

Lectures 3 to 5

Module I - Applications

Applications

Nowadays there is no field of engineering without the foot-print of composite materials in some form. The following list is not the exhaustive list but to name a few. The application of composite materials can be broadly classified in to

Aerospace applications

Road and Rail transport applications

Offshore accord water vehicles

Building and other civil structures

Chemical Industries

Electrical, Electronics and communication applications

Mechanical systems and machine elements

Consumer durable products and sports applications

Biomedical applications

High performance composites being costlier, is used mostly in defense applications where the performance is given high priority and not the cost.

Aircraft and military applications:

The aerospace vehicles can be classified in to

- 1) Aircraft
- 2) Rockets and Missiles
- 3) Space crafts

Composites are mostly used in aerospace vehicles due to weight saving, high strength to weight ratio, high stiffness to weight ratio, and low fuel consumption. Fuel consumption is

controlled by reducing the weight of the structure by using proper design criterion and by providing the aerodynamic shape to the structure. The most commonly used materials for weight reduction are some light weight metals and the alloys. Due to the increased speed, increase in usage and other specific requirements, new materials are essential and composite materials become the right choice. The primary advantage of composite materials is that these materials can be tailor made to meet any specific requirement and any complex shape can be easily made with composites. Few examples of aircraft and structural parts of aircraft which made use of composites is illustrated in the following pages.

Composites are used since weight reduction is very much critical for higher speeds.



In 1969, Horizontal stabilizers of F-14 aircraft were made of boron fiber-reinforced epoxy skins. Carbon fiber-reinforced epoxy is used in wing, fuselage and empennage components.

Figure 1.2a F-14 Fighter Aircraft

(Source: www.militaryfactory.com)



The airframe of AV-8B and F-22 fighter aircraft contain nearly 25% by weight of carbon fiber-reinforced polymers.

Figure 1.2b AV-8B Fighter Aircraft

(Source: www.airliners.net)



Figure 1.2c B-2 Fighter Aircraft
(Source:www.globalsecurity.org)

The outer skin of B-2 and other stealth aircraft are almost made of carbon fiber-reinforced polymers.



Figure 1.3a Airbus A310
(Source:www.widebodyaircraft.nl)

Airbus was the first commercial aircraft manufacturer to make use of composites in their A310 aircraft.



Figure 1.3b Airbus A320
(Source:www.aviationnews.eu)

The Airbus A320 was the first commercial aircraft to use an all-composite tail.



Figure 1.3c Boeing 777

(Source: www.bubblews.com)

About 10% of Boeing 777's structural weight is made of carbon fiber-reinforced epoxy and about 50% is made of aluminum alloys.



Figure 1.3d Boeing 787 Dreamliner

(Source: www.247attractiveman.com)

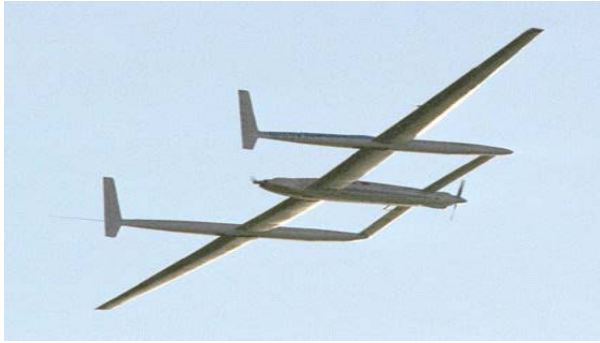
Boeing's 787 Dreamliner will be made of carbon fiber-reinforced polymers upto 50% of its structural weight.



Figure 1.3e Lear Fan 2100

(Source : www.museumofflight.org)

The Lear Fan 2100, a business aircraft had carbon and Kevlar composites up to 70% of its airframe weight.



The Rutan Voyager, the first-ever nonstop flight around the world in 1986, was an all-composite airplane.

