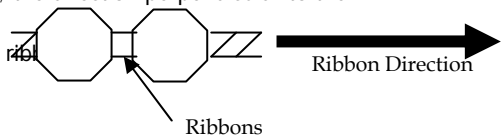
Resin-rich - Describes a localized buildup of resin in **excess** of the expected resin/fiber ratio in a composite.

Resin-starved - Describes an area in a composite that **lacks** sufficient resin to achieve thorough fiber wetout.

Resin transfer molding (RTM) - A closed molding process in which catalyzed resin is transferred into an enclosed mold cavity to impregnate a pre-positioned fibrous reinforcement (see preform). The mold and/or resin may or may not be heated. RTM involves relatively low tooling and equipment costs and enables fabricators to consolidate large parts.

Resin viscosity - Describes a resin system's solid-to-liquid transition resistance to flow, which can be altered by temperature and pressure to achieve desired flow characteristics. (Also see viscosity.)

Ribbon direction - On a honeycomb core, the length of the core splice; the direction perpendicular to the direction of cell expansion (w-direction). The direction of one continuous ribbon



Reaction injection molding (RIM) - A process involving high-pressure mixing of two highly reactive resin components to promote fast cure; primarily used in the molding of parts with polyurethane matrices.

Reinforced reaction injection molding (RRIM) - Reaction injection molding process in which one of the two mixed components is reinforced, usually with flake glass or milled fibers, to stiffen the part and reduce thermal expansion (see previous entry).



Roving - Large filament-count tow; a collection of continuous glass fiber filaments, either as untwisted strands or twisted yarn.

RTM - See *resin transfer molding*.

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S

S-glass - The standard abbreviation for "structural glass," which is a magnesia/alumina/silicate glass fiber reinforcement designed to provide the very high tensile strength required in high-performance composites.

Sandwich structure - A composite component featuring a lightweight core material (usually honeycomb, foam or balsa wood) placed between (hence the term "sandwich") two relatively thin, dense, high-strength, functional and/or decorative skins. (Also see core.)

Scrim - Low-cost, woven reinforcing fabric in an open mesh construction.

Sealant - A paste or liquid that, when applied to a joint, hardens in place to form a seal. (caulk, silicone)

Secondary bonding - The joining, by means of adhesive, of two or more already cured composite parts.

Secondary structure - Aerospace structure that is not critical to flight safety. (In contrast to primary structure.)

Separator - A permeable layer that separates and also acts as a release film (e.g., porous, Teflon-coated fiberglass). Placed between lay up and bleeder to facilitate bleeder systems' removal from laminate after cure.

Shear - An action or stress resulting from force (F) applied in a direction parallel to the plane of adhesion between the surfaces of two adjacent components or layers, causing or tending to cause one to slide relative to the other.



Shear strength - The maximum shear stress that a material is capable of sustaining.

Sheet molding compound (SMC) - A ready-to-mold, glass fiber-reinforced polyester material primarily used in compression molding.

Shelf life - Length of time a material can be stored and continue to meet specification requirements, remaining suitable for its intended use. (Also see storage life.)



Shot - One complete cycle on an injection-molding machine.

Shot weight - The measured amount of compound required to completely fill the mold in injection or transfer molding processes.

Silicon carbide fiber - Reinforcing fiber with high strength and modulus; density is equal to that of aluminum. May be formed as wires by chemical vapor deposition onto a carbon-filament core, or as filaments. Used in both organic and metal-matrix composites.

Sizing - A chemical solution used to coat fiber filaments, facilitating operations such as weaving or braiding. Sizing protects the filament from water absorption and abrasion (to minimize fiber wear) and also can be used to bind together and stiffen warp yarns during weaving. Sizing is usually removed and replaced with finish before matrix application. Also called size.

Skin - The relatively dense laminate adhered to the outer surfaces of the core material in a sandwich structure (also called a face sheet)..

Soft tool - Tool made of composites or a similar "soft" material that is vulnerable to damage during use, storage or transportation. (In contrast to hard tool.) ie. Rubber cauls, silicone intensifiers or dams.

Solvent - A liquid capable of dissolving another substance. Certain solvents find application as evaporative diluents in paints or coatings and/or as cleaning solutions in maintenance operations. Isopropyl Alcohol, Acetone, MEK (Methyl Ethyl Ketone)

Spec - Colloquial abbreviation for "specification"; describes the required properties and characteristics a particular material or part must have in order to be acceptable to a potential user.

Specific gravity - The density (mass per unit of volume) of a material divided by the density of water at a standard temperature.



Sprayup - A technique in which continuous strand roving is fed into a chopper gun, which chops the roving into predetermined lengths and sprays the chopped fiber, along with a measured amount of resin and catalyst, onto an open mold.

Stacking sequence - Arrangement of ply orientations and material components in a laminate specified with respect to some reference direction (also see ply schedule).

Staple - Collection of short filaments of spinnable length.

Stiffness - Measure of the resistance of a material to deformation. The ratio of applied stress to resulting strain for a particular material.

Storage life - The length of time a material can be stored and retain specific properties. (Also see shelf life.)

