

Glossary of Terms

Ablative Material: A material which absorbs heat (while part of it is being consumed by heat) through a decomposition process (pyrolysis) taking place near the surface exposed to the heat.

Accelerator: A material mixed with a catalyzed resin to speed up the chemical reaction between the catalyst and resin; used in polymerising resins.

Addition Reaction: A polymerisation reaction in which no by-products are formed.

Additive: Any substance added to another, usually to improve properties.

Adherend: A body held to another body by an adhesive.

Adhesion, mechanical: Adhesion between surfaces in which the adhesive holds the parts together by interlocking action.

Adhesive Failure: A rupture of adhesive bond that appears to be a separation at the adhesive/adherend interface.

Adhesive Film: A polymer resin adhesive, usually thermosetting, in the form of a thin dry film of resin, used under heat and pressure as an interleaf in the production of laminated materials or for bonding to core materials.

Ageing: The process or the effect on materials of exposure to an environment for an interval of time.

Air-bubble void: Non-interconnected air entrapment within and between the plies of reinforcement.

Air Locks: Surface depressions on a moulded part, caused by trapped air between the mould surface and the plastic.

Ambient: The surrounding environmental conditions, e.g., pressure or temperature.

Amorphous: Describes polymers that have no order to their molecules, thus no crystalline component.

Anisotropic: Exhibiting different properties in response to stresses applied along axes in different directions.

Anisotropic Laminate: One in which the strength properties are different in different directions.

Aramid: Aromatic polyamide fibres characterised by excellent high temperature, flame-resistance, and electrical properties. Aramid fibres are used to achieve high strength, high

modulus reinforcement in plastic composites. More usually found as polyaramid - a synthetic fibre (trade name Kevlar or Twaron).

Areal Weight: The weight of fibre per unit area (width times length) of tape or fabric.

Ash Content: The solid residue remaining after a reinforcing substance has been incinerated or strongly heated.

Aspect Ratio: The ratio of length to diameter of a fibre.

A Stage: An early stage in the polymerisation reaction of certain thermosetting resins (especially phenolic) in which the material, after application to the reinforcement, is still soluble in certain liquids and is fusible; sometimes referred to as resole. (*See also* B stage, C stage.)

Autoclave: A closed pressure vessel used for curing laminates under pressure and heat.

Autoclave Moulding: After lay-up, the entire assembly is placed in an autoclave. The additional pressure achieves higher fibre to resin ratios and improved removal of air.

Axial Winding: In filament-wound reinforced plastics, a winding with the filaments parallel to the axis.

Back Pressure: Resistance of a material, because of its viscosity, to continued flow when a mould is closing.

Bag Moulding: A technique in which the consolidation of the material in the mould is effected by the application of fluid pressure through a flexible membrane.

Balanced Design: In filament-wound reinforced plastics, a winding pattern so designed that the stresses in all filaments are equal.

Balanced Laminate: All laminate plies, except those at 0°/90°, are placed in plus/minus pairs (not necessarily adjacent) symmetrically about the lay-up centreline. This minimises distortion on demoulding.

Balanced Twist: An arrangement of twist in a plied yarn or cord which will not cause twisting on itself when the yarn or cord is held in the form of an open loop.

Barcol Hardness: A hardness value obtained by measuring the resistance to penetration of a sharp steel point under a spring load. The instrument, the Barcol Impressor, gives a direct reading on a scale of 0 to 100. The hardness value is often used as a measure of the degree of cure of a plastic.

Bare Glass: Glass (yarns, roving or fabrics) from which the sizing or finish has been removed or before it has been applied.

Base: The reinforcing material (glass fibre, paper, cotton, asbestos, etc.) which is impregnated with resin in the forming of laminates.

Bearing Stress: The applied load divided by the bearing area. (Maximum bearing stress is the maximum load sustained by the specimen during the test divided by the original bearing area.)

Bias Fabric: A fabric in which warp and weft fibre are at an angle (usually $\pm 45^\circ$) to the length.

Biaxial Load: A loading condition in which a laminate is stressed in at least two different directions in the plan of the laminate.

Biaxial Winding: In filament winding, a type of winding in which the helical band is laid in sequence, side by side, with no crossover of fibres.

Bidirectional Laminate: A reinforced plastic laminate with the fibres oriented in two directions (usually, but not necessarily, $0/90^\circ$) in the plane of the laminate. (See also Unidirectional laminate.)

Binder: The agent applied to glass mat or preforms to bond the fibres before laminating or moulding.

Bismaleimide: A type of polyimide resin that cures by an addition reaction, avoiding formation of volatiles, and has temperature capabilities between those of epoxy and polyimide.

Bleeder Cloth: A layer of woven or non-woven material, not a part of the composite, that allows excess gas and resin to escape during cure.

Bleedout: The excess liquid resin that migrates to the surface of a laminate in any pressure moulding process.

Blister: Undesirable rounded elevation of the surface of a plastic with boundaries that are more or less sharply defined, resembling in shape a blister on the human skin.

Block Copolymer: An essentially linear copolymer in which there are repeated sequences of polymer segments of different chemical structure some of which may be crystalline in nature, others of which may be amorphous.

Bond Strength: The amount of adhesion between bonded surfaces; a measure of the stress required to separate a layer of material from the base to which it is bonded. (See also Peel strength.)

Boron Fibre: A fibre usually of a tungsten-filament core with elemental boron vapor deposited on it to impart strength and stiffness.

Braiding: A process for assembling fibres into a tubular shape.

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

Bridging: A region of a contoured part which has cured without being properly compacted against the mould.

B Stage: An intermediate stage in the reaction of certain thermosetting resins. The resin in an uncured prepreg or preform is usually in this stage. (See also A stage, C stage.)

Bubble: A spherical internal void; globule of air or other gas trapped in a plastic.

Buckling: Crimping of fibres in a composite material, often occurring in glass-reinforced thermoset due to resin shrinkage during cure.

Bulk Density: The density of a moulding material in loose form (granular, nodular, etc.), expressed as a ratio of weight to volume.

Burst Strength: Hydraulic pressure required to burst a vessel of given thickness; commonly used in testing filament-wound composite structures.

Butt Joint: See Joint.

CAD: Computer-aided design.

CAM: Computer-aided manufacturing.

Carbon-carbon: A composite of carbon fibre in a carbon matrix.

Carbon Fibre: An important reinforcing fibre known for its light weight, high strength, and high stiffness that is produced by pyrolysis of an organic precursor fibre in an inert atmosphere at temperatures above 1800°F (982°C). The material may also be graphitised by heat treating above 3000°F (1649°C).

Catalyst: A substance which changes the rate of a chemical reaction without itself undergoing permanent change in its composition; a substance which markedly speeds up the cure of a compound when added in small quantity compared with the amounts of primary reactants.

Catenary: A measure of the difference in length of the strands in a specified length of roving as a result of unequal tension; the tendency of some strands in a taut horizontal roving to sag lower than the others.

Caul Plate: A sheet the size of the platens used in hot pressing, or other pressure moulding processes.

