

FRP involves two distinct processes, the first is the process whereby the fibrous material is manufactured and formed, the second is the process whereby fibrous materials are bonded with the matrix during moulding

Fibre

Manufacture of fibre fabric

Reinforcing Fibre is manufactured in both two-dimensional and three-dimensional orientations:

1. Two-dimensional fibre glass-reinforced polymer is characterized by a laminated structure in which the fibers are only aligned along the plane in **x-direction**, and **y-direction** of the material. This means that no fibers are aligned in the through-thickness or the **z-direction**, this lack of alignment in the through thickness can create a disadvantage in cost and processing. Costs and labor increase because conventional processing techniques used to fabricate composites, such as wet hand lay-up, autoclave and resin transfer molding, require a high amount of skilled labor to cut, stack and consolidate into a preformed component.
2. Three-dimensional fiberglass-reinforced polymer composites are materials with three-dimensional fiber structures that incorporate fibers in the **x-direction**, **y-direction** and **z-direction**. The development of three-dimensional orientations arose from industry's need to reduce fabrication costs, to increase through-thickness mechanical properties, and to improve impact damage tolerance; all were problems associated with two-dimensional fibre-reinforced polymers.

Manufacture of fibre preforms

Fibre preforms are how the fibres are manufactured before being bonded to the matrix. Fibre preforms are often manufactured in sheets, continuous mats, or as continuous filaments for spray applications. The four major ways to manufacture the fibre preform is through the textile processing techniques of **weaving**, **knitting**, **braiding** and **stitching**.

1. Weaving can be done in a conventional manner to produce two-dimensional fibres as well in a multilayer weaving that can create three-dimensional fibres. However, multilayer weaving is required to have multiple layers of warp yarns to create fibres in the z- direction creating a few disadvantages in manufacturing, namely the time to set up all the **warp** yarns on the **loom**. Therefore, most multilayer weaving is currently used to produce relatively narrow width products, or high value products where the cost of the preform production is acceptable. Another one of the main problems facing the use of multilayer woven fabrics is the difficulty in producing a fabric that contains fibres oriented with angles other than 0° and 90° to each other respectively.
2. The second major way of manufacturing fibre preforms is Braiding. Braiding is suited to the manufacture of narrow width flat or tubular fabric and is not as capable as weaving in the production of large volumes of wide fabrics. Braiding is done over top of mandrels that vary in cross-sectional shape or dimension along their length. Braiding is limited to objects about a brick in size. Unlike standard weaving, braiding can produce fabric that contains fibres at 45-degree angles to one another. Braiding three-dimensional fibres can be done using four step, two-step or Multilayer Interlock Braiding. Four step or row and column braiding utilizes a flat bed containing rows and columns of yarn carriers that form the shape of the desired preform. Additional carriers are added to the outside of the array, the precise location and quantity of which depends upon the exact preform shape and structure required. There are four separate sequences of row and column motion, which act to interlock the yarns and produce the braided preform. The yarns are mechanically forced into the structure between each step to consolidate the structure in a similar process to the use of a reed in weaving. Two-step braiding is unlike the four-step process because the two-step includes a large number of yarns fixed in the axial direction and a fewer number of braiding yarns. The process consists of two steps in which the braiding carriers move completely through the structure between the axial carriers. This relatively simple sequence of motions is

capable of forming preforms of essentially any shape, including circular and hollow shapes. Unlike the four-step process, the two-step process does not require mechanical compaction the motions involved in the process allows the braid to be pulled tight by yarn tension alone. The last type of braiding is multi-layer interlocking braiding that consists of a number of standard circular braiders being joined together to form a cylindrical braiding frame. This frame has a number of parallel braiding tracks around the circumference of the cylinder but the mechanism allows the transfer of yarn carriers between adjacent tracks forming a multilayer braided fabric with yarns interlocking to adjacent layers. The multilayer interlock braid differs from both the four step and two-step braids in that the interlocking yarns are primarily in the plane of the structure and thus do not significantly reduce the in-plane properties of the preform. The four-step and two-step processes produce a greater degree of interlinking as the braiding yarns travel through the thickness of the preform, but therefore contribute less to the in-plane performance of the preform. A disadvantage of the multilayer interlock equipment is that due to the conventional sinusoidal movement of the yarn carriers to form the preform, the equipment is not able to have the density of yarn carriers that is possible with the two step and four step machines.

3. Knitting fibre preforms can be done with the traditional methods of Warp and [Weft] Knitting, and the fabric produced is often regarded by many as two-dimensional fabric, but machines with two or more needle beds are capable of producing multilayer fabrics with yarns that traverse between the layers. Developments in electronic controls for needle selection and knit loop transfer, and in the sophisticated mechanisms that allow specific areas of the fabric to be held and their movement controlled. This has allowed the fabric to form itself into the required three-dimensional preform shape with a minimum of material wastage.
4. Stitching is arguably the simplest of the four main textile manufacturing techniques and one that can be performed with the smallest investment in specialized machinery. Basically stitching consists of inserting a needle, carrying the stitch thread, through a stack of fabric layers to form a 3D structure. The advantages of stitching are that it is possible to stitch both dry and prepreg fabric, although the tackiness of the prepreg makes the process difficult and generally creates more damage within the prepreg material than in the dry fabric. Stitching also utilizes the standard two-dimensional fabrics that are commonly in use within the composite industry therefore there is a sense of familiarity concerning the material systems. The use of standard fabric also allows a greater degree of flexibility in the fabric lay-up of the component than is possible with the other textile processes, which have restrictions on the fibre orientations that can be produced.