Strain - Deformation resulting from applied stress. Measured as the change in length per unit of length in a given direction; expressed as a percentage or in inches/inch.

Strand- See *tow*.

Stress - Internal resistance to change in size or shape, expressed in units of force (load) per unit area. pounds/sq. inches

Stress concentration - A magnification of applied stress in the region of a notch, void, hole or inclusion.

Stress corrosion - Preferential attack of areas under stress in a corrosive environment that alone would not have caused corrosion.

Stress crack - External or internal cracks in a composite caused by tensile stresses. Cracking may be present internally, externally or in combination.



Structural adhesive - An adhesive used to transfer loads between adhesively bonded surfaces. Epoxies such as 3M Scotchweld.

Structural bond - A bond that joins load-bearing components in an assembly.

Structural Reaction Injection Molding (SRIM) - A closed molding process employing a fiber reinforced preform or mat that is injected with a reactive resin to impregnate the fibers and cure quickly.

Structural repair manual (SRM) - Document prepared by an OEM that designates original structural materials (both composite and metal) used for a specific aircraft. It usually includes schematics for all parts and listings of fastener types and adhesives. It also suggests general repair methodologies and curing parameters (e.g., autoclave requirements) that will maintain structural integrity. Updated periodically by OEMs based on input from repair technicians.

Substrate - Material that provides the surface on which an adhesive-containing substance is applied for any purpose, such as bonding or coating.

Surfacing veil - A reinforcing fabric specifically designed to block out the fiber patterns of underlying reinforcements. It often adds ultraviolet protection to the structure as well. (Also see veil.)

Symmetric laminate - 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. Notation { }s means symmetric

Synthetic fiber - Fiber made of materials other than glass or carbon, such as polyester.



T

Tack - Stickiness of an uncured prepreg.

Tape - Thin, unidirectional prepreg, available in up to 12-inch widths in carbon fiber. (Also see unidirectional. "UD" or "UNI")

Tape laying - An automated fabrication process in which pre-impregnated tape is laid side by side and/or overlapped to form a structure.

Tensile strength - The maximum tensile stress sustained by a test specimen before failure during a tension test.

Tex- A unit of linear density equal to the weight in grams of 1,000m of filament fibers, yarns or strands.

Tg - See *glass-transition temperature*.

Thermal conductivity - The ability to conduct heat.

Thermal stress cracking - Crazing and cracking of some thermoplastic resins from overexposure to elevated temperatures (or rapid cooling).

Thermocouple - Wire assembly used with a control device to sense temperature.

Thermoplastics - A class of plastics that can be repeatedly softened by heating and hardened by cooling through a temperature range characteristic of the plastic, and that in the softened state can be reshaped by means of molding or extrusion.

Thermosets - A class of plastics that, when cured by thermal and/or chemical or other means, become substantially infusible and insoluble. Once cured, a thermoset cannot be returned to the uncured state.



Thixotropic - Describes substances that have high static shear strength and low dynamic shear strength, which results in a predictable, time-dependent loss of viscosity under shear (e.g., when mixed, sprayed or otherwise subjected to force) and subsequent substantial to complete return to the higher at-rest viscosity when shear force is removed. Highly thixotropic resins, for example, may be applied easily with spray equipment, yet immediately afterward resist running on a vertical surface.

Tool - The mold, either one- or two-sided and either open or closed, in or upon which composite material is placed in order to make a part.

Tooling resin - A plastic resin, typically epoxy or silicone, used to make a tool.

Toughness - Measure of the ability of a material to absorb energy.

Tow - Continuous, ordered assembly of essentially parallel, collimated filaments, normally continuous filaments without twist. Same as strand but used when the reference is specific to carbon fiber.

Tow size - Designates the number of filaments in a tow, denoted by a number followed by K, indicating multiplication by 1,000 (for example, 12K tow has 12,000 filaments).

Tracer - A visually different or distinctive fiber, tow, or yarn added to a prepreg to verify fiber alignment or to distinguish warp fibers from fill fibers.

Triaxial fabric - Fabric with three non-interwoven layers - oriented at $+45^\circ$, -45° and either 0° or 90° - which are bonded together, usually by through-the-thickness stitching, to form a single sheet of fabric. (See also biaxial fabric, quadraxial fabric.)

Twist - Measure of the number of turns per unit length that a fiber bundle makes around its axis. "Z"-twist denotes a right-handed twist, while "S"-twist denotes a left-handed twist. "U" is often used to represent no twist and "N" means never twisted.



U

Ultrahigh molecular weight (UHMW) polyethylene - A polyethylene (PE) resin with very high molecular weight and very high abrasion resistance and impact strength.

Unidirectional (UD) - General term denoting orientation of fibers in one direction.

Ultraviolet (UV) cure - The process of curing resins and adhesives with ultraviolet light.



V

Vacuum-bag molding - Molding technique wherein a part layed up on an open mold is cured under a layer of sealed film from which entrapped air has been removed by vacuum. The technique more effectively consolidates the laminate and reduces void content, compared to conventional open molding.