Centrifugal Casting: A high production technique for cylindrical composites, such as pipe, in which chopped fibre and resin is positioned inside a hollow mandrel designed to be heated and rotated as resin is added and cured.

Ceramic Matrix Composites: Materials consisting of a ceramic or carbon fibre surrounded by a ceramic matrix, usually silicon carbide.

Charge: The measurement or weight of material (liquid, preformed, or powder) used to load a mould at one time or during one cycle.

Chemical Vapour Deposition (CVD): A process in which desired reinforcement material is deposited from vapour phase onto a continuous core; boron or tungsten, for example.

Chill: (1) To cool a mould by circulating water through it. (2) To cool a moulding with an air blast or by immersing it in water.

Circuit: In filament winding (1) one complete traverse of the fibre-feed mechanism of a winding machine; (2) one complete traverse of a winding band from one arbitrary point along the winding path to another point on a plane through the starting point and perpendicular to the axis.

Circumferential ("circ") Winding: In filament-wound reinforced plastics a winding with the filaments essentially perpendicular to the axis.

Clamping Pressure: In injection moulding and transfer moulding the pressure applied to the mould to keep it closed, in opposition to the fluid pressure of the compressed moulding material.

Co-curing: Simultaneous bonding and curing of components, or dissimilar materials.

Coefficient of Elasticity: The reciprocal of Young's modulus in a tension test.

Coefficient of Expansion: The fractional change in dimension of a material for a unit change in temperature. Also called *coefficient of thermal expansion*.

Coefficient of Friction: A measure of the resistance to sliding of one surface in contact with another surface.

Coefficient of Thermal Expansion: The change in length per unit length produced by a unit rise in temperature.

Cohesion: (1) The propensity of a single substance to adhere to itself. (2) The internal attraction of molecular particles toward each other. (3) The force holding a single substance together.

Cohesive Failure: Failure of a bonded joint within the adhesive itself.

Cold-setting Adhesive: A synthetic resin adhesive capable of hardening at normal room temperature in the presence of a hardener.

Co-mingled Yarn: A hybrid yarn made with two types of materials intermingled in a single yarn, for example, thermoplastic filaments intermingled with carbon filaments to form a single yarn.

Composite: A homogeneous material created by synthetic assembly of two or more materials (a selected filler or reinforcing elements and compatible matrix binder) to obtain specific characteristics and properties. Composites are subdivided into the following classes on the basis of the form of the structural constituents; *fibrous*: the dispersed phase consists of fibres; *flake*: the dispersed phase consists of flat flakes, *laminar*: composed of layer of laminate constituents; *particulate*: dispersed phase consists of small particles, *skeletal*: composed of a continuous skeletal matrix filled by a second material.

Compression Moulding: A technique for moulding thermoset plastics in which a part is shaped by placing the fibre and resin into an open mould cavity, closing the mould, and applying heat and pressure until the material has cured or achieved its final form.

Compression Moulding Pressure: The pressure applied to the moulding material in the mould.

Compressive Modulus E_c : Ratio of compressive stress to compressive strain below the proportional limit. Theoretically equal to Young's modulus determined from tensile experiments.

Compressive Strength: (1) The ability of a material to resist a force that tends to crush. (2) The crushing load at the failure of a specimen divided by the original sectional area of the specimen.

Compressive Stress: The compressive load per unit area of original cross section carried by the specimen during the compression test.

Condensation Reaction: A polymerisation reaction in which simple by-products (for example, water) are formed.

Consolidation: A processing step that compresses fibre and matrix to reduce voids and achieve a desired density.

Contact Moulding: A process for moulding reinforced plastics in which reinforcement and resin are placed on an open mould, cure is at room temperature using a catalyst-promotor system or by heat in an oven, and no additional pressure is used.

Continuous Filament: An individual flexible fibre of glass of small diameter and great or indefinite length.

Continuous-filament Yarn: Yarn formed by twisting two or more continuous filaments into a single continuous strand.

Continuous Roving: Parallel filaments coated with sizing, gathered together into single or multiple strands, and wound into a cylindrical package. It may be used to provide continuous reinforcement in woven roving, filament winding, pultrusion, prepregs, or high strength moulding compounds, or it may be used chopped.

Cooling Fixture: A fixture used to maintain the shape or dimensional accuracy of a moulding after it is removed from the mould and until the material is cool enough to hold its shape.

Core: (1) The central member of a sandwich construction to which the faces of the sandwich are attached. (2) A channel in a mould for circulation of heat-transfer media.

Count: (1) For fabric the number of warp and weft yarns per cm in woven cloth. (2) For yarn the size based on relation of length and weight. Basic unit is a *tex* which is the weight in grammes of 1000 linear metres of the fibre.

Coupling Agent: Any chemical substance designed to react with both the reinforcement and matrix phases of a composite material to form or promote a stronger bond at the interface; a bonding link.

Cowoven Fabric: A reinforcement fabric woven with two different types of fibres in individual yarns, for example, thermoplastic fibres woven side by side with carbon fibres.

Crazing: Fine cracks which may extend in a network on or under the surface of a plastic material.

Creel: A device for holding the required number of fibre bobbins in the desired position for unwinding.

Creep: The change in dimension of a plastic under load over a period of time not including the initial instantaneous elastic deformation; at room temperature it is called *cold flow*.

Crimp: The waviness of a fibre, particularly in a woven fabric.

Critical Length: The minimum length or a fibre necessary for matrix shear loading to develop fibre ultimate strength by a matrix.

Critical strain: The strain at the yield point.

Crosswise direction: Refers to cutting specimens and to application of load. For rods and tubes, crosswise is the direction perpendicular to the long axis. For other shapes or materials that are stronger in one direction than

in another, crosswise is the direction that is weaker. For materials that are equally strong in both directions, crosswise is an arbitrarily designed direction at right angles to the length.

Crystallinity: The quality of having a molecular structure with atoms arranged in an orderly, three-dimensional pattern.

C Stage: The final stage in the reaction of certain thermosetting resins in which the material is relatively insoluble and infusible. The resin in a fully cured thermoset moulding is in this stage. (*See also* A stage, B stage.)

Cure: To change the properties of a resin by chemical reaction, which may be condensation or addition; usually accomplished by the action of heat or catalyst, or both, and with or without pressure.

Curing Agent: Hardener, a catalytic or reactive agent added to a resin to cause polymerisation. Curing agents participate in the polymerisation process. They may be latent - curable only at elevated temperatures - or they may be activated at room temperature (25°C).

Curing Temperature: Temperature at which a cast, moulded, or extruded product, a resin impregnated reinforcement, an adhesive, etc., is subjected to curing.

Curing Time: The length of time a part is subjected to heat or pressure, or both, to cure the resin. (Further cure may take place after removal of the assembly from the conditions of heat or pressure.)

Cycle: The complete, repeating sequence of operations in a process or part of a process. In moulding, the cycle time is the elapsed time between a certain point in one cycle and the same point in the next.

D glass: A high-boron-content glass made especially for laminates requiring precisely controlled dielectric constant.

Damage Tolerance: A measure of the ability of structures to retain load carrying capability after exposure to sudden loads (for example, ballistic impact).