Figure 1.3f Rutan Voyager

(Source: www.en.wikipedia.org)

The list of parts of aircraft made of composite may be summarized as below:

- gliders
- Helicopter blades
- Transmission shafts
- Ailerons, rudders, elevators, flaps, spoilers etc
- Engine cowlings
- Rocket boosters
- Nozzles
- Antenna cover
- Fin and Fuselage portions
- Nose radome, doors, fairings
- Aircraft wing parts (skin, spars and stiffeners)

❖ **Automotive applications**

Based on the usage and shape the automobile vehicles, the automobile structure can be grouped in to three categories which include;

- Chassis components
- Body components
- Engine components

Composites are used in all the three major parts of the vehicles.

Composites are used in automobile industries due to the following reasons:

- 1) High specific strength (strength to weight ratio), due to which there is improvement in fuel efficiency.
- 2) Low wear and tear due to vibrations
- 3) Attractive styling
- 4) High resistance to damage
- 5) High resistance to corrosion, bio-degradation and extreme environmental conditions.
- 6) High thermal insulation and sound deadening properties
- 7) Easy repairing and maintenance free structural elements

E-glass fiber-reinforced sheet molding compound composites are used in the hood or door panels, radiator supports, bumper beams, roof frames, door frames, engine valve covers, timing chain covers, oil pans etc. Unileaf E-glass fiber-reinforced epoxy springs are used in place of multileaf steel springs.

In buses and trucks the GFRP composites are used to make, bus bodies, Roof panel, Engine Bonnet, Tail gates, mud wings, bumper bars, Window frames, doors, front grills and dash boards.

In cars the parts of car body, head lamp, rear window frame, tail lamp skirts, instrument panel, leaf spring and cabins are made of composites.

The body of refrigerated containers, petrol tankers, chemical tankers and milk tankers are made of composite panels.

In railways the parts of wash basin, battery box, seat and back rest, bathroom cubicles, window frames, guides, louvers, under carriage water tank and vacuum reservoirs are made of composite materials.

For all these applications mostly Glass reinforced composite products are used due to low cost and easy availability. Also the structural elements are mostly less stressed and hence glass fibers with polyester or Vinylester resins are used for these applications. The processing techniques are mostly Hand layup technique and compression moulding techniques for making these products.

Carbon fiber-reinforced polymers are used in the BMW M6 roof panel.

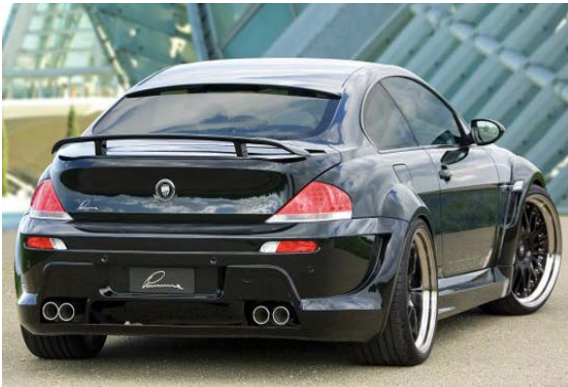


Fig 1.4a BMW M6 car

(Source : www.worldcarfans.com)



Carbon fiber-reinforced composite is extensively used in race cars. In Formula 1 race car, chassis, interior, and suspension components are made by the carbon FRC.

Fig.1.4b: Race car made of composites

(Source : www.en.wikipedia.org)

Like automobiles, in railways also the following sections of train use composite materials.

- Wagons
- Fronts of power units
- Doors, seats, interior panels

❖ Marine applications:

Glass fiber composites are widely used in marine applications due to the following reasons:

- 1) Most of the conventionally used metals get corroded easily and timber and other natural materials decay quickly and glass fiber composites on the other hand has high corrosion resistant and can provide maintenance free service for longer duration.
- 2) GFRP boat hulls are maintenance free
- 3) Most of the complex shapes which provide buoyancy effect can be easily made.
- 4) GFRP boats can be made with less number of joints and structural elements and they are cost competitive.
- 5) Repair of composite products are easier
- 6) GFRP products are very light with high strength and stiffness and hence better substitute for steel materials.

