Composites with a polymeric matrix

1. Particulate composites

- particles in elastomers
- particles in thermoplastics
- particles in thermosets

2. Fibrous composites

- fibers in thermoplastics
- fibers in thermosets

3. Combined composites

1. **Particulate composites with a polymeric matrix**

Polymeric matrices have low strength (themselves) and have low heat resistance, in particular. Adding a mixture of dispersion particles to a polymeric matrix increases the modulus of elasticity, thermal stability, reduces shrinkage and improves other properties.

To reinforce the material we mostly use powders of micronized minerals, particularly kaolin, talc, mica, limestone. To improve the sliding properties and abrasion resistance, we use for example particles of bronze with a graphite or molybdenum sulphide. To achieve electrical conductivity metal powders (Al, Cu, and Ag) of high concentration are added. To increase stiffness particles of larger dimension (1 mm and more) are used.

Particles in elastomers

Elastomers are generally very homogeneous; therefore we can use very small particles to depressively solidify the elastomers.

A specific example is conveyor belts(الحزام الناقل) or tires, where we use from 10 to 20 % of silica powder, talc(بودرة) or carbon black for the base rubber. It often also combines several kinds of dispersion.

Particles in thermoplastics

For thermoplastics there are usually used larger particles with a diameter of 10 µm. They reduce the shrinkage (or final shrinkage), increase the toughness, suppress the viscoelastic behaviour, increase the attenuation and suppress(تخفيف ومنع)vibrations

Typical examples:

Polystyrene and cellulose particles (sawdustنشارة الخشب) - anti-vibration material

Polyethylene and 70-80 % of lead powder - protection against radiation (X-ray, gamma-ray) etc.

Particles in thermosets

For thermosets there are also used larger particles with a diameter of at least 10 µm. The effects are: an increase of firmness(الثبات والقوة), moderation of crack growth, an increase of electrical insulation - quartz/silica sand, reduction of flammability - hydrated Al_2O_3 powder.

2-Fibrous composites with a polymeric matrix:

Fibrous (Fiber) composites with a polymeric matrix are the most common and most traditional composite materials. Reinforcement fibers are used mainly in thermoplastics and in thermosets as well. The most frequently used fibers are glass, carbon, boron and others.

As thermoset matrices the most commonly used are epoxy, formaldehyde, polyurethane and other resins.

The thermoplastic matrices are the most common type. A low-cost representative is polypropylene. More expensive and chemically and thermally more resistant are polyamides.

Fibers in thermoplastics

As the matrix is used: polyamide, polyethylene, polypropylene and polycarbonate. The optimum amount of fibers is about 40-50 %.

For glass fibers in the thermoplastic the critical fiber length is about 0.2 mm. This allows preferably to produce granules of thermoplastics, where the individual granules already contain glass fibers of a sufficient length. As for thermoset composites, the properties are highly anisotropic and depend on the loading specifications.

Fibers in thermosets

The classic and the oldest type of mass-produced composites are polymer and glass fiber. Around 90 % of all thermoset composites contain glass fibers. Typically used fibers are continuous or at least long.

The optimum amount of fibers is 60-75 %, a higher amount in the composite has a larger number of pores.

Basic matrices that are used are:

Polyester - is the most common matrix because polyester resins generally have good mechanical, electrical and chemical properties. Polyesters are suitable in a slightly alkaline medium and excellent in a mildly acidic medium.

Polyvinyl esters have good resistance to an acidic and alkaline medium, particularly at high temperatures. PVE profiles with glass fibers have good thermal and electrical insulating properties.

Epoxy - epoxies have excellent mechanical and electrical properties and are commonly used with carbon or glass fibers. (They also have) good electrical insulation properties in a wide range of temperatures, considerable resistance to water, alkali solutions and acids and some solvents.

Phenol - phenolic resins are used for the requirement of high fire resistance, high heat resistance, have low smoke generation and limit flames during combustion.

3. **Combined composites**

It is often not only one single composite material, but the component is composed of several different materials being appropriately combined. An example is the construction of modern fibreglass skis(الزلاجات) or tire construction. It also often combines several kinds of dispersion.

The production of fiber composites with a polymeric matrix

I. **The manual laying(ترتيب) (using a fabric)**

It is the most traditional method of production, where the glass reinforcement is placed into a mould and subsequently saturated with a binder. The desired thickness is gradually built up from layers (lamination), then the binder is cured and the segment (the workpiece) is removed from the mould. It is the least demanding technology.

There are various manual or semi-automatic production methods. Specifically, there is for example the manual production of embedding the fabric in the form and over rolling, semi-automatic production by embedding the fabric in a form and over pressing, semi-automatic production by embedding the fabric in the form using overpressure or automated production by embedding the fabric in the form using a vacuum.