Damping (Mechanical): Mechanical damping gives the amount of energy dissipated as heat during the deformation of a material. Perfectly elastic materials have no mechanical damping. Damping also diminishes the intensity of vibrations.

Daylight: The distance in the open position between the moving and fixed tables (platens) of a hydraulic press. For a multidaylight press, daylight is the distance between adjacent platens.

Debond: An unplanned nonadhered or unbonded region in an assembly.

Deflection Temperature Under Load: The temperature at which a simple beam has deflected a given amount under load (formerly called *heat-distortion temperature*).

Deformation Under Load: The dimensional change of a material under load for a specific time following the instantaneous elastic deformation caused by the initial application of the load; also called *cold flow* or *creep*.

Delaminate: To split a laminated plastic material along the plane of its layers. (See also *Laminate*.)

Delamination: Physical separation or loss of bond between laminate plies.

Denier: A yarn and filament numbering system in which the yarn number is equal numerically to the weight in grams of 30,000 ft (9144 m) (used for continuous filaments). The lower the denier the finer the yarn.

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 success with 95% statistical confidence. B-basis allowable: material property exceeds the design allowable 90 times out of 100. A-basis allowable: material property exceeds the design allowable 99 times out of 100.

Dielectric: A nonconductor of electricity.

Dielectric Constant: (1) The ratio of the capacity of a capacitor having a dielectric material between the plates to that of the same capacitor when the dielectric is replaced by a vacuum. (2) A measure of the electrical charge stored per unit volume at unit potential.

Dimensional stability: Ability of a plastic part to retain the precise shape to which it was moulded, cast, or otherwise fabricated.

Displacement Angle: In filament winding the distance of advance of the winding ribbon on the equator after one complete circuit.

Doctor roll: A device for regulating the amount of liquid material on the rollers of a spreader; also called *doctor bar* or *doctor blade*.

Doily: In filament winding the planar reinforcement applied to a local area between windings to provide extra strength in an area where a cutout is to be made, e.g., port openings.

Dome: In filament winding the portion of a cylindrical container that forms the integral ends of the container.

Doubler: Localised area of extra layers of reinforcement, usually to provide stiffness or strength for fastening or other abrupt load transfers.

Draft: The taper or slope of the vertical surfaces of a mould designed to facilitate removal of moulded parts.

Draft Angle: The angle between the tangent to the surface at that point and the direction of ejection.

Drape: The ability of preimpregnated broad goods or dry fabrics to conform to an irregular 3-D shape; textile conformity.

Dry Winding: Filament winding using preimpregnated roving, as differentiated from wet winding. (See also *Wet winding*.)

Dry Lay-up: Construction of a laminate by layering preimpregnated reinforcement in a female or male mould, usually followed by bag moulding or autoclave moulding.

DSC: Differential scanning calorimeter. Instrumentation for measuring chemical reactions by observing exothermic or endothermic (heat output or heat input) reactions of materials - usually over a programmed temperature cycle.

Dwell: (1) A pause in the application of pressure to a mould, made just before the mould is completely closed, to allow gas to escape from the moulding material. (2) In filament winding the time the traverse mechanism is stationary while the mandrel continues to rotate to the appropriate point for the traverse to begin a new pass. (3) A pause in the temperature rise of a cure cycle, where the part being cured is held at a constant temperature for a period.

Edgewise: Refers to the application of load. The load is applied edgewise when it is applied to the edge of the original sheet or specimen.

E Glass: A borosilicate glass; the type most used for glass fibres for reinforced plastics; suitable for electrical laminates because of its high resistivity. (Also called *electric glass*.)

Ejection: Removal of a moulding from the mould impression by mechanical means, by hand, or by using compressed air.

Elastic Deformation: The part of the total strain in a stressed body which disappears upon removal of the stress.

Elasticity: The property of plastics materials by virtue of which they tend to recover their original size and shape after deformation.

Elastic Limit: The greatest stress which a material is capable of sustaining without permanent strain remaining upon the complete release of the stress. A material is said to have passed its elastic limit when the load is sufficient to initiate plastic (nonrecoverable) deformation.

Elastic Recovery: The fraction of a given deformation that behaves elastically.

Elastic recovery = $\frac{\text{elastic extension}}{\text{total extension}}$

Electroformed Moulds: A mould made by electroplating metal on the face of a mould.

Elongation: Deformation caused by stretching; the fractional increase in length of a material stressed in tension. (When expressed as percentage of the original gauge length, it is called *percentage elongation*.)

End: A strand of roving consisting of a given number of filaments gathered together (the group of filaments is considered an *end* or *strand* before twisting and a *yarn* after twist has been applied): an individual warp yarn, thread, fibre, or roving.

Even Tension: The process whereby each end of roving is kept in the same degree of tension as the other ends.

Exotherm: The liberation or evolution of heat during curing of a plastic product.

Fabric: A material constructed of interlaced yarns, fibres, or filaments, usually planar.

Fabric, nonwoven: A material formed from fibres or yarns without interlacing.

Fabric, woven: A material constructed of interlaced yarns, fibres, or filaments.

Fabricating, fabrication: The manufacture of plastic products from moulded parts, rods, tubes, sheeting, extrusions, or other form by appropriate operations such as punching, cutting, drilling, and tapping. Fabrication includes fastening plastic parts together or to other parts by mechanical devices, adhesives, heat sealing, or other means.

Fatigue: The failure or decay of mechanical properties after repeated applications of stress. (Fatigue tests give information on the ability of a material to resist the development of cracks, which eventually bring about failure as a result of a large number of cycles.)

Fatigue Life: The number of cycles of deformation required to bring about failure of the test specimen under given set of oscillating conditions (pressure/load).

Fatigue Limit: The stress below which a material can be stressed cyclically for an infinite number of times without failure.

Fatigue Strength: (1) The maximum cyclic stress a material can withstand for a given number of cycles before failure occurs. (2) The residual strength after being subjected to fatigue.

Felt: A fibrous material made from interlocked fibres by mechanical or chemical action, mois-

ture, or heat; made from asbestos, cotton, glass, etc.

Fibre-composite Material: A material consisting of two or more discrete physical phases, in which a fibrous phase is dispersed in a continuous matrix phase. The fibrous phase may be macro-, micro-, or submicroscopic, but must retain its physical identity so that it can be removed from the matrix intact.

Fibre Glass: An individual filament made by extruding fibres from molten glass.

Fibre Diameter: The measurement of the diameter of individual filaments.

Fibre-matrix Interface: The region separating the fibre and matrix phases, which differs from them chemically, physically, and mechanically. In most composite materials, the interface has a finite thickness (nanometers to thousands of nanometers) because of diffusion or chemical reactions between the fibre and matrix. Thus, the interface can be more properly described by the terms *interphase* or *interfacial zone*.

Fibre Pattern: (1) Visible fibres on the surface of laminates or mouldings. (2) The thread size and weave of fabrics.