Glass fiber-reinforced polyesters are used in sail boats, fishing boats, life boats, anti-marine ships, rescue crafts, hovercrafts and yachts. Due to higher strength of kevlar-49 fibers, these fibers are nowadays used for making boat hulls, decks, bulkheads, frames, masts and spars. Carbon fiber-reinforced epoxy is used in racing boats. Composites are used in naval ships, hulls, decks, bulkheads, masts, propulsion shafts, rudders, hunters, frigates, destroyers etc. Royal Swedish Navy is the largest composite ship producers in the world.

Most of the offshore structures which are made by composite materials include

Building elements in the harbor

Buoys of different types and

Light houses

❖ Sporting goods

Due to light weight, high damping properties and design flexibility, FRC are widely used in making the following sports goods:

Tennis and squash rackets

- Skis, Fishing rods
- Hockey sticks
- Arrows, Javelins
- Baseball bats
- Helmets
- Exercise equipments
- Athletic shoe soles and heels

Golf rackets are nowadays made of carbon fiber-reinforced epoxy due to its light weight. Glass fiber-reinforced epoxy is preferred over wood and aluminum in pole-vault poles because of its high strain energy storage capacity.



Fig.1.4c: B-2 Stealth Bomber

(Source : www.en.wikipedia.org)

Space shuttle



Figure 1.4d: Space Shuttle

(Source : www.en.wikipedia.org)

**Demonstrator control surface featuring ribs and spars made
by diaphragm forming combined with RTM and skins made
by resin film infusion**

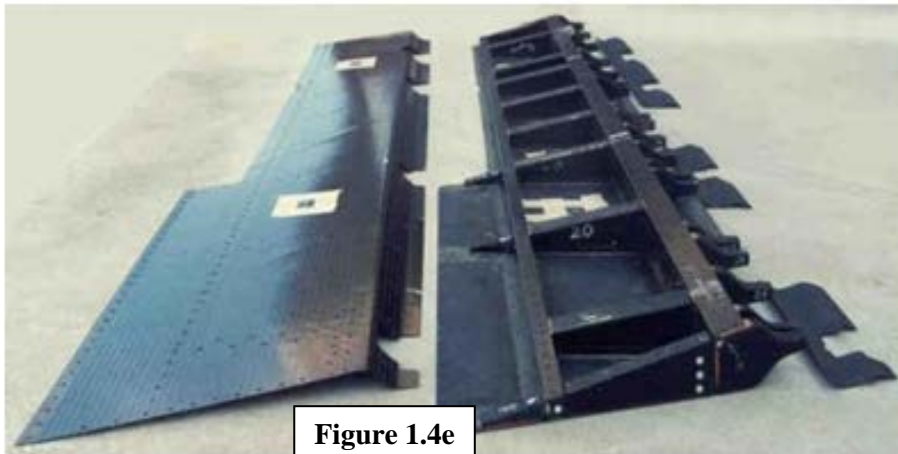


Figure 1.4e: Ribs and Spars made by resin film infusion (Source : comptec, I.I.T. Madras)

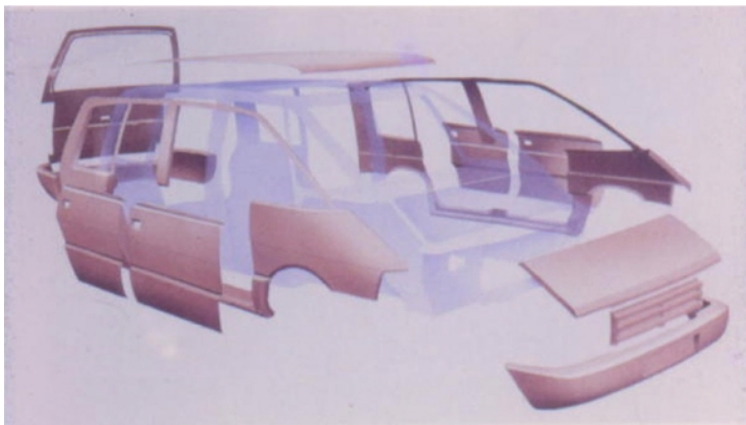


Figure 1.4f: Composite car frame

(Source : comptec, I.I.T. Madras)