Vacuum-assisted resin transfer molding (VARTM) - An infusion process by which a vacuum draws resin into a one-sided mold; a cover, either rigid or flexible, is placed over the laminate and taped or otherwise fixed to form a vacuum-tight seal. (See previous entry.)

Veil - An ultrathin, nonwoven mat often composed of organic fibers as well as glass fibers and used primarily as a corrosion barrier.

Vinyl esters - A class of thermosetting resins containing ester of acrylic and/or methacrylic acids.

Viscosity - Describes the tendency of a material to resist flow. Viscosity is measured in comparison with water, and computed in centipoise (cps). The higher the number, the greater the resistance to flow.

Void - Any pocket of enclosed gas or air within a composite.

Volatiles - Materials, such as water and alcohol, in a sizing or resin formulation that can be vaporized at ambient or slightly elevated temperatures. (Products produced due to chemical reactions during cure).

Volatile content - The percent of volatiles that are driven off as a vapor from a plastic or an impregnated reinforcement during cure.

Volatile organic compounds (VOCs) - Chemical substances, such as solvents, that readily evaporate or volatilize into the air. Many VOCs also are considered hazardous air pollutants (HAPs) because of potential health concerns.



W

Warp - Fiber bundles in a woven fabric that run parallel to the length of the loom and lengthwise along the longer dimension of the finished fabric.

Warpage - Dimensional distortion in a composite.

Water absorption - Ratio of the weight of water absorbed by a material to the weight of dry material.

Waterjet - High-pressure water stream used for cutting polymer composite parts.

Weave - To interlace fibers in a pattern, often based on a 0°/90° grid; the fabric pattern formed by interlacing yarns. Interlacing patterns vary. In plain weave, for instance, warp and fill fibers alternate to make both fabric faces identical. A satin weave pattern is produced by a warp tow over several fill tows and under one fill tow (e.g., eight-harness satin features one warp tow over seven fill tows and under the eighth).

Weft - See *fill*.

Wet layup - Application of a resin to dry reinforcements in the mold. (Typically done via spray gun or bucket and brush)

Wet winding - A filament winding technique that impregnates fiber strands with resin immediately before they contact the mandrel.

Wetout - Saturation with resin of all voids between reinforcement strands and filaments.

Wetting agent - A surface-active agent that promotes wetting by decreasing a liquid's cohesion.

Whisker - A short, single crystal fiber or filament used as a reinforcement in a matrix.

Wind angle - Measure in degrees between the direction parallel to the filaments and an established reference point.



Winding - Any process in which continuous material is applied under controlled tension to a rotating form (mandrel) in a predetermined geometric relationship to make a structure. (See filament winding.)

Winding pattern - In filament winding, the recurring pattern of the filament path after a certain number of mandrel revolutions.

Wire - Large diameter (greater than about 2 mils) high-performance fiber (e.g., see boron fiber or silicon carbide fiber). In contrast, see filament and fiber.

Wire mesh - Fine wire screen used to dissipate the electrical charge from lighting. (Astro Strike is a brand name we use).

Woof - Same as fill.

Woven roving - Heavy, coarse fabric produced by weaving continuous roving bundles.

Wrinkle - Imperfection in the surface of a laminate that looks like a crease in one of the outer layers. This occurs in vacuum-bag molding when the bag is improperly placed.

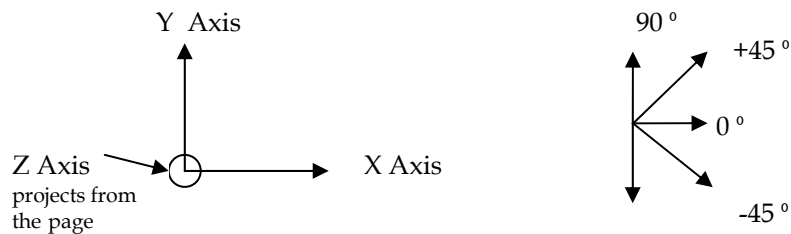
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X

X-axis - Usually, the axis in the plane of the laminate used as 0° reference. Typically, the y-axis is the axis in the plane of the laminate perpendicular to the x-axis, and the z-axis is the reference axis normal to the laminate plane in the composite laminate. (See also laminate coordinate axes, off-axis laminate and principal axis.)



Y

Y-axis - The axis in the plane of a laminate perpendicular to the x-axis.

Yarn - A continuous, ordered assembly of essentially parallel, collimated filaments, usually with a twist.

Yield point - The first stress in a material, less than the maximum rate attainable stress, at which the strain increases at a higher rate than the stress. The point at which permanent deformation of a stressed specimen begins to take place. (Also see stress and strain.)

Yield - The ultimate stress for composites, unlike metals composites tend not to yield prior to ultimate failure.

Young's modulus - Ratio of normal stress to the corresponding strain for tensile or compressive stresses less than a material's proportional limit.

Z

Z-axis - The axis perpendicular to the plane formed by the x and y axes. In a sheet laminate, if the x and y axes are parallel to the length and width, respectively, the z-axis would indicate sheet thickness. (See x-axis and y-axis.)

Zero bleed - Laminate fabrication procedure that does not allow loss of resin during cure.



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