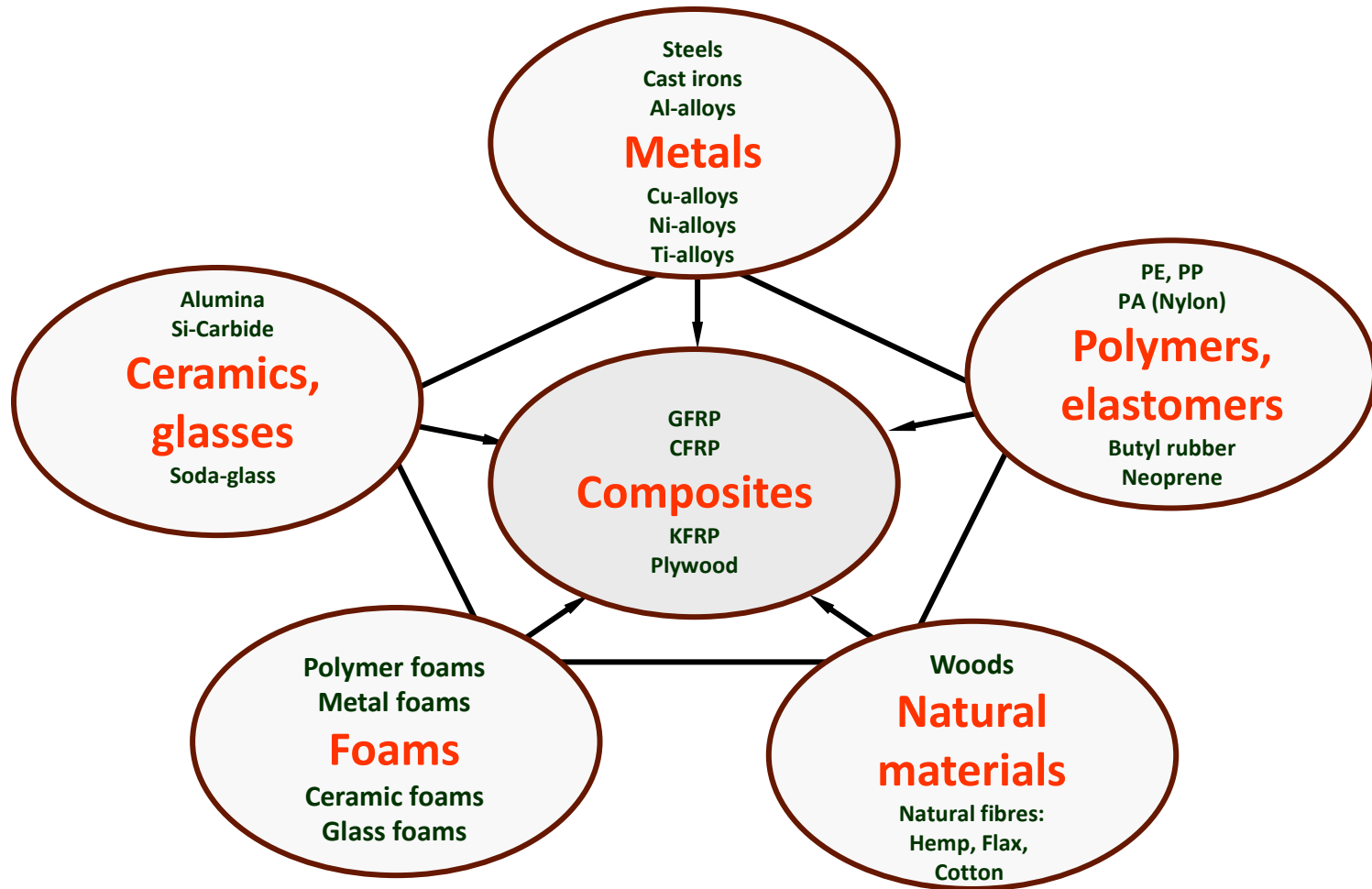


COMPOSITE MATERIALS

The world of materials



Definition

- A broad definition of composite is: Two or more chemically distinct materials which when combined have improved properties over the individual materials.
- The constituents retain their identities in the composite; that is, they do not dissolve or otherwise merge completely into each other, although they act in concert.

Advantages of Composites

- Light in weight
- Strength-to-weight and Stiffness-to-weight are greater than steel or aluminum
- Fatigue properties are better than common engineering metals
- Composites cannot corrode like steel
- Possible to achieve combinations of properties not attainable with metals, ceramics, or polymers alone

Components in a Composite Material

- Nearly all composite materials consist of two phases:
 1. Primary phase - forms the *matrix* within which the secondary phase is imbedded
 1. Secondary phase - imbedded phase sometimes referred to as a *reinforcing agent*, because it usually serves to strengthen the composite
 - The reinforcing phase may be in the form of fibers, particles, or various other geometries

Functions of the Matrix Material (Primary Phase)

- Provides the bulk form of the part or product made of the composite material
- Holds the imbedded phase in place, usually enclosing and often concealing it
- When a load is applied, the matrix shares the load with the secondary phase, in some cases deforming so that the stress is essentially born by the reinforcing agent

The Reinforcing Phase (Secondary Phase)

- Function is to reinforce the primary phase
- Imbedded phase is most commonly one of the following shapes:
 - Fibers
 - Particles
 - Flakes

Factors in Creating Composites

Matrix material

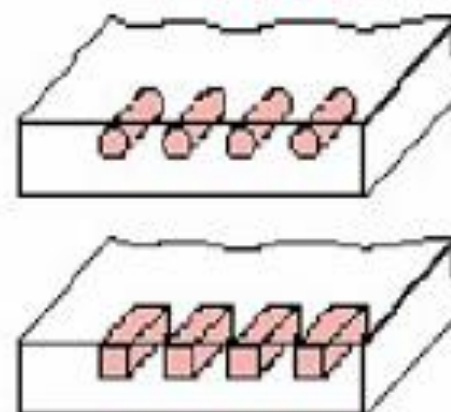
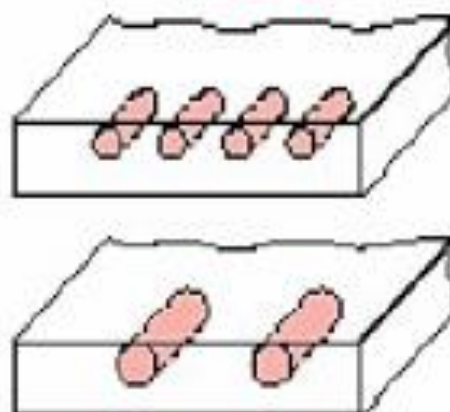
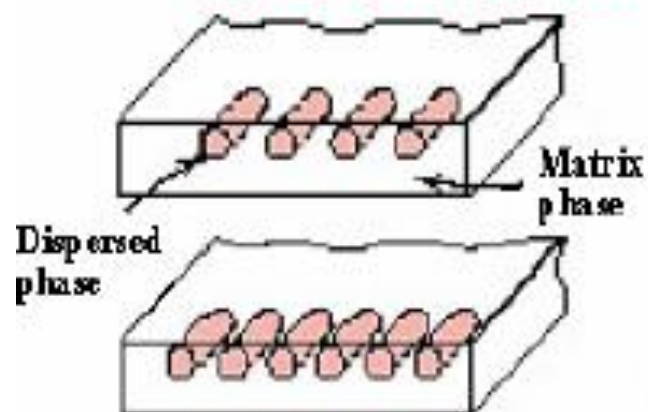
Reinforcement material

- *Concentration*
- *Size*
- *Shape*
- *Distribution*
- *Orientation*

concentration

size

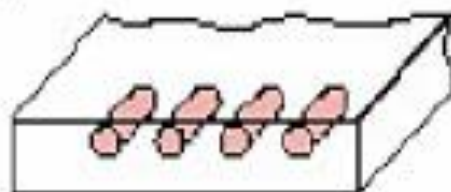
shape



(a)

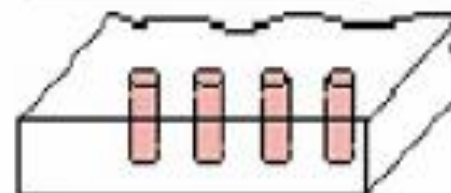
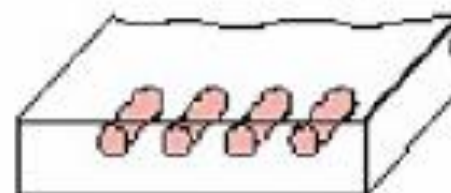
(b)

(c)



(d)

distribution

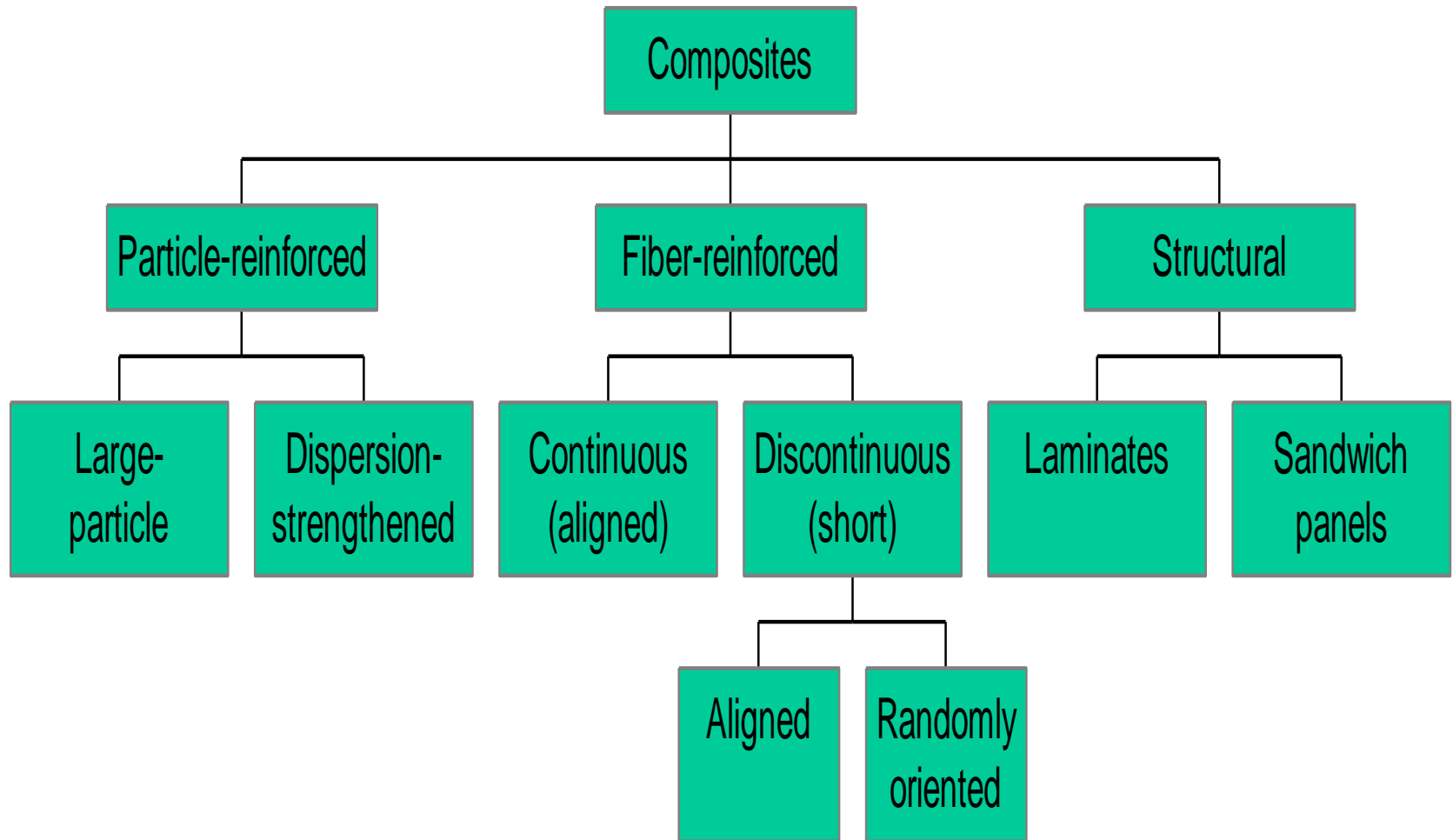


(e)

orientation

Classification

Based on type of reinforcement



Large particle reinforced composites

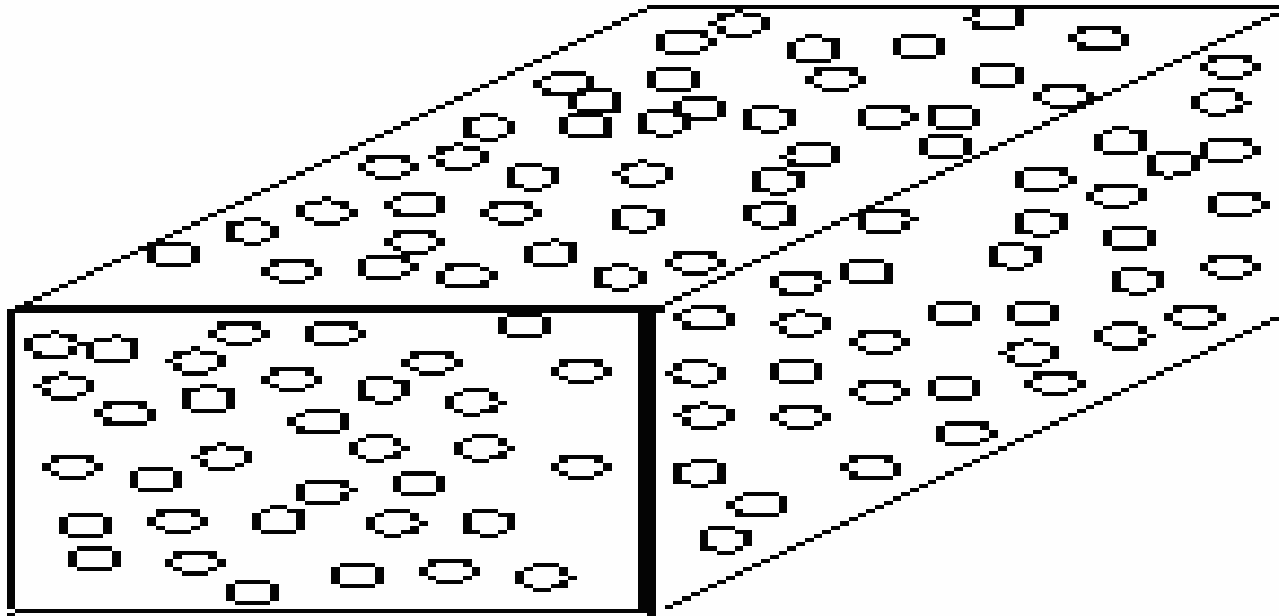
- Particle size is 1-50 μm
- Concentration usually ranges from 15-40% by volume
- The particulate phase is harder and stiffer than the matrix.
- Particles provide strength to the composite by restraining the movement of the matrix

- **Cermets**-tungsten carbide or titanium carbide
- **Vulcanized rubber**- carbon black in rubber
- **Concrete**- sand and gravel particulate in a surry of cement matrix.

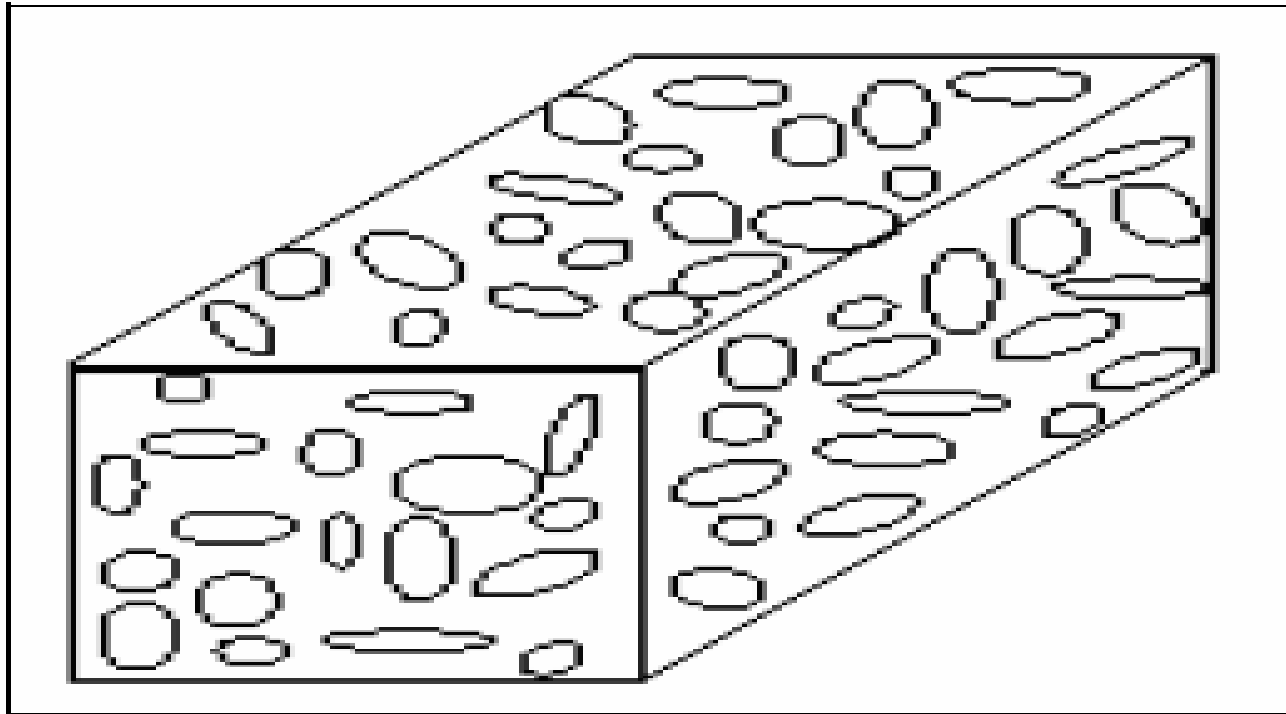
Dispersion strengthened composites

- Uniformly dispersed fine, hard and inert particles of size less than $0.1\mu\text{m}$ are used as reinforcement
- The volume fraction is between 5-15%
- These particles are stronger than the pure metal matrix and can be metallic, inter-metallic or nonmetallic.
- Matrix is the load bearing phase
- Eg. SAP, TD-Nickel, $\text{Cu-Al}_2\text{O}_3$, $\text{Cu-Zn-Al}_2\text{O}_3$

Particules as the reinforcement (Particulate composites)



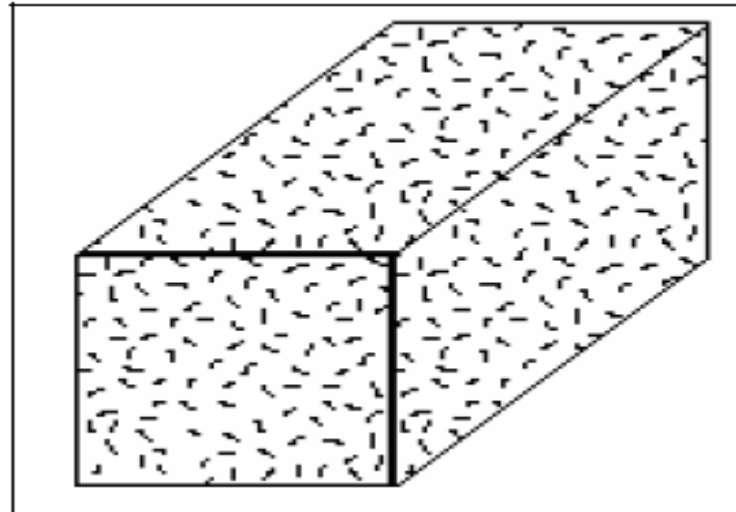
Fillers as the reinforcement (Filler composites)



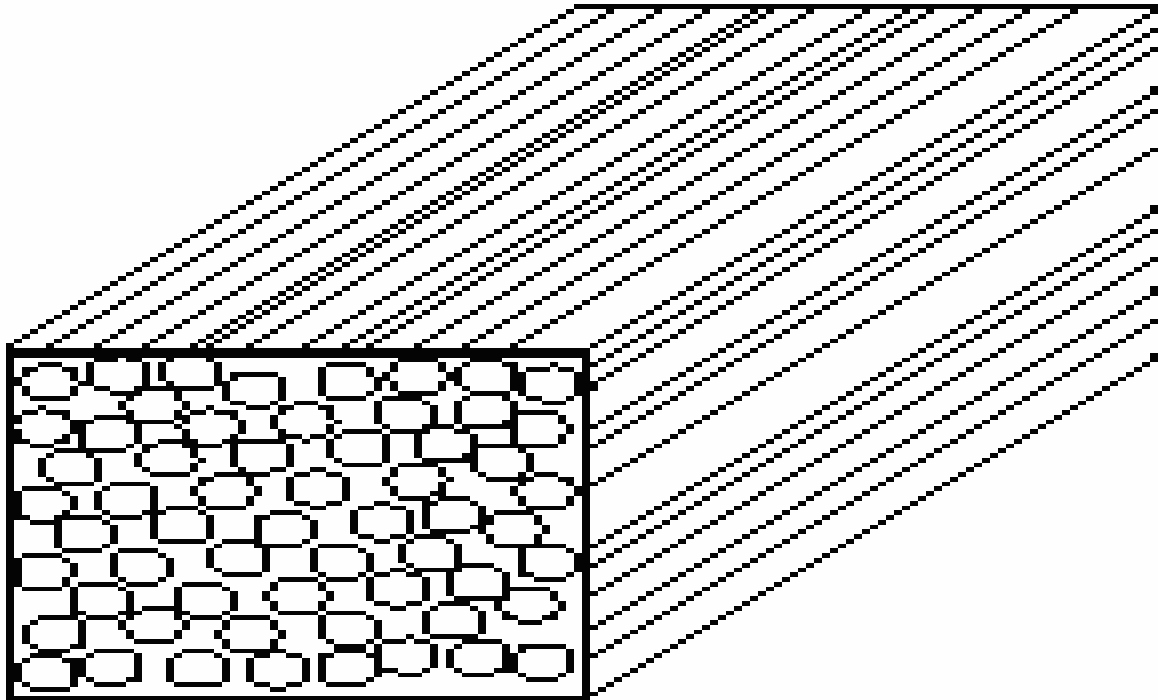
Fibre Reinforced Composites(FRP)

1. Continuous fibre reinforced composites
2. Discontinuous fibre reinforced composites

Random fiber (short fiber) reinforced composites

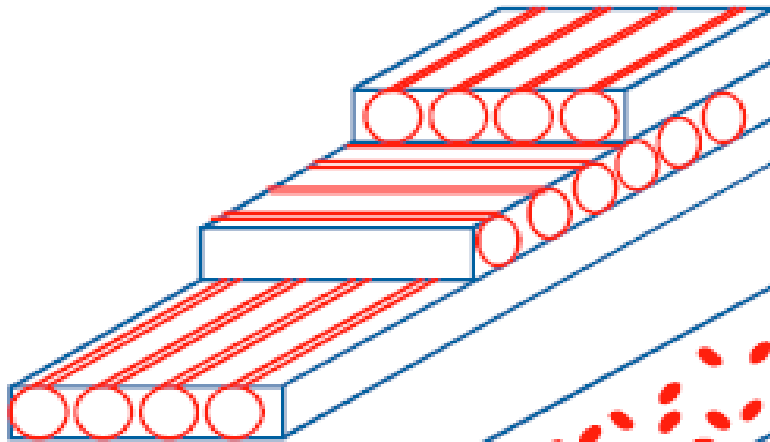


Continuous fiber (long fiber) reinforced composites



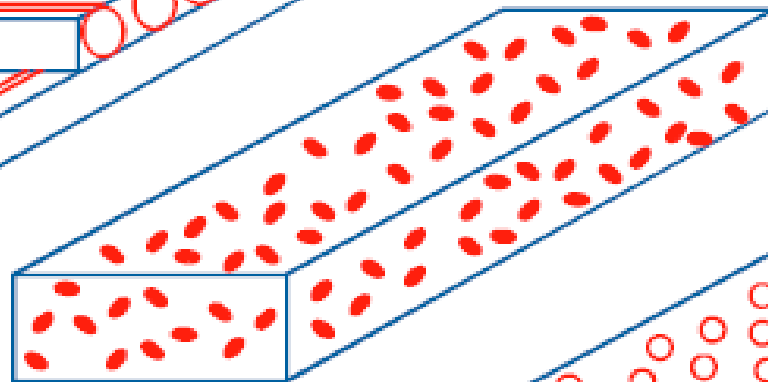
Typical Reinforcement Geometries for Composites

CONTINUOUSLY REINFORCED

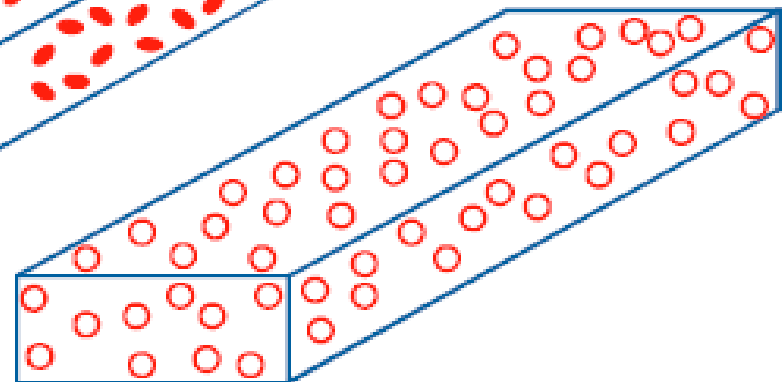


Fibres

DISCONTINUOUSLY REINFORCED



Whiskers and chopped fibres

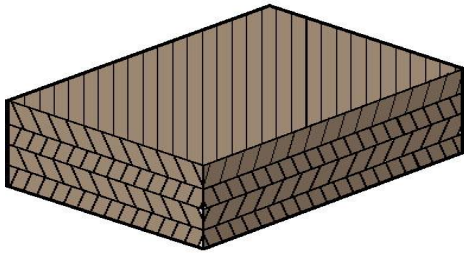


Particulates

OTHER COMPOSITE STRUCTURES

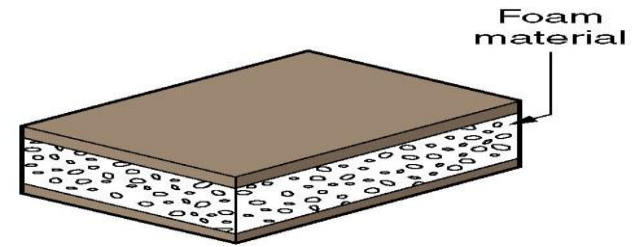
Laminar composite structure :-

Two or more layers bonded together in an integral piece

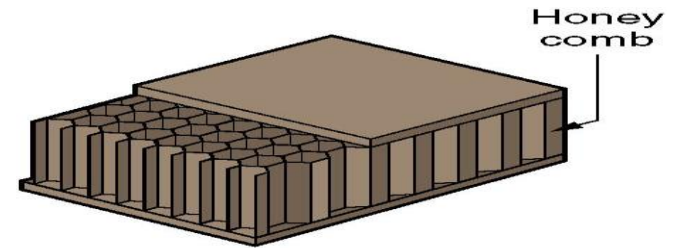


(a)

Sandwich structure:- foam & honey cores



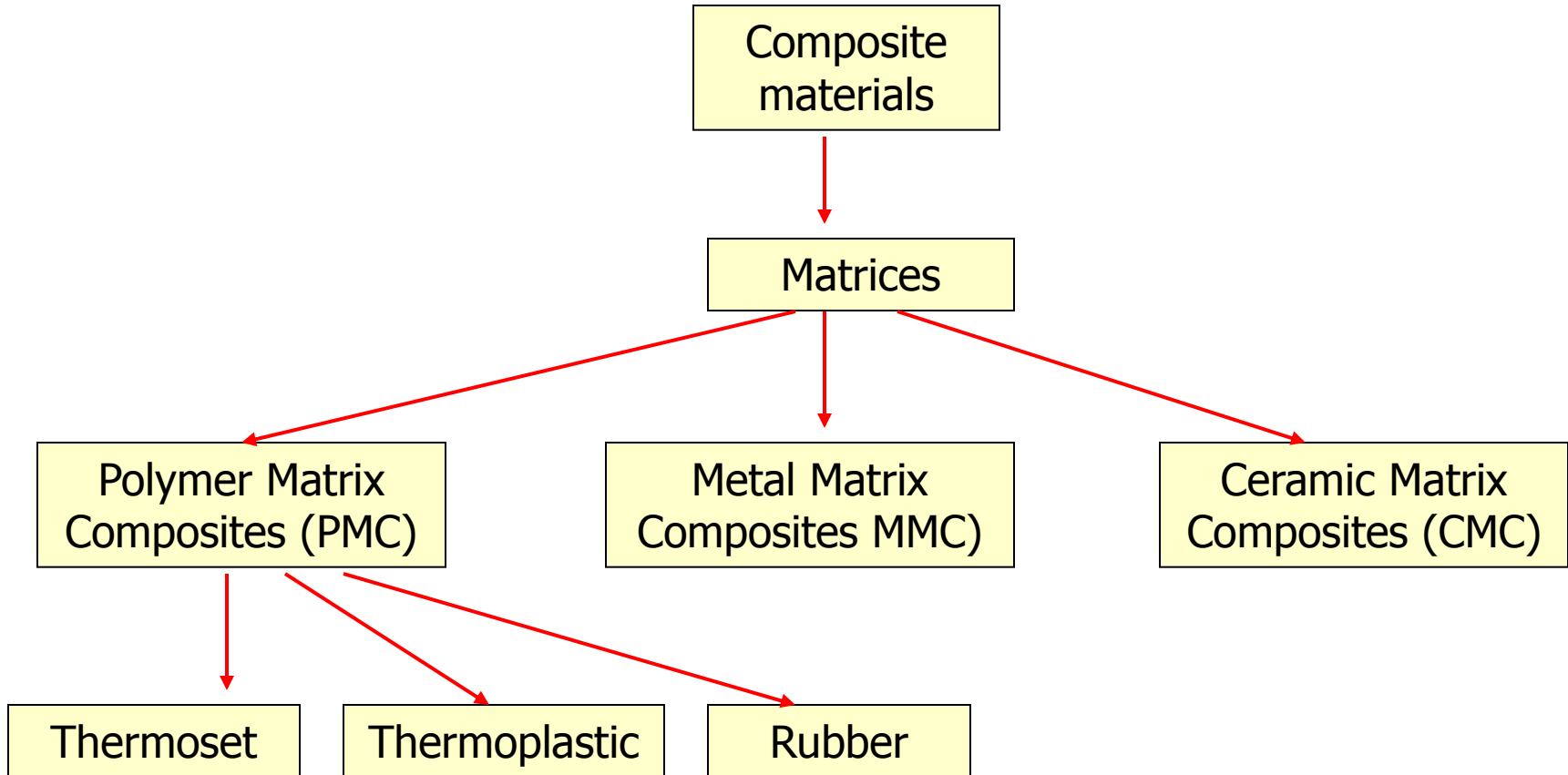
(b)



(c)

Consists of a thick core of low density foam bonded on both faces to thin sheets of a different material

Classification based on Matrices



Role of matrix phase

- Primary function of the matrix phase in a composite is to hold and bind the reinforcing phase in position within it
- Act as a medium through which the external load is transmitted and distributed to the reinforcing phase.
- It separates fibres from each other
- Protects the individual fibres from surface damage due to abrasion and oxidation
- Improves fracture toughness of the composite
- Withstand heat or cold, conduct or resist electricity, control chemical attack

Polymer Matrix Composites

In PMCs *polymer* is the primary phase in which a secondary phase is imbedded as fibers, particles, or flakes

- Commercially, PMCs are more important than MMCs or CMCs
- Low density, high specific strength, high specific stiffness, ease of fabrication.
- *Examples:* Rubber reinforced with carbon black and fiber-reinforced plastic (FRPs)

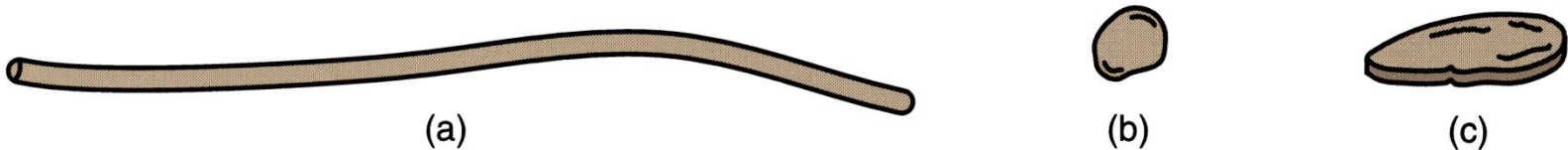
MATRIX & REINFORCEMENT

MATRIX

- Thermosetting polymers are the most common matrix materials
 - Principal TS polymers are:
 - Phenolics – *used with particulate reinforcing phases*
 - Polyesters and epoxies - *most closely associated with FRPs*
- Nearly all rubbers are reinforced with carbon black

REINFORCEMENT

- Possible geometries - (a) fibers, (b) particles & (c) flakes



- Particles and flakes are used in many plastic molding compounds
- Of most engineering interest is the use of fibers as the reinforcing phase in FRPs

Glass fibre reinforced polymer composites

- Contains glass fibre as reinforcing phase in a polymer matrix
- Glass fiber
 - Continuous or discontinuous
 - Dia b/w 3-20 μm
- Lim: not very stiff and rigid
- Automobile and marine bodies, storage containers, plastic pipes, industrial flooring

Carbon fibre reinforced polymer composites

- Contains carbon fibre as reinforcing phase in a polymer matrix
- Advantages
 - High specific strength and specific modulus
 - Higher strength at elevated temperatures
 - Not affected by moisture or acids
- Applications
 - Aerospace application
 - Sports and recreational equipments
 - Pressure vessels

Aramid fibre reinforced polymer composites

- Aramid-polyamide-kevlar or nomex
- Advantages
 - High toughness and impact resistance
 - Resistance to creep and fatigue failure
- Applications
 - Bullet proof vests and armor
 - Sports goods, missile cases
 - Pressure vessels, clutch linings and gaskets

Metal matrix composites

- Metals with low density and low temperature toughness are preferred as matrix metal.
- Aluminium, titanium, magnesium and their alloys
- Advantages
 - Higher operating temperatures
 - Non flammability and creep resistance
 - Greater resistance to degradation by organic fluids.
- Applications
 - Aerospace application
 - Gas turbine blades
 - Electrical contacts

Ceramic Matrix Composites

- Primary objective for developing CMCs was to enhance the toughness while retaining the high temperature properties.
- High melting points and good resistance to oxidation
- But low tensile strength, impact resistant and shock resistance
- eg. Small particles of partially stabilized Zirconia are dispersed within a matrix material Al_2O_3

Hybrid composites

- Obtained by using different kinds of fibers in a single

Applications

1. Aircraft and aerospace applications
2. Automotive applications
3. Marine applications
4. Sporting industries
5. Biomaterials
6. Industrial applications

Lower Drag Brace for the F16

Lower Drag Brace of F16:

Landing gear

Titanium Matrix Composite

Monofilament SiC fibres in a Ti-matrix.



Lightweight Composite Core for Power Lines

Lightweight Aluminum Conductor Composite Core (ACCC)

- Composite Technology Corporation (CTC)
- Twice the amount of electric power as conventional power lines.



Brake rotors for high speed train

Brake rotors for high speed train

- particulate reinforced Aluminium alloy (AlSi7Mg+SiC particulates)
- Weight of cast iron rotor is 120 kg/piece while MMC it is 76 kg/piece



Cylinder liner

Boxter engine block

- Cylinder liner AlSi9Cu3 alloy with 25% Si.
- Squeeze casting infiltration



F-16 Fuel Access Door Covers

- High specific strength and stiffness good bearing strength
- Al Composites
- 6092/SiC/17.5p
- Wrought P/M material
- Elimination of the skin cracking problem



F-16 Ventral Fins

- High specific stiffness and strength
- Al-matrix composites
- Rolled P/M
- 6092/SiC/17.5p
- Decreased deflections provide an increase in fin life



Recreational products

Skating shoe

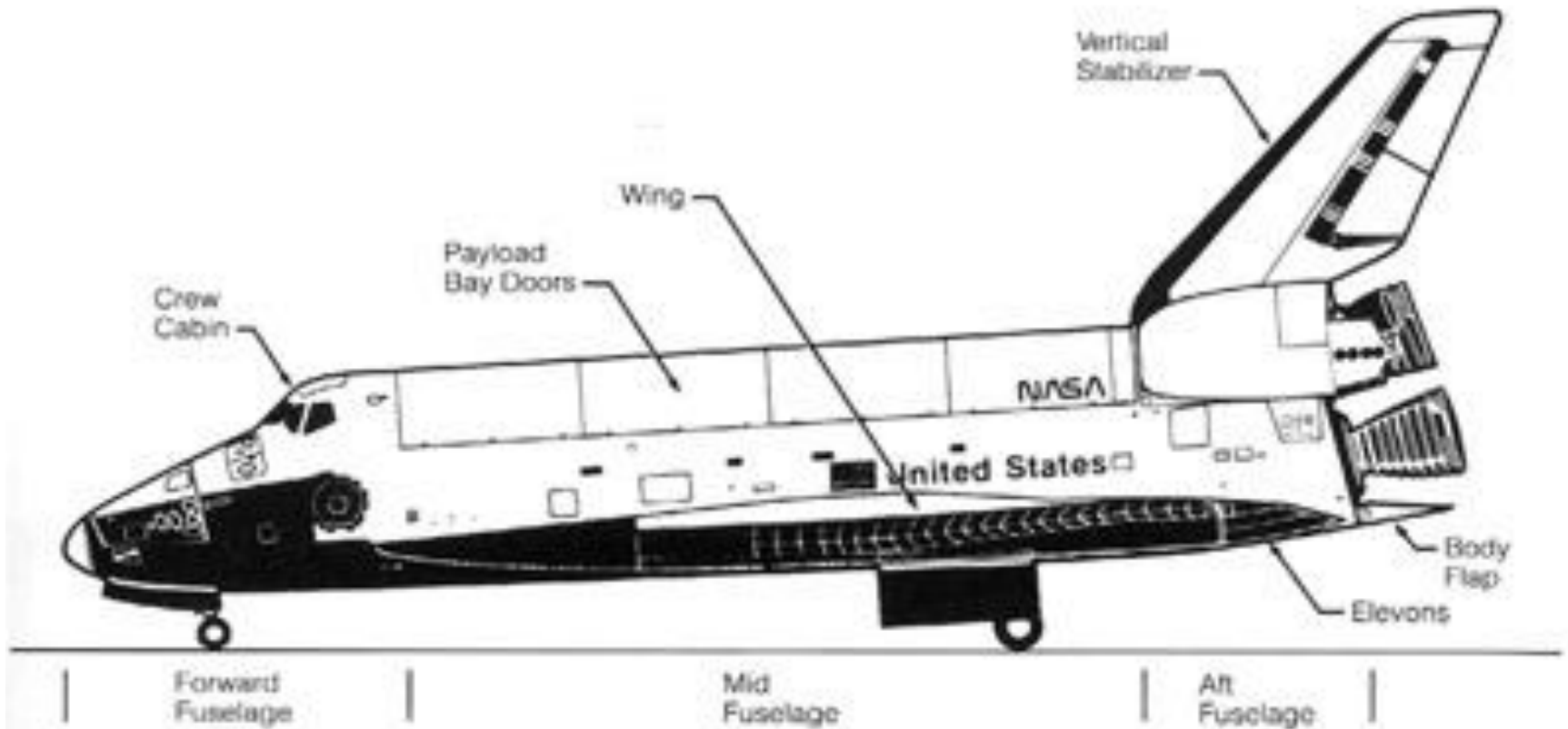
Base ball shafts

Horse shoes

Bicycle Frames



Space Shuttle



Sketch of Space Shuttle Orbiter in the landing configuration viewed from -Y position identifies aerodynamic flight surfaces.

- Mid fuselage frames of Space Shuttle was made of MMCs

Common MMCs and Applications

TABLE 9.3

Metal-Matrix Composite Materials and Applications

| Fiber | Matrix | Applications |
|----------------------|--------------------------|---|
| Graphite | Aluminum | Satellite, missile, and helicopter structures |
| | Magnesium | Space and satellite structures |
| | Lead | Storage-battery plates |
| | Copper | Electrical contacts and bearings |
| Boron | Aluminum | Compressor blades and structural supports |
| | Magnesium | Antenna structures |
| | Titanium | Jet-engine fan blades |
| Alumina | Aluminum | Superconductor restraints in fission power reactors |
| | Lead | Storage-battery plates |
| | Magnesium | Helicopter transmission structures |
| Silicon carbide | Aluminum, titanium | High-temperature structures |
| | Superalloy (cobalt-base) | High-temperature engine components |
| Molybdenum, tungsten | Superalloy | High-temperature engine components |

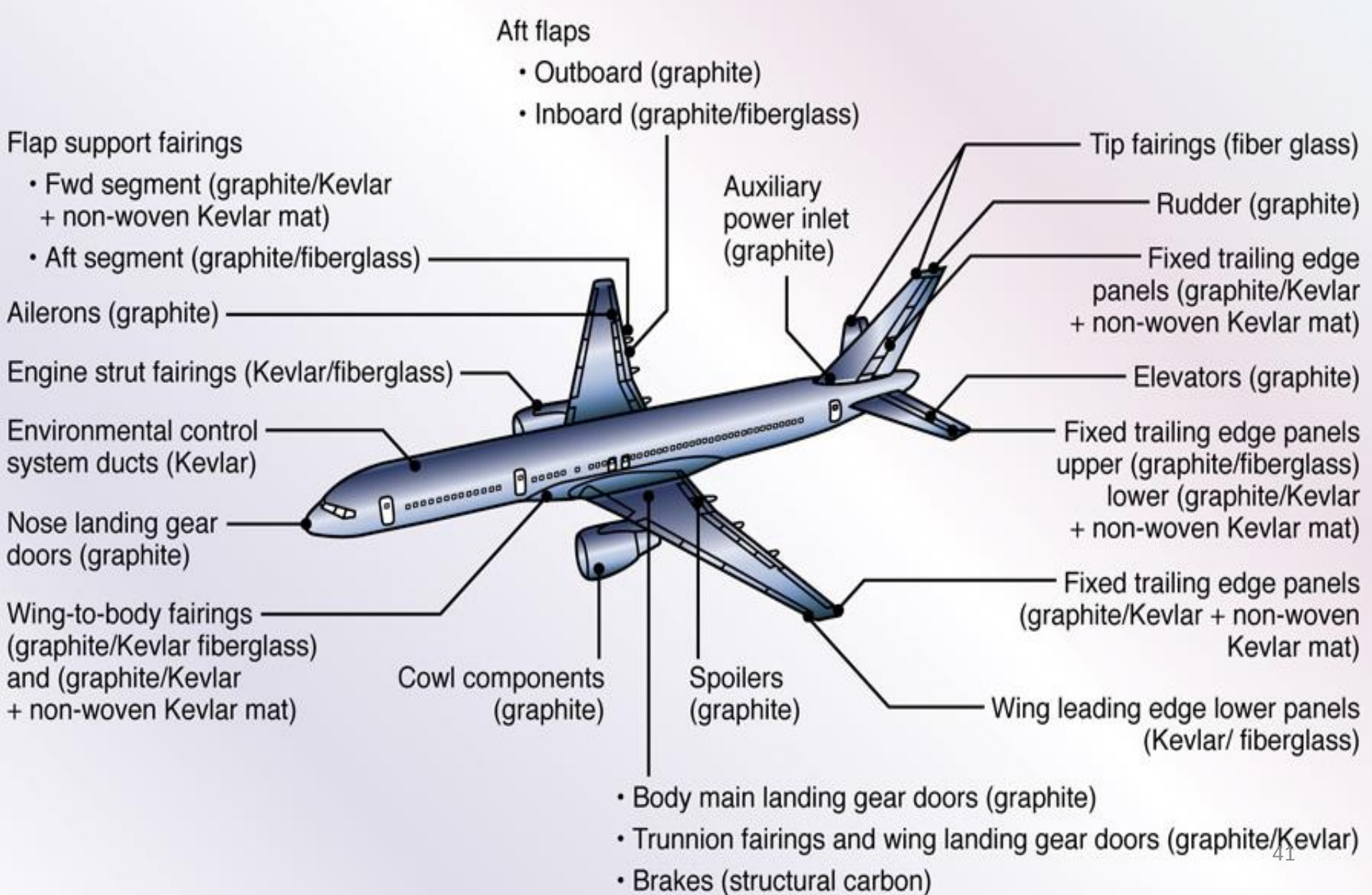
Metal Matrix Automotive Brake Caliper

Aluminum-matrix composite brake caliper using nanocrystalline alumina fiber reinforcement.



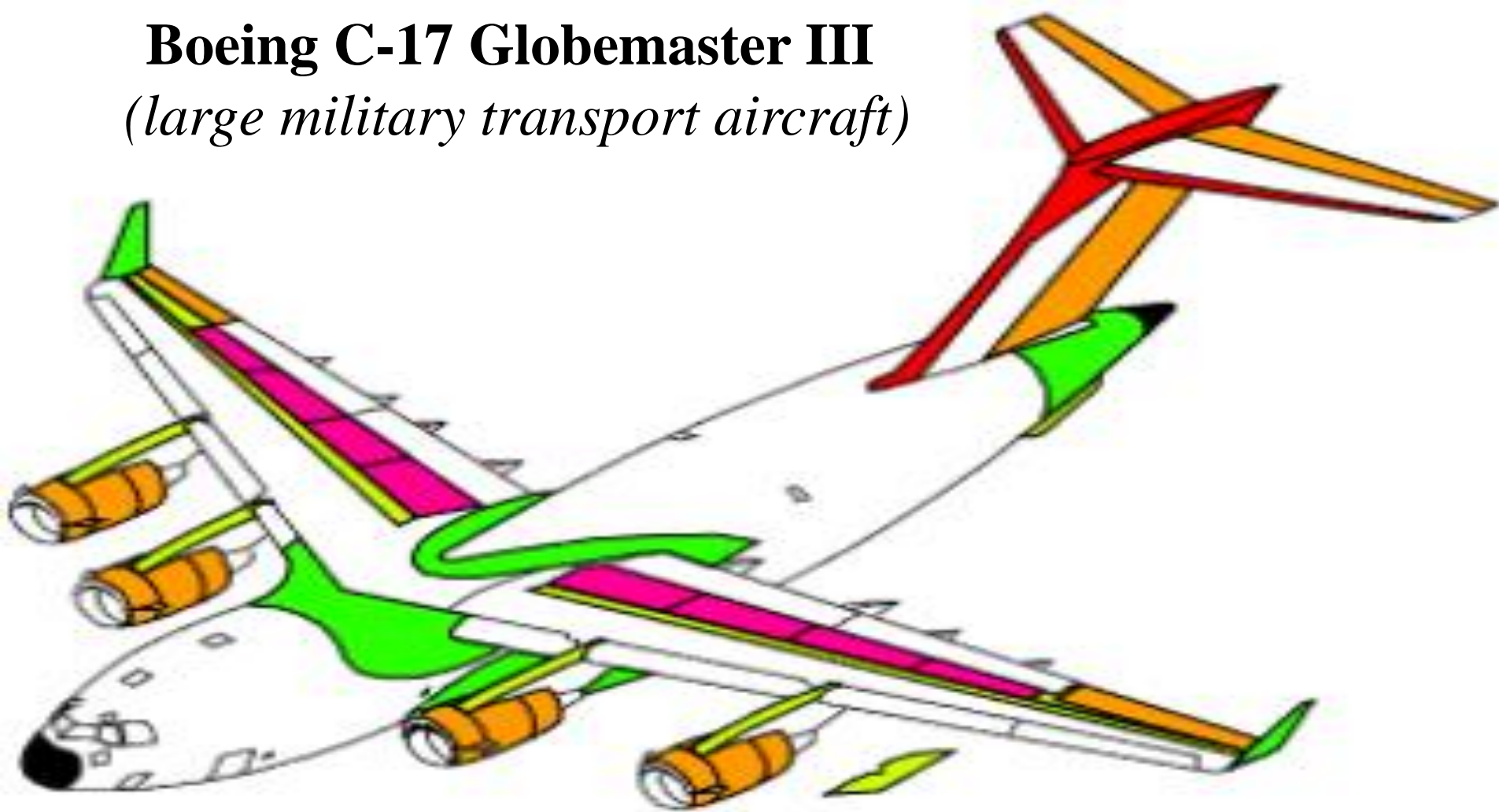
Application of advanced composite materials in Boeing 757-200 commercial aircraft.

Source: Courtesy of Boeing Commercial Airplane Company.



Boeing C-17 Globemaster III