Fibre Placement: A continuous process for fabricating composite shapes with complex contours and/or cutouts by means of a device that lays preimpregnated fibres (in tow form) onto a non-uniform mandrel or tool. It differs from filament winding (below) in several ways: there is no limit on fibre angles; compaction takes place online via heat, pressure, or both; and fibres can be added and dropped as necessary. The process produces more complex shapes and permits a faster shutdown rate than filament winding.

Filament: Any fibre whose aspect ratio (length to effective diameter) is for all practical purposes infinity, i.e., a continuous fibre.

Filament Winding: A process for fabricating a composite structure in which continuous reinforcements (filament, wire, yarn, tape, or other) impregnated with a matrix material either previously or during the winding are placed over a rotating removable form or mandrel in a prescribed way to meet certain stress conditions. When the right number of layers has been applied, the wound form is cured and the mandrel removed.

Fill: (Also known as weft). Yarn oriented at right angles to the warp in a woven fabric.

Filler: A relatively inert material added to a plastic mixture to reduce cost, modify mechanical properties, serve as a base for colour effects, or improve the surface texture.

Fillet: A radiused joint of adhesive between two surfaces being bonded.

Filling Yarn: The transverse threads or fibres in a woven fabric, i.e., fibres running perpendicular to the warp; also called *weft*.

Film Adhesive: A synthetic resin adhesive in the form of a thin dry film of resin with or without a carrier.

Finish: A material applied to the surface of fibres in a fabric used to reinforce plastics, and intended to improve the physical properties of the reinforced plastics over those obtained using reinforcement without finish. Not to be confused with "size" (q.v.).

Flame Resistance: Ability of a material to not support flame once source of heat is removed.

Flame Retardants: Chemicals used to reduce or eliminate the tendency of a resin to burn.

Flame-retarded Resin: A resin compounded with certain chemicals to reduce or eliminate its tendency to burn.

Flammability: A measure of the extent to which a material will support combustion.

Flatwise: Refers to cutting specimens and the application of load. The load is applied flatwise when it is applied perpendicular to the flat face of the original sheet or specimen.

Flexural Modulus: The ratio, within the elastic limit, of the applied stress on a test specimen in flexure to the corresponding strain in the outermost fibres of the specimen.

Flexural Rigidity: (1) For fibres this is a measure of the rigidity of individual strands or fibres; the force couple required to bend a specimen to unit radius of curvature. (2) For plates the measure of rigidity is $D = EI$, where E is the modulus of elasticity and I is the moment of inertia.

Flexural Strength: (1) The resistance of a material to breakage by bending stresses. (2) The strength of a material in bending expressed as the tensile stress of the outermost fibres of a bent test sample at the instant of failure. For plastics this value is usually higher than the straight tensile strength. (3) The unit resistance to the maximum load before failure by bending.

Flow: The movement of resin under pressure, allowing it to fill all parts of a mould.

Foamed Plastics: Resins in sponge form; may be flexible or rigid; cells may be closed or interconnected.

Fracture Toughness: A measure of the damage tolerance of a material containing initial flaws or cracks.

FRP: Fibrous reinforced plastic, any type of plastic-reinforced cloth, mat, strands, or any other form of fibrous material.

FVF: Fibre Volume Fraction. The ratio of the volume of fibre in a laminate to the total volume of fibre and resin.

FWF: Fibre Weight Fraction. The ratio of the weight of fibre in a laminate to the total weight of fibre and resin.

Gauge Length: Length over which deformation is measured.

Gap: In filament winding the space between successive windings, which are usually intended to lie next to each other.

Gel: The initial jellylike solid phase that develops during the formation of a cured resin from a liquid.

Gel Time: For thermosetting resins the time between introduction of a catalyst or hardener into a resin and gel formation.

Gelcoat: A filled resin applied to the surface of a mould before lay-up. (The gelcoat becomes an integral part of the finished laminate and is usually used to improve surface appearance, etc.)

Glass Filament: A form of glass that has been drawn to a small diameter and extreme length. Most filaments are less than 0.005 in (130 microns) in diameter.

Glass Finish: A material applied to the surface of a glass reinforcement to improve its effect upon the physical properties of the reinforced plastic.

Glass Flake: Thin, irregularly shaped flakes of glass typically made by shattering a continuous thin-walled tube of glass.

Glass Transition: The reversible change in an amorphous polymer or in amorphous regions of a partially crystalline polymer from (or to) a viscous or rubbery condition to (or from) a hard and relatively brittle state. The glass transition generally occurs over a relatively narrow temperature region and is similar to the solidification of a liquid to a glassy state; it is not a phase transition. The *glass transition temperature* is the approximate midpoint of the temperature range over which glass transition takes place. See extra notes in Formulated Products Article.

Glass-transition Temperature Tg: The 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.

Greige: Fabric before finishing; yarn or fibre before bleaching or dyeing. Also called *grey goods*, *greige goods*, *greige grey*.

Hand: The softness of a piece of fabric, as determined by the touch (individual judgement).

Hand Lay-up: The process of placing (and working) successive plies of reinforcing material or resin-impregnated reinforcement in position on a mould by hand, then cured to the formed shape.

Hardener: A substance or mixture added to a plastic composition to promote or control the curing action by taking part in it.

Hardness: The resistance to surface indentation, usually measured by the depth of penetration (or arbitrary units related to depth of penetration) of a blunt point under a given load using a particular instrument according to a prescribed procedure. (e.g. Barcol hardness, Rockwell hardness number.)

Heat-distortion Temperature: Temperature at which a test bar deflects a certain amount under specified temperature and a stated load.

Heat Resistance: The property or ability of plastics and elastomers to resist the deteriorating effects of elevated temperatures.

HM: High-modulus. Often applied to carbon fibres having a tensile modulus >350 GPa.

Honeycomb: Manufactured product of resin-impregnated sheet material (paper, glass fabric, etc.) or sheetmetal formed into hexagonal-shaped cells; used as a core material in sandwich construction.

Hoop Stress: The circumferential stress in a material of cylindrical form subjected to internal or external pressure.

Hybrid Fabric: Two or more reinforcing fibres in a fabric, such as aramid and glass, or carbon and aramid.

Hydraulic Press: A press in which the moulding force is created by the pressure exerted on a fluid.

Hydrophilic: Capable of absorbing water.

Hydrophobic: Capable of repelling water.

Hygroscopic: Capable of absorbing and retaining atmospheric moisture.

IM: Intermediate-modulus often applied to carbon fibres having a tensile modulus of approximately 300 GPa.

Impact Strength: The ability of a material to withstand shock loading; the work done in fracturing a test specimen in a specified manner under shock loading.

Impregnate: In reinforced plastics, to saturate the reinforcement with a resin.

Impregnated Fabric: A fabric impregnated with a synthetic resin. (See also Prepreg.)

Inert filler: A material added to a plastic to alter its properties through physical rather than chemical means.

Inhibitor: A substance which retards a chemical reaction; used in certain types of monomers and resins to prolong storage life.

Injection Moulding: A technique developed for processing thermoplastics which are heated and forced under pressure into closed moulds and cooled.

Instron: A make of mechanical testing instrument used to determine the tensile and compressive properties of materials.