II. **Winding(لف او التواء)**

It is a technology based on a continuous winding of a fiber bundle or otherwise modified reinforcement to the circular form. The fibers are wound either already moistened with resin, or are moistened after winding. The method of winding continuous fibers onto an appropriate form and the simultaneous or following pouring of polymer is mainly used for hollow, rotary symmetrical parts. It is thus possible to produce even very large parts.

Example: winding the wind turbine tower(برج التوربين) with a height of 55 m and a diameter of 8 m, it is a composite with 50 % of the graphite fibers in an epoxy matrix, the resulting composite has a density of 1.7 g.cm^3, and tensile stress of 1150 MPa.

For the production of various profiles of plastic composites with continuous fibers there has been developed a production method called pultrusion(الانصهار). The continuous fibers are pulled through a forming nozzle (or slot) in which they are simultaneously saturated with a polymer. It is possible to use both thermoplastics and thermosets. The method is fully automatic and very productive.

III. **Drawing (fiber drawing)**

Technology based on drawing fiber bundles, mats(حصير) and fabrics(نسيج) in a resin bath, where the reinforcement is saturated. Then the (saturated) reinforcement is formed into a desired shape and cured.

IV. **The injection and blowing method**

It is used for preparation of composites from granular material which already contains the fibers. You can use slightly modified equipment for the injection, blowing or pressing of conventional plastics. The method can be used for thermoplastics and thermosets as well. The plastic melt has during the processing (e.g. injection) usually relatively high viscosity. This causes the individual fibers to orient in the direction of the melt flow; therefore it is possible to achieve a partial orientation of the fibers of the product.

Applications of Fibrous Composites

- Aerospace Industries (Carbon/Epoxy PMCs)

-Automobile Industry (Epoxy based PMCs)

-Springs and bumper(ممتص الصدمات) systems (Reinforced Thermosets)

-Tooling(الادوات) (Epoxy based PMCs)

-Fiberglass reinforced plastic has been used for boat hulls(اجسام القوارب), fishing rods, tennis rackets, golf club shafts, helmets(الخوذ), skis(زلاجات), bows and arrows(القوس والسهم).

Space craft (مركبة فضائية): Antenna structures(هياكل الهوائيات), Solar reflectors, Satellite structures, Radar, Rocket engines, etc.

-Aircraft: Jet engines(المحركات النفاثة), Turbine blades(ريش التوربين), Turbine shafts(قضيب), Compressor blades, Airfoil surfaces(سطح جناح الطائرة), Wing box structures(صندوق الجناح), Fan blades, Engine bay doors, Rotor shafts in helicopters, Helicopter transmission structures, etc.

-Miscellaneous:

(1) Bearing materials(موادالتحمل), Pressure vessels, Abrasive materials(مواد قاشطة), Electrical machinery, Truss members(اجزاء ناقل الحركة), Cutting tools, Electrical brushes(فرش كهربائية), etc.

(2) Automobile: Engines, bodies, Piston, cylinder, connecting rod, crankshafts, bearing materials, etc.

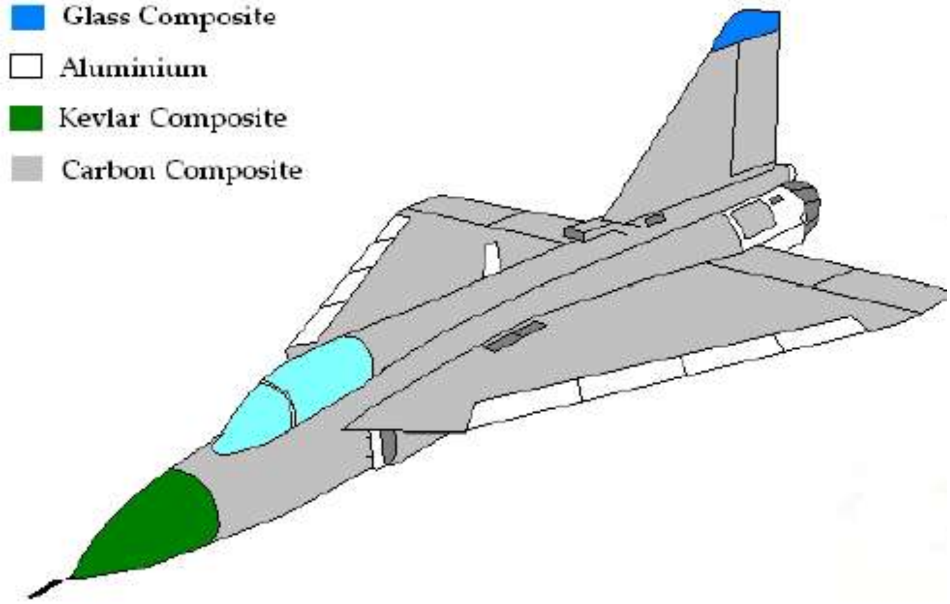
TABLE 16-3 ■ *Examples of fiber-reinforced materials and applications*