Figure 1.4g1: Composite body frame

(Source : comptec, I.I.T. Madras)

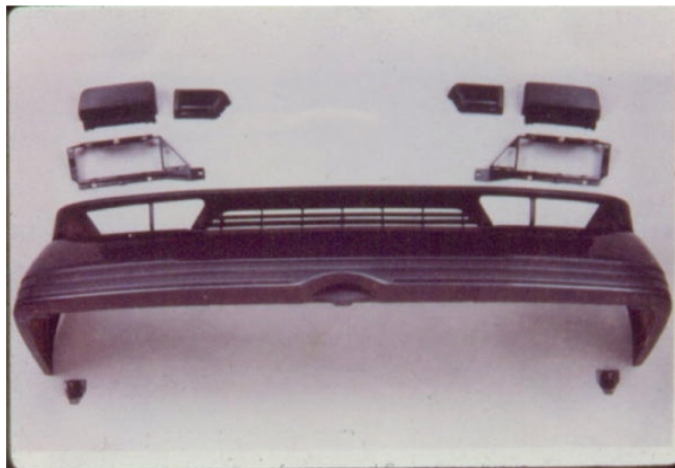


Figure 1.4g2: Bumper made of glass filled polyurethane

(Source : comptec, I.I.T. Madras)



Fig.1.4h1: Composite structure of ship

(Source : comptec, I.I.T. Madras)



Fig.1.4h2: Composite boats (Source : comptec, I.I.T. Madras)

❖ Infrastructure

Due to non-corrosion character, FRC is used in bridge construction. Due to light weight, FRC is preferred for constructing large bridges. Other areas in which composites are widely used, include

- Buildings
- Other civil structures

Building and Civil Engineering

- About 16% of GRP goes into this field
- Used for achieving complex architectural forms
- Costlier than many other construction materials
- A few kilogram of consumption of FRP can lead to fairly large market

Advantages in Civil Engineering Applications

- Used for portable prefabricated houses and offices
- Used for creating various architectural forms in buildings
- Used for replacing timber in buildings
- Translucent decorative and roofing panels
- Used for the renovation and remodelling of old buildings

Fibers like carbon, Kevlar and boron are not used in building constructions due to high cost and difficulty in getting these fibers. Some of FRP products in civil constructions are given below.

Window frames

Bathroom panels

Cladding panels

Internal partitions

Roof light sheets

Domes and other roof structures

Pipes and ducts

Pipes and pipe fittings

Wash basins and kitchen sinks

Petrol station canopy

Swimming pools

Diving boards

Translucent roofing sheets

Doors and window frames

Door panels

Overhead water storage tank

False ceiling panels

Pipe lines for transporting oil and chemicals

Lining of cannels



Figure 1.4i1 composite pipes (Source : comptec, I.I.T. Madras)



Figure 1.4i2 composite toilet (Source : comptec, I.I.T. Madras)

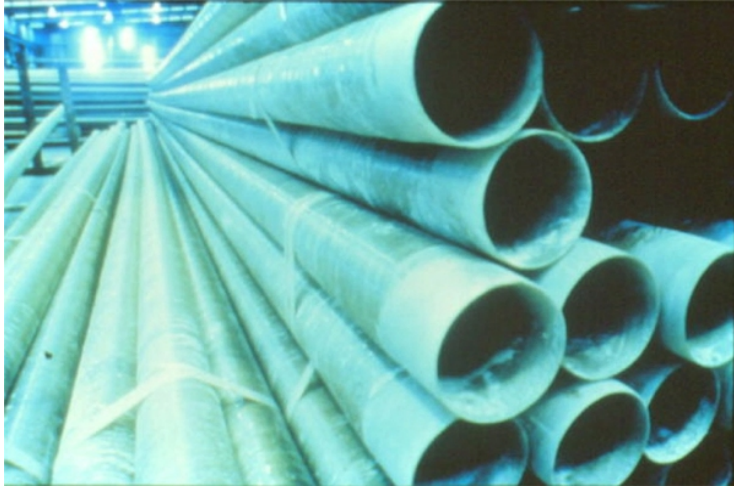


Figure 1.4i3 composite pipe (Source : comptec, I.I.T. Madras)