Insulating Resistance: The electric resistance between two conductors or systems of conductors separated only by insulating material.

Interface: The junction point or surface between two different media; on fibres, the contact area between the fibre and sizing or finish; in a laminate, the contact area between the reinforcement and the laminating resin.

Interlaminar: Existing or occurring between two or more adjacent laminae.

Interlaminar Shear: The shearing force tending to produce displacement between two laminae along the plane of their interface; usually the weakest element of a composite.

Interlaminar Shear Strength: The maximum shear stress existing between layers of a laminated material.

Internal Stress: Stress created within a laminate due to different rates of contraction or expansion of the fibres and resin system.

Isotropic Laminates: One in which the strength properties are equal in all directions.

Izod Impact Test: A destructive test designed to determine the resistance of a plastic to the impact of a suddenly applied force.

Joint: The location at which two adherends are held together with a layer of adhesive. *Butt joint:* the edge faces of the two adherends are at right angles to the other faces of the adherends. *Scarf joint:* a joint made by cutting away similar angular segments of two adherends and bonding them with the cut areas fitted together. *Lap joint:* a joint made by placing one adherend partly over another and bonding together the overlapped portions.

Laminate: A composite material consisting of one or more layers of fibre impregnated with a resin system and cured, sometimes with heat and pressure.

Laminate Ply: One layer of a product which is itself produced from by two or more layers of materials.

Lap: In filament winding the amount of overlap between successive windings, usually intended to minimise gapping.

Lap Joint: See joint.

Lay: (1) In glass fibre the spacing of the roving bands on the roving package expressed in the number of bands per inch. (2) In filament winding the orientation of the ribbon with some reference, usually the axis of rotation.

Lay-up: (1) As used in reinforced plastics, the reinforcing material placed in position in the mould. (2) The process of placing the reinforcing material in position in the mould. (3) The resin-impregnated reinforcement. (4) The component materials, geometry, etc., of a laminate.

Lengthwise Direction: Refers to cutting specimens and the application of loads. For rods and tubes, lengthwise is the direction of the long axis. For other shapes of materials that are stronger in one direction than in the other lengthwise is the direction that is stronger. For materials that are equally strong in both directions lengthwise is an arbitrarily designated direction that may be with the grain, direction of flow in manufacture, longer direction, etc. (See also Crosswise direction.)

Liner: In a filament-wound pressure vessel the continuous, usually flexible, coating on the inside surface of the vessel used to protect the laminate from chemical attack or to prevent leakage under stress.

Liquid-crystal Polymers: A newer type of thermoplastic, melt processible, with high orientation in moulding, improved tensile strength, and high-temperature capability.

Load-deflection Curve: A curve in which increasing loads are plotted on the y-axis and the deflections caused by those loads are plotted on the x-axis.

Loss on Ignition: Weight loss, usually expressed as percent total, after burning off an organic sizing from glass fibres or an organic resin from a glass-fibre laminate.

Mandrel: (1) An internal mould for hollow components. (2) In filament winding, the core around which resin-impregnated fibre is wound to form pipes, tubes, or vessels.

Mat: A fibrous material for reinforced plastic consisting of randomly oriented chopped filaments with a binder, available in sheets of various widths, weights, and lengths.

Matched Metal Moulding: A reinforced-plastic manufacturing process in which matching

male and female metal moulds are used (similar to compression moulding) to form the part.

Matrix: See Resin

Mechanical Adhesion: Adhesion between surfaces in which the adhesive holds the parts together by interlocking action.

Metallic Fibre: Manufactured fibre composed of metal, plastic-coated metal, metal-coated plastic, or a core completely covered by metal.

Micron: A unit of length replaced by the micrometer (μm); $1\mu\text{m} = 10^{-6} \text{ m} = 10^{-3} \text{ mm} = 0.00003937 \text{ in} = 39.4\mu\text{in}$.

Mil: 1 mil = 0.001 in.

Milled Fibres: Continuous glass strands hammer-milled into small modules of filamentised glass. Useful as anticrazing reinforcing fillers for adhesives.

MMC: Metal-matrix composite; material in which continuous carbon, silicon carbide, or ceramic fibres are embedded in a metallic matrix.

Modulus: A number which expresses a measure of some property of a material, e.g., modulus of elasticity, shear modulus, etc. Using "modulus" alone without modifying terms is confusing and should be avoided.

Modulus in Compression: See Compressive modulus.

Modulus in Flexure: See Flexural modulus.

Modulus, Initial, or Young's Modulus: See Modulus of elasticity.

Modulus in Shear: See Shear modulus.

Modulus in Tension: See Tensile modulus.

Modulus of Elasticity: The ratio of the stress or applied load to the strain or deformation produced in a material that is elastically deformed. Also called *Young's modulus*.

Modulus of Elasticity in Torsion: The ratio of the torsion stress to the strain in the material over the range for which this value is constant.

Modulus of Rigidity: See Flexural rigidity.

Modulus of Rupture: See Flexural strength.

Mohs Hardness: A measure of the scratch resistance of a material; the higher the number the greater the scratch resistance (diamond is 10).

Mould: The cavity in or on which the moulding material is placed and from which it takes form.

Mould-release Agent: A liquid or powder used to prevent sticking of moulded articles in the mould. Often a wax or silicon-based coating.

Moulding Shrinkage: The immediate shrinkage which a moulded part undergoes when it is removed from a mould and cooled to room temperature.

Moulding: The shaping of a moulding material in or on a mould. Sometimes used to denote the finished part.

Moulding Cycle: The time required for the complete sequence of operations on a moulding to produce one set of mouldings.

Monomer: (1) A simple molecule capable of reacting with like or unlike molecules to form a polymer. (2) The smallest repeating structure of a polymer, also called a *mer*.

Multicircuit Winding: In filament winding a winding that requires more than one circuit before the band repeats by lying adjacent to the first band.

Multifilament Yarn: A multitude of fine, continuous filaments (often 5 to 100), usually with some twist in the yarn to facilitate handling. Sizes range from 5 to 10 denier up to a few hundred denier. Individual filaments in a multifilament yarn are usually about 1 to 5 denier.

Nesting: In reinforced plastics placing plies of fabric so that the yarns of one ply lie in the valleys between the yarns of the adjacent ply (nested cloth).

NDI (Non Destructive Inspection): A process or procedure for determining material or part characteristics without permanently altering the test subject. Nondestructive testing (NDT) is broadly considered synonymous with NDI.

Nonwoven Fabric: Fabric produced by loosely bonding together yarns, rovings, etc.

Notch Sensitivity: Extent to which the sensitivity of a material to fracture is increased by the presence of a surface inhomogeneity such as a notch, a sudden change in section, a crack, or a scratch. Low notch sensitivity is usually associated with ductile materials and high notch sensitivity with brittle materials.

Novolac: A phenolic-aldehyde resin which remains permanently thermoplastic unless a source of methylene groups is added; a linear thermoplastic B-staged resin.

Offset Yield Strength: The stress at which the strain exceeds by a specific amount (the offset) an extension of the initial proportional portion of the stress-strain curve.

Orange Peel: An uneven surface of a coating resembling that of orange peel.

Organic: Designating or composed of matter originating in plant or animal life or com-

posed of chemicals of hydrocarbon origin, natural or synthetic.

Orthotropic: Having three mutually perpendicular planes of elastic symmetry.

Out-life: The period of time a prepreg material remains in a handleable form and with properties intact outside of the specified storage environment; for example, out of the freezer in the case of thermoset prepreps.

Overlap: A simple adhesive joint, in which the surface of one adherend extends past the leading edge of another.

PAN: Polyacrylonitrile. The precursor for most carbon fibres.

Parallel-laminated: Laminated so that all the layers of material are oriented approximately parallel with respect to the grain or strongest direction in tension.

Peel Ply: A tightly woven polyester or nylon fabric which is applied to the outside layer of a laminate. This is removed or sacrificed to achieve improved bonding of additional plies and leaves a clean, resin-rich surface ready for bonding.

Peel Strength: Bond strength, obtained by peeling apart layers. (See also Bond strength.)

Permanent Set: The deformation remaining after a specimen has been stressed in tension a prescribed amount for a definite period and released for a definite period.

Phenolic, Phenolic Resin: A synthetic resin produced by the condensation of an aromatic alcohol with an aldehyde, particularly of phenol with formaldehyde. (See also A stage, B stage, C stage, Novolac.) Phenolics have particularly good fire-resistance properties.

Pick: An individual filling yarn, running the width of a woven fabric at right angles to the warp, also called *fill*, *woof*, *weft*.

Pinhole: A tiny hole in the surface of, or through a coating material.

Pit: Small regular or irregular crater in the surface of a moulding, usually with width about the same order of magnitude as the depth.

Pitch: A residual petroleum product used in the manufacture of certain carbon fibres.

Planar Helix Winding: A winding in which the filament path on each dome lies on a plane which intersects the dome while a helical path over the cylindrical section is connected to the dome paths.

Planar Winding: A winding in which the filament path lies on a plane intersecting the winding surface.

Plastic: A material that contains as an essential ingredient an organic substance of high molecular weight, is solid in its finished state and at some stage in its manufacture or processing into finished articles can be shaped by flow; made of plastic. A *rigid plastic* is one with a stiffness or apparent modulus of elasticity greater than 690 MPa at 23°C. A *semirigid plastic* has a stiffness or apparent modulus of elasticity between 69 and 690 MPa at 23°C.

Plastic Deformation: Change in dimensions of an object under load that is not recovered when the load is removed; opposite of elastic deformation. See also Elastic recovery.

Platens: The mounting plates of a press, to which the entire mould assembly is bolted.

Plied Yarn: A yarn formed by twisting together two or more single yarns in one operation.

Ply: One of the layers that make up a stack or laminate.

PMR-15: A type of Polyimide resin.

Poisson's Ratio n: A constant relating to change in cross-sectional area to change in length when a material is stretched; $n = 1/2$ for rubbery materials, $1/4$ to $1/2$ for crystals and glasses.

Polyacrylonitrile (PAN): A product used as a base material in the manufacture of certain carbon fibres.

Polyamide: A polymer in which the structural units are linked by amide or thioamide groups; many polyamides are fibre-forming.

Polyesters: Thermosetting resins produced by dissolving unsaturated, generally linear alkyd resins in a vinyl active monomer, e.g., styrene, methyl styrene, or diallyl phthalate.

Polyimide: A polymer produced by heating polyamic acid; a highly heat-resistant resin [$> 600^\circ\text{F}$ ($> 316^\circ\text{C}$)] suitable for use as a laminating resin or an adhesive.

Polymer: A high-molecular-weight organic compound, natural or synthetic, whose structure can be represented by a repeated small unit (mer), e.g., polyethylene, rubber, cellulose. Synthetic polymers are formed by addition or condensation polymerisation of monomers.

Polymerisation: A chemical reaction in which the molecules of a monomer are linked together to form large molecules whose molecular weight is a multiple of that of the original substance. When two or more monomers are involved, the process is called *copolymerisation* or *heteropolymerisation*.

Polymerise: To unite molecules of the same kind into a compound having the elements in the same proportion but possessing much

higher molecular weight and different physical properties.

Postcure: Additional elevated-temperature cure, usually without pressure, to improve final properties and/or complete the cure. Complete cure and ultimate mechanical properties of certain resins are attained only by exposure of the cured resin to temperatures higher than those of initial curing.

Pot Life: The length of time a quantity of catalysed resin system in a container remains liquid prior to gelation, also called *working life*.

PPS: Polyphenylene sulfide.

Precure: The full or partial setting of a synthetic resin or adhesive in a joint before the clamping operation is complete or before pressure is applied.

Precursor: For carbon fibres, the rayon, PAN, or pitch fibres from which carbon fibres are made.

Preform: A preshaped fibrous reinforcement of mat or cloth formed to the desired shape on a mandrel or mock-up before being placed in a mould press, or RTM tool.

Preform Binder: A resin applied to the chopped strands of a preform, usually during its formation, and cured so that the preform will retain its shape and be handleable.

Preimpregnation: The practice of mixing resin and reinforcement and effecting partial cure before use or shipment to the user. (See also Prepreg.)

Prepreg: Ready-to-mould material in rolled-sheet form, which may be cloth, mat or fibres impregnated with resin and stored for use. The resin is partially cured to a soft and slightly sticky B stage and supplied to the fabricator, who lays up the finished shape and completes the cure with heat and pressure.

Pressure: Force measured per unit area.

Pressure-bag Moulding: A process for moulding reinforced plastics, in which a tailored flexible bag is placed over the contact lay-up on the mould, sealed, and clamped in place. Fluid pressure, usually compressed air, is exerted on the bag, and the part is cured.

Primary Structure: The main structure.

Primer: A coating applied to a surface before the application of an adhesive or lacquer, enamel, or the like to improve the performance of the bond.

Promoter: See Accelerator.

Proportional Limit: The greatest stress which a material is capable of sustaining without deviation from proportionality of stress and strain (Hooke's Law); it is expressed in force per unit area.

Pultrusion: Reversed extrusion of resin-impregnated roving in the manufacture of rods, tubes, and structural shapes of a permanent cross section. After passing through the resin dip tank the roving is drawn through a die to form the desired cross section.

Quasi-isotropic: Approximating isotropy by orientation of plies in several directions.

Ramping: A gradual, programmed increase/decrease in temperature or pressure, during the cure cycle of composite parts.

Reinforced Plastic: A plastic with strength properties greatly superior to those of the base resin, resulting from the presence of reinforcements embedded in the composition.

Reinforcement: A strong inert material bonded into a plastic to improve its strength, stiffness, and impact resistance. To be effective, the reinforcing material must form a strong adhesive bond with the resin.

Release Agent: A material which is applied in a thin film to the surface of a mould to keep the resin from bonding to it. *See also* Mould Release.

Release Film: A thin plastic film applied on top of a laminate stack before it is cured. It is usually perforated, allowing excess resin to flow out and be absorbed by a bleeder cloth.

Resilience: (1) The ratio of energy returned on recovery from deformation to the work input required to produce the deformation (usually expressed as a percentage). (2) The ability to regain an original shape quickly after being strained or distorted.

Resin: A solid, semisolid, or pseudo-solid organic material which has an indefinite (often high) molecular weight, exhibits a tendency to flow when subjected to stress, usually has a softening or melting range. Most resins are polymers. In reinforced plastics the material used to bind together the reinforcement material, the matrix. *See also* Polymer.

Resin Content: The amount of resin in a laminate expressed as a percentage of total weight.

Resin-rich Area: Space which is filled with resin and lacking reinforcing material.

Resin-starved Area: Area of insufficient resin, usually identified by low gloss, dry spots, or fibre show.

RIFT: Resin Infusion under Flexible Tooling.

Ribbon: A fibre having essentially a rectangular cross section, where the width-to-thickness ratio is at least 4:1.

RIM: Reaction-injection moulding.

Rockwell Hardness Number: A value derived from the increase in depth of an impression as the load on an indenter is increased from a fixed minimum value to a higher value and then returned to the minimum value.

Room Temperature-curing Adhesives: Adhesives that set (to handling strength) at 20 to 30°C and later reach full strength without heating.

Roving: A loose assembly of continuous filaments of glass fibre substantially without twist.

RRIM: Reinforced reaction-injection moulding.

RTM: Resin-transfer moulding. A moulding process in which catalysed resin is transferred into an enclosed mould into which the fibre reinforcement has been placed; cure normally is accomplished without external heat, RTM combines relatively low tooling and equipment costs with the ability to mould large structural parts.

S Glass: A magnesia-alumina-silicate glass, especially designed to provide filaments with very high tensile strength.

Sandwich Constructions: Panels composed of a lightweight core material (honeycomb, foamed plastic, etc.) to which two relatively thin, dense, high-strength faces or skins are adhered.

Satin: A particular, fairly flat weave pattern in fabrics in which each warp fibre flocks over 4 or more weft fibres, and vice versa.

Scarf Joint: *See* Joint.

Scrim: A nonwoven open-weave reinforcing fabric made from continuous-filament yarn in an open-mesh construction. Often used to support an adhesive film.

Secondary Structure: A structure of secondary importance.

Self-extinguishing Resin: A resin formulation which will burn in the presence of a flame but which will extinguish itself within a specified time after the flame is removed.

Selvage: The edge of a woven fabric finished off so as to prevent the yarns from unraveling.

Set: (1) To convert into a fixed or hardened state by chemical or physical action, such as condensation polymerisation, oxidation, vulcanisation, gelation, hydration, or evaporation of volatiles. (2) The irrecoverable deformation or creep usually measured by a prescribed test procedure and expressed as a percentage of original dimension.

Set Up: To harden, as in curing.

Shear: An action or stress resulting from applied forces and tending to cause two contiguous parts of a body to slide relative to each other in a direction parallel to their plane of contact.

Shear Modulus G: The ratio of shearing stress t to shearing strain g within the proportional limit of a material.

Short-beam Shear Strength: The interlaminar shear strength of a parallel-fibre-reinforced plastic material as determined by three-point flexural loading of a short segment.

Shrinkage: The tendency of a resin system to contract in volume when transitioning from the liquid to the used state.

Silicon Carbide Fibre: A reinforcing fibre with high strength and modulus: density is equal to that of aluminium. It is used in organic- and metal-matrix composites.

Size: Any treatment consisting of starch, gelatin, oil, wax, or other suitable ingredient applied to yarn or fibres at the time of formation to protect the surface and facilitate handling and fabrication or to control the fibre characteristics. The treatment contains ingredients which provide surface lubricity and binding action but, unlike a finish, no coupling agent. Before final fabrication into a composite, the size is usually removed by heat-cleaning and a finish is applied.

Sizing Content: The percent of the total strand weight made up by the sizing, usually determined by burning off the organic sizing ("loss on Ignition").

Skein: A continuous filament, strand, yarn, roving, etc., wound up to some measurable length and generally used to measure various physical properties.

Skin: The laminate part of a sandwich structure.

SMC: Sheet-moulding compound.

S-N Curve: Stress per number of cycles to failure. Used to define fatigue behaviour.

Specific Gravity: The ratio of the weight of any volume of a substance to the weight of an equal volume of another substance, usually water, taken as standard at a constant or stated temperature.

Specific Heat: The quantity of heat required to raise the temperature of a unit mass of a substance 1 degree under specified conditions.

Specimen: An individual piece or portion of a sample used to make a specific test.

Splice: To join two ends of fibre yarn or strand, usually by means of an air-drying glue. Such a join.

Spray-up: Technique in which a spray gun is used as the processing tool. In reinforced plastics, for example, fibrous glass and resin can be simultaneously deposited in a mould. In essence, roving is fed through a chopper and ejected into a resin stream, which is directed at the mould by either of two spray systems.

Sprayed-metal Moulds: Moulds made by spraying molten metal onto a master until a shell of predetermined thickness is achieved. The shell is then removed and backed up with plaster, cement, casting resin, or other suitable material. Used primarily as a mould in sheet-forming process.

Starved Joint: An adhesive joint which has been deprived of the proper film thickness of adhesive due to insufficient adhesive spreading or application of excessive pressure during lamination.

Stiffness: The relationship of load and deformation; a term often used when the relationship of stress to strain does not conform to the definition of Young's modulus. (See Stress-strain.)

Strain: As applied to composite laminates: The resultant change in dimension of a material when subjected to a stress, expressed as a fraction or percentage of the original dimension.

Stress: Most commonly defined as engineering stress; the ratio of the applied load P to the original cross-sectional area A .

Stress Concentration: Magnification of the level of an applied stress in the region of a notch, void, or inclusion.

Stress Corrosion: Preferential attack of areas under stress in a corrosive environment, where this factor alone would not have caused corrosion.

Stress Crack: External or internal cracks in a plastic caused by tensile stresses less than that of its basic mechanical strength. The stresses which cause cracking may be present internally or externally or may be combinations of these stresses.

Stress Relaxation: The decrease in stress under sustained constant strain, also called *stress decay*.

Stress-strain Curve: Simultaneous readings of load and deformation, converted into stress and strain, plotted as y and x -axes, respectively, to obtain a stress-strain diagram.

Structural adhesive: An adhesive used for transferring loads between adherends.

Structural Bond: A bond that joins basic load-bearing parts of an assembly; the load may be either static or dynamic.

Surfacing Mat: A very thin mat, of highly filamentized fibres used primarily to produce a smooth surface on a reinforced plastic laminate.

Surface Treatment: A treatment applied to carbon fibre during its manufacture to alter the fibre's surface chemistry.

Syntactic Foam: A cellular plastic which is put together by incorporating hollow spheres or microballoons in a resin matrix; opposite of foamed plastic, in which the cells are formed by gas bubbles released in the liquid plastic by chemical or mechanical action.

Tack: Stickiness of an adhesive, resin or prepreg material.

Tape: A form of unidirectional prepreg consisting of continuous fibres that are aligned along the tape axis parallel to each other and held together purely by the impregnating resin.

Tape Laying: A fabrication process in which prepreg tape is laid side by side or overlapped to form a structure. The process can be automated with robotic arms.

Tenacity: The strength of a yarn or of a filament of a given size; equals breaking strength divided by denier.

Tensile Modulus: The ratio of the tension stress to the strain in the material over the range for which this value is constant.

Tensile Strength or Stress: The maximum tensile load per unit area of original cross section, sustained by the specimen during a tension test. Tensile strength is interpreted to mean the maximum tensile load sustained by the specimen during the test, whether this coincides with the tensile load at the moment of rupture or not.

Tex: A measure of the mass of 1000lm of a fibre, tow or strand expressed in grammes. Sometimes expressed as dtex (decitex) where 1dtex equals 0.1x tex and is equivalent to the mass in grammes of 10,000lm of fibre, tow or strand.

Thermal Conductivity: Ability of a material to conduct heat; the physical constant for quantity of heat that passes through a unit cube of a substance in unit time when the difference in temperature of two faces is 1 degree.

Thermoplastic: A plastic material capable of being repeatedly softened by increase of temperature and hardened by decrease in temperature; applicable to those materials whose change upon heating is substantially physical rather than chemical and which can be shaped by flow into articles by moulding and extrusion. Examples include, polypropylene, ABS, nylon, polyethylene.

Thermoset: A plastic material which changes into a substantially infusible and unmouldable material after it is cured by application of heat or by chemical means. Although a thermoset material will soften at its T_g, it will never return to its precured liquid state. Examples include epoxy and unsaturated polyester.

Thixotropic: Gel-like at rest but fluid when agitated; having high static shear strength and low dynamic shear strength at the same time.

Thread Count: The number of yarns (threads) per inch (millimetre) in either lengthwise (warp) or crosswise (weft) direction of woven fabrics.

Torsional Rigidity (Fibres): The resistance of a fibre to twisting.

Toughness: The resistance of a material to crack propagation.

Tow: A large bundle of continuous filaments, generally 1000 or more, usually designated by a number followed by "K," indicating multiplication by 1000; for example, 12K tow has 12,000 filaments. Normally applied to carbon fibre.

Transition Temperature: The temperature at which the properties of a material change.

Twist: The turns about its axis per unit of length in a yarn or other textile strand.

UHM: Ultra-high modulus.

Ultimate Elongation: The elongation at rupture of a material. Also called 'Elongation at break' or 'Strain to failure'.

Ultimate Tensile Strength: The ultimate or final stress sustained by a specimen in a tension test; at moment of rupture.

Ultraviolet: Zone of invisible radiations beyond the violet end of the spectrum of visible radiations. Since ultraviolet wave lengths are shorter than the visible, their photons have more energy, enough to initiate some chemical reactions and to degrade most plastics.

Unidirectional: Refers to fibres that are oriented in the same direction, such as unidirectional fabric, tape, or laminate, often called UD.

Unidirectional Laminate: A reinforced plastic laminate in which substantially all the fibres are oriented in the same direction.

Vacuum-bag Moulding: A process for moulding laminates in which a sheet of flexible material is placed over the lay-up on the mould and sealed. A vacuum is applied between the sheet and the lay-up. The entrapped air is pulled out of the lay-up and removed by the vacuum. Atmospheric pressure provides the consolidation pressure.

Veil: An ultrathin mat similar to a surface mat, often composed of organic fibres as well as glass fibres.

Viscosity: The property of resistance to flow exhibited within the body of a liquid or semi-solid expressed in terms of relationship between applied shearing stress and resulting rate of strain in shear.

Void Content: The percentage of voids in a laminate.

Void: Gaseous pockets trapped and cured into a laminate usually within the matrix.

Volatile Content: The percent of volatiles driven off as a vapour from a plastic or an impregnated reinforcement.

Volatiles: Materials in a sizing or a resin formulation capable of being driven off as a vapour at room temperature or slightly above.

Warp: (1) The yarn running lengthwise in a woven fabric; a group of yarns in long lengths and approximately parallel, put on beams or warp reels for further textile processing, including weaving. (2) A change in dimensions of a cured laminate from its original moulded shape.

Water Absorption: Ratio of the weight of water absorbed by a material upon immersion to the weight of the dry material.

Water Jet: A high pressure stream of water used for cutting composites and other materials.

Weathering: The exposure of materials outdoors. In *artificial weathering*, plastics are exposed to cyclic laboratory conditions of high and low temperatures, high and low relative humidities, and ultraviolet radiant energy, with or without direct water spray, in an attempt to produce changes in their properties similar to those observed on long continuous exposure outdoors. Laboratory exposure conditions are usually intensified beyond those in actual outdoor exposure to achieve an accelerated effect.

Weave: The particular manner in which a fabric is formed by interlacing yarns. In plain weave, the warp and weft fibres alternate to make both fabric faces identical; in satin weave, the pattern produces a satin appearance, with the warp tow over several weft tows and under the next one (for example, eight-harness satin would have warp tow over seven weft tows and under the eighth).

Web: A textile fabric, paper or a thin metal sheet of continuous length handled in roll form, as contrasted with the same material cut into sheets.

Weft: The transverse threads of fibres in a

woven fabric running perpendicular to the warp; also called *fill*, and *woof*.

Wet Lay-up: A process in which liquid resin is applied as the reinforcement is laid up.

Wet-out: The condition of an impregnated roving or yarn wherein substantially all voids between the sized strands and filaments are filled with resin.

Wet-out Rate: The time required for a resin to fill the interstices of a reinforcement material and wet the surface of the reinforcement fibres; usually determined by optical or light-transmission means.

Wetting Agent: A surface-active agent usually in a resin formulation that promotes wetting by decreasing the cohesion within a liquid.

Wet Winding: In filament winding the process of winding glass on a mandrel where the strand is impregnated with resin just before contact with the mandrel.

Whisker: A very short fibre form of reinforcement, usually crystalline.

Winding Pattern: In filament winding: (1) The total number of individual circuits required for a winding path to begin repeating by laying down immediately adjacent to the initial circuit. (2) A regularly recurring pattern of the filament path after a certain number of mandrel revolutions, leading to the eventual complete coverage of the mandrel.

Winding Tension: In filament winding the amount of tension on the reinforcement as it makes contact with the mandrel.

Woven Fabrics: Fabrics produced by interlacing strands at more or less right angles.

Woven Roving: A heavy glass-fibre fabric made by weaving glass roving.

Yarn: An assembly of twisted fibres or strands, natural or manufactured, to form a continuous yarn suitable for use in weaving or otherwise interweaving into textile materials.

Yield Point: The first stress in a material, less than the maximum attainable stress, at which an increase in strain occurs without an increase in stress. Only materials that exhibit this unique phenomenon of yielding have a yield point.

Yield Strength: The stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain; the lowest stress at which a material undergoes plastic deformation. Below this stress, the material is elastic; above it, plastic.

Young's Modulus: See Modulus of elasticity.