Material	Applications
Borsic aluminum	Fan blades in engines, other aircraft and aerospace applications
Kevlar™-epoxy and Kevlar™-polyester	Aircraft, aerospace applications (including space shuttle), boat hulls, sporting goods (including tennis rackets, golf club shafts, fishing rods), flak jackets
Graphite-polymer	Aerospace and automotive applications, sporting goods
Glass-polymer	Lightweight automotive applications, water and marine applications, corrosion-resistant applications, sporting goods equipment, aircraft and aerospace components

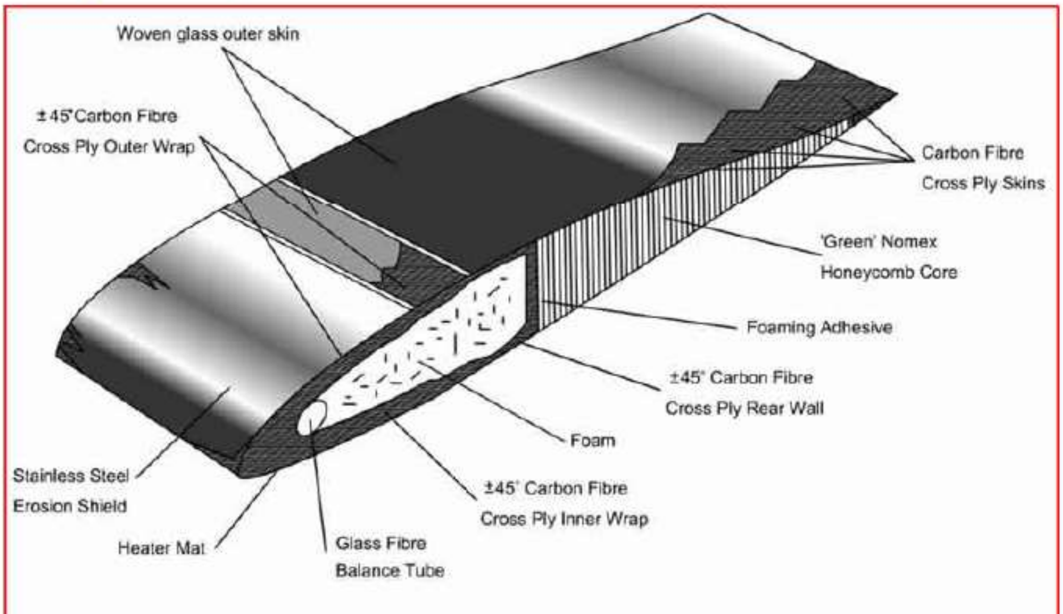
TABLE 16-1 ■ *Examples and applications of selected dispersion-strengthened composites*

System	Applications
Ag-CdO	Electrical contact materials
$Al\text{-}Al_2O_3$	Possible use in nuclear reactors
Be-BeO	Aerospace and nuclear reactors
$Co\text{-}ThO_2$, Y_2O_3	Possible creep-resistant magnetic materials
Ni-20% $Cr\text{-}ThO_2$	Turbine engine components
Pb-PbO	Battery grids
$Pt\text{-}ThO_2$	Filaments, electrical components
$W\text{-}ThO_2$, ZrO_2	Filaments, heaters

Aerospace: Use of composites in LCA Tejas



Aerospace: Helicopter Blade

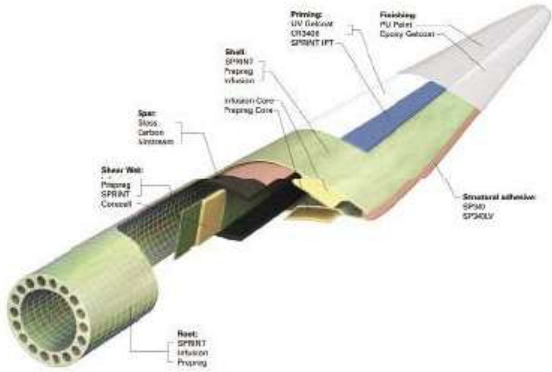


Cross-Sectional View of a Composite Blade

Automobile/Transportation:

Sports:

Wind Energy:



Medical:

Civil/Infrastructure:

Marine:

water lubricated propeller shaft bearings