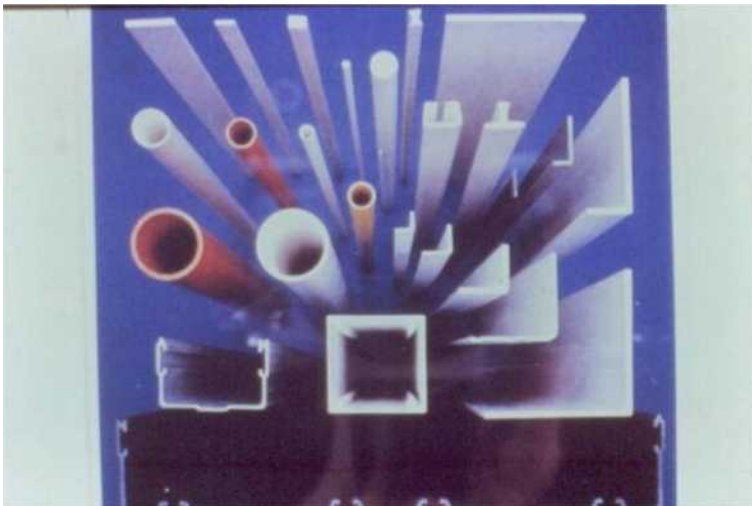


Figure 1.4i4 composite tubes and sheets (Source : comptec, I.I.T. Madras)

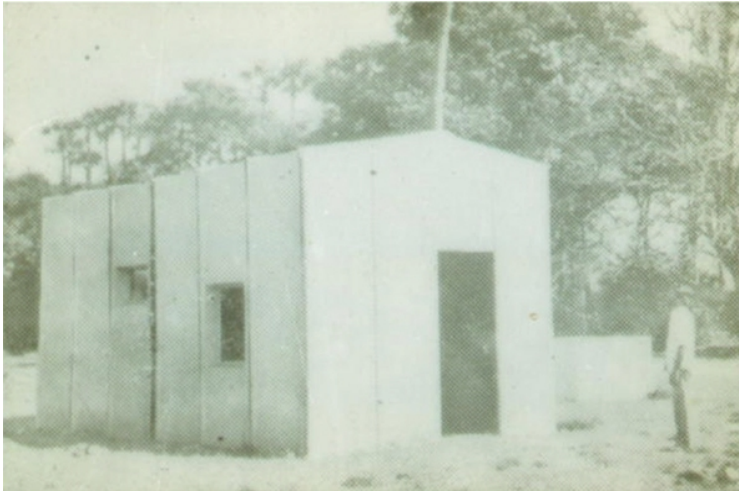


Figure 1.4i5 jute fiber home model (Source : comptec, I.I.T. Madras)



Figure 1.4i6 fiber tables and chairs (Source : comptec, I.I.T. Madras)



Figure 1.4i7 composite door (Source : comptec, I.I.T. Madras)



Figure 1.4i8 composite window (Source : comptec, I.I.T. Madras)



Figure 1.4j1 Wood rivet dome (Source : comptec, I.I.T. Madras)

Composites are highly used in Chemical Industries.

Filament wound Pressure bottles for gas storage



Figure 1.4j2 Pressure storage bottles (Source : comptec, I.I.T. Madras)



Figure 1.4j3 Fuel storage tanks

(Source : comptec, I.I.T. Madras)



Figure 1.4j4 Storage tanks (Source : comptec, I.I.T. Madras)

Advantages of composites in Chemical equipment and corrosion resistant products

- Low cost of fabrication compared with other chemical resistant materials
- Used as anti-corrosive materials and also as construction materials.
- Thermosets are mainly used because of their adaptability to fabrication of large products.
- Thermoplastics without any reinforcements are used as lining materials.
- 50% to 2/3rd of GRP produced in India is used for the corrosive resistant product manufacture.

APPLICATIONS

Tanks and vessels

- Fuel storage tanks
- Reactors
- Boiling tubs

Towers and columns

- Distillation column
- Cooling towers

Pumps, Fans, Blowers

- Centrifugal pumps
- Fans and blowers

Misc. Applications

- Valves and filters
- Water treatment equipment
- Electroplating equipment
- Photographic trays

Composites in Electrical, Electronics and Communication

- GRP are transparent to electromagnetic and sonar signals.
- GRP have properties like electrical insulation with high strength and light weight.
- Used for making printed circuit boards.
- GRP provides radio transparency and are easily mouldable to any shape.

APPLICATIONS

ELECTRICAL APPLICATIONS

- A.C. motor starter
- Transformer fuse block
- Cable ducts
- Switch activators
- Electrical separators
- Activator cases
- Low/high tension insulators

Electronic applications

- Printed circuit boards
- Electromagnetic antennas
- Sonar and laser
- Radomes
- Radio and transistor housing



Figure 1.7a Radomes (Source : comptec, I.I.T. Madras)

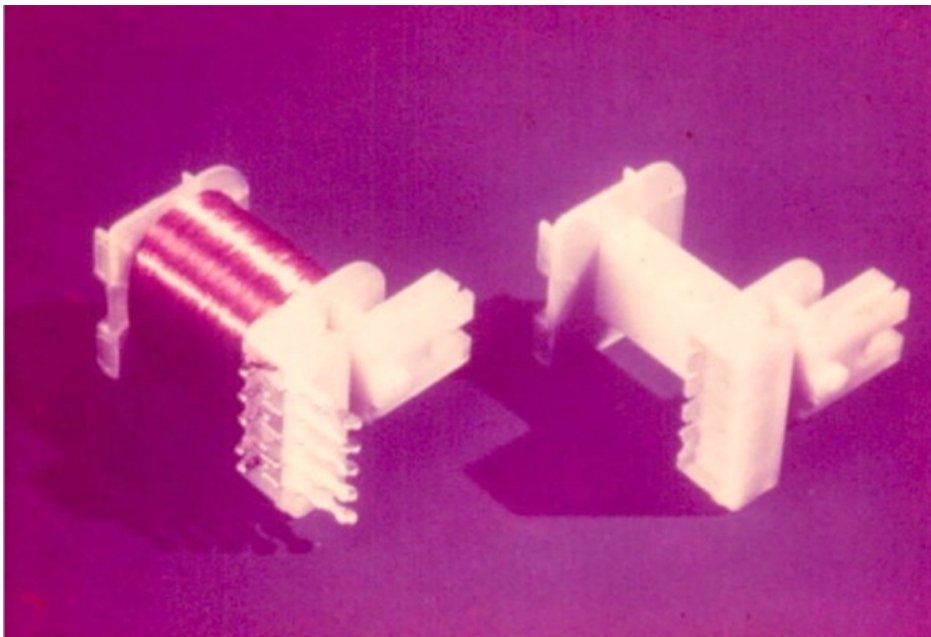


Figure 1.4k1 cable ducts (Source : comptec, I.I.T. Madras)

Machine Elements and Mechanical

Engineering Applications

Gears and bearings

Various linkages of robots

Fan housing

Axial flow fan blades in power plants

Cooling towers and cooling tower fan blades

Wind mill blades

Automobile leaf springs

Automobile drive shafts

Automobile engine

Hydraulic cylinders

Kinetic energy storing

Springs and suspensions

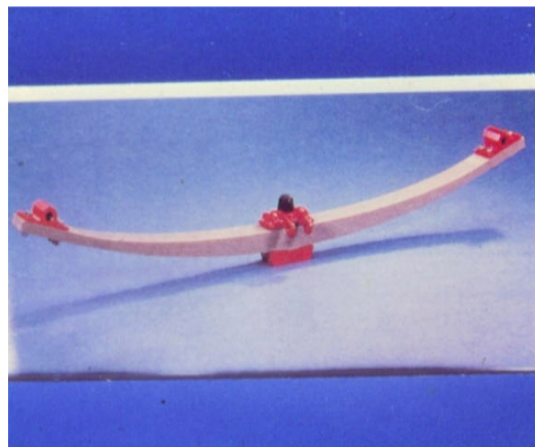
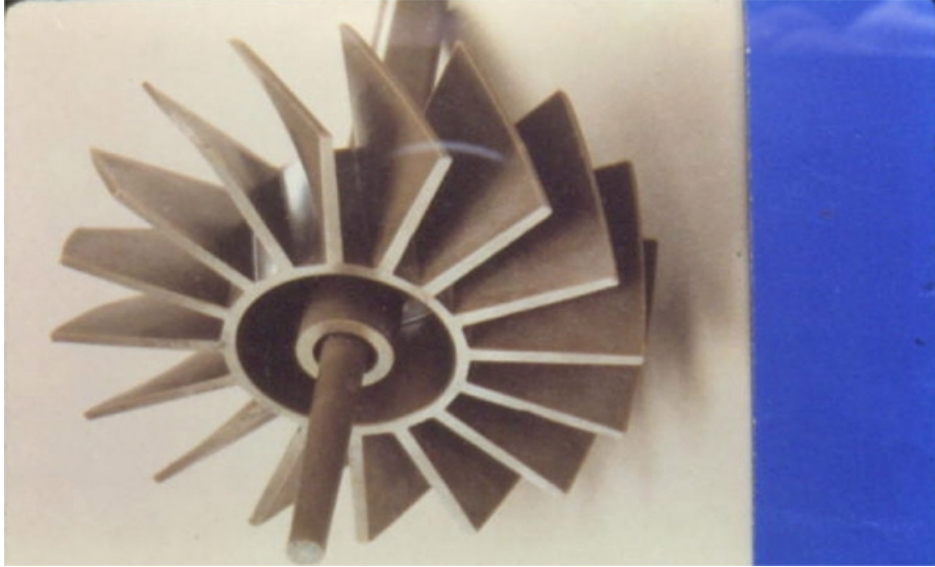


Figure 1.411 : Composite Leaf Spring (Source : comptec, I.I.T. Madras)



PEEK Composite

Figure 1.412 : Turbine blades (Source : comptec, I.I.T. Madras)

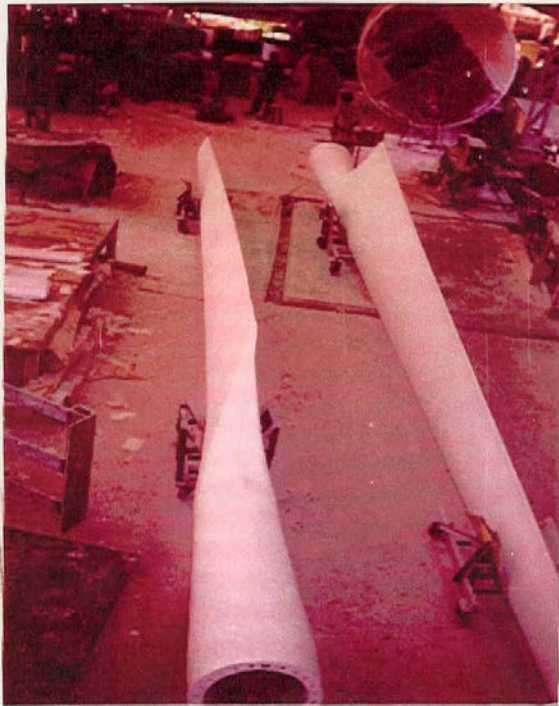
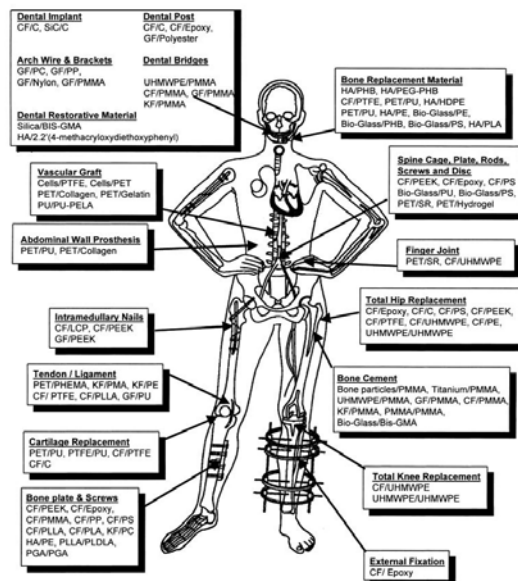


Figure 1.4L3: Wind mill Blade (Source : comptec, I.I.T. Madras)



Figure 1.4L5 Brake caliper (Source : comptec, I.I.T. Madras)

Replacement of various human body parts with composite materials



(Source : comptec, I.I.T. Madras)

Composite material are promising in medicine

Implants are done by composites due to

- Mechanical properties similar to natural tissues
- Biological compatibility
- Can be formed into various shapes
- Bio stable material are used for long term implants

PSU-HAP : Polysulphone-Hydroxyapatite

PGLA-HAP : Poly (Lactide-co-glicol)-Hydroxyapatite

- Durability test is done by creep test

Rehabilitation Aid – Poly propylene – carbon/glass fiber

Figure 1.4m Rehabilitation aid (Source : comptec, I.I.T. Madras)



Figure 1.4m1 Artificial foot(Source : comptec, I.I.T. Madras)

Some of the human parts are replaced by composites

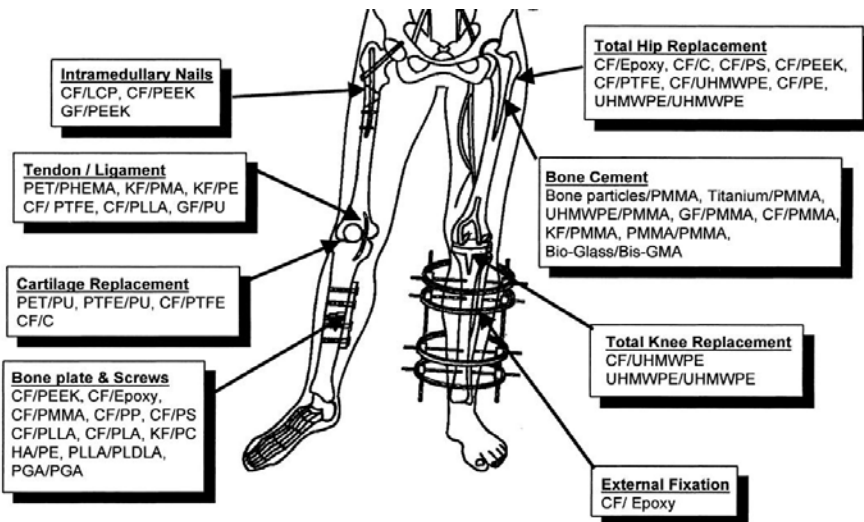


Figure 1.4m2 The parts of human leg being replaced by composites (Source : comptec, I.I.T. Madras)

CF: carbon fibers
C: carbon
BIS-GMA: bis-phenol A glycidyl methacrylate
GF: glass fibers
HA: hydroxyapatite
KF: kevlar fibers
PP: Polypropylene
PLDLA: poly(L-DL- lactide)
PLLA: poly (L-lactic acid)
PGA: polglycolic acid
PS: polysulfone
PC: polycarbonate
PEEK: polyetheretherketone
PMA: polymethylacrylate
PMMA: Polymethylmethacrylate
PU: polyurethane
PTFE: polytetrafluoroethylene
PET: polyethyleneterephthalate
PEA: polyethylacrylate
SR: silicone rubber
PELA: Block co-polymer of lactic acid and polyethylene glycol
LCP: liquid crystalline polymer
PHB: polyhydroxybutyrate, PEG: polyethyleneglycol,
PHEMA: poly(20hydroxyethyl methacrylate)
UHMWPE: ultra-high-molecular weight polyethylene

Various applications of different polymer composite biomaterials.