Glass fibre

"Fibreglass reinforced plastics" or FRPs (commonly referred to simply as [fibreglass](#)) use textile grade [glass fibres](#). These textile fibres are different from other forms of glass fibres used to deliberately trap air, for insulating applications (see [glass wool](#)). Textile glass fibres begin as varying combinations of SiO_2 , Al_2O_3 , B_2O_3 , CaO , or MgO in powder form. These mixtures are then heated through direct melting to temperatures around 1300 degrees Celsius, after which dies are used to extrude filaments of glass fibre in diameter ranging from 9 to 17 μm . These filaments are then wound into larger threads and spun onto bobbins for transportation and further processing. Glass fibre is by far the most popular means to reinforce plastic and thus enjoys a wealth of production processes, some of which are applicable to aramid and carbon fibres as well owing to their shared fibrous qualities.

Roving is a process where filaments are spun into larger diameter threads. These threads are then commonly used for woven reinforcing glass fabrics and mats, and in spray applications.

Fibre fabrics are web-form fabric reinforcing material that has both warp and weft directions. Fibre mats are web-form non-woven mats of glass fibres. Mats are manufactured in cut dimensions with chopped fibres, or in continuous mats using continuous fibres. Chopped fibre glass is used in processes where lengths of glass threads are cut between 3 and 26 mm, threads are then used in plastics most commonly intended for moulding processes. Glass fibre short strands are short 0.2–0.3 mm strands of glass fibres that are used to reinforce thermoplastics most commonly for injection moulding.

Carbon fibre

Carbon fibres are created when polyacrylonitrile fibres (PAN), Pitch resins, or Rayon are carbonized (through oxidation and thermal pyrolysis) at high temperatures. Through further processes of graphitizing or stretching, the fibres strength or elasticity can be enhanced respectively. Carbon fibres are manufactured in diameters analogous to glass fibres with diameters ranging from 4 to 17 μm . These fibres are wound into larger threads for transportation and further production processes.^[2] Further production processes include weaving or braiding into carbon fabrics, cloths and mats analogous to those described for glass that can then be used in actual reinforcements.

Aramid fibre

Aramid fibres are most commonly known as Kevlar, Nomex and Technora. Aramids are generally prepared by the reaction between an amine group and a carboxylic acid halide group (aramid). Commonly, this occurs when an aromatic polyamide is spun from a liquid concentration of sulphuric acid into a crystallized fibre. Fibres are then spun into larger threads in order to weave into large ropes or woven fabrics (Aramid). Aramid fibres are manufactured with varying grades to based on varying qualities for strength and rigidity, so that the material can be somewhat tailored to specific design needs concerns, such as cutting the tough material during manufacture

Reinforcing material ^[2]	Most common matrix materials	Properties improved
Glass fibres	UP, EP, PA, PC, POM, PP, PBT, VE	Strength, elasticity, heat resistance
Wood fibres	PE, PP, ABS, HDPE, PLA	Flexural strength, tensile modulus, tensile strength
Carbon and aramid fibres	EP, UP, VE, PA	Elasticity, tensile strength, compression strength, electrical strength.
Inorganic particulates	Semicrystalline thermoplastics, UP	Isotropic shrinkage, abrasion, compression strength
Microspheres	Glass microspheres	Weight reduction relative to solid fillers

Applications

Fibre-reinforced plastics are best suited for any design program that demands weight savings, precision engineering, finite tolerances, and the simplification of parts in both production and operation. A moulded polymer artefact is cheaper, faster, and easier to manufacture than cast aluminium or steel artefact, and maintains similar and sometimes better tolerances and material strengths.

Carbon-fibre-reinforced polymers

Rudder of Airbus A310

- Advantages over a traditional rudder made from sheet aluminium are:
 - 25% reduction in weight
 - 95% reduction in components by combining parts and forms into simpler moulded parts.
 - Overall reduction in production and operational costs, economy of parts results in lower production costs and the weight savings create fuel savings that lower the operational costs of flying the aeroplane

Glass-fibre-reinforced polymers

Engine intake manifolds are made from glass-fibre-reinforced PA 66.

- Advantages this has over cast aluminium manifolds are:
 - Up to a 60% reduction in weight
 - Improved surface quality and aerodynamics
 - Reduction in components by combining parts and forms into simpler moulded shapes.

Automotive gas and clutch pedals made from glass-fibre-reinforced PA 66 (DWP 12–13)

- Advantages over stamped aluminium are:
 - Pedals can be moulded as single units combining both pedals and mechanical linkages simplifying the production and operation of the design.
 - Fibres can be oriented to reinforce against specific stresses, increasing the durability and safety.

Aluminium windows, doors and facades get thermally insulated by using thermal insulation plastics made of glass fibre reinforced polyamide. In 1977 Ensinger GmbH produced first insulation profile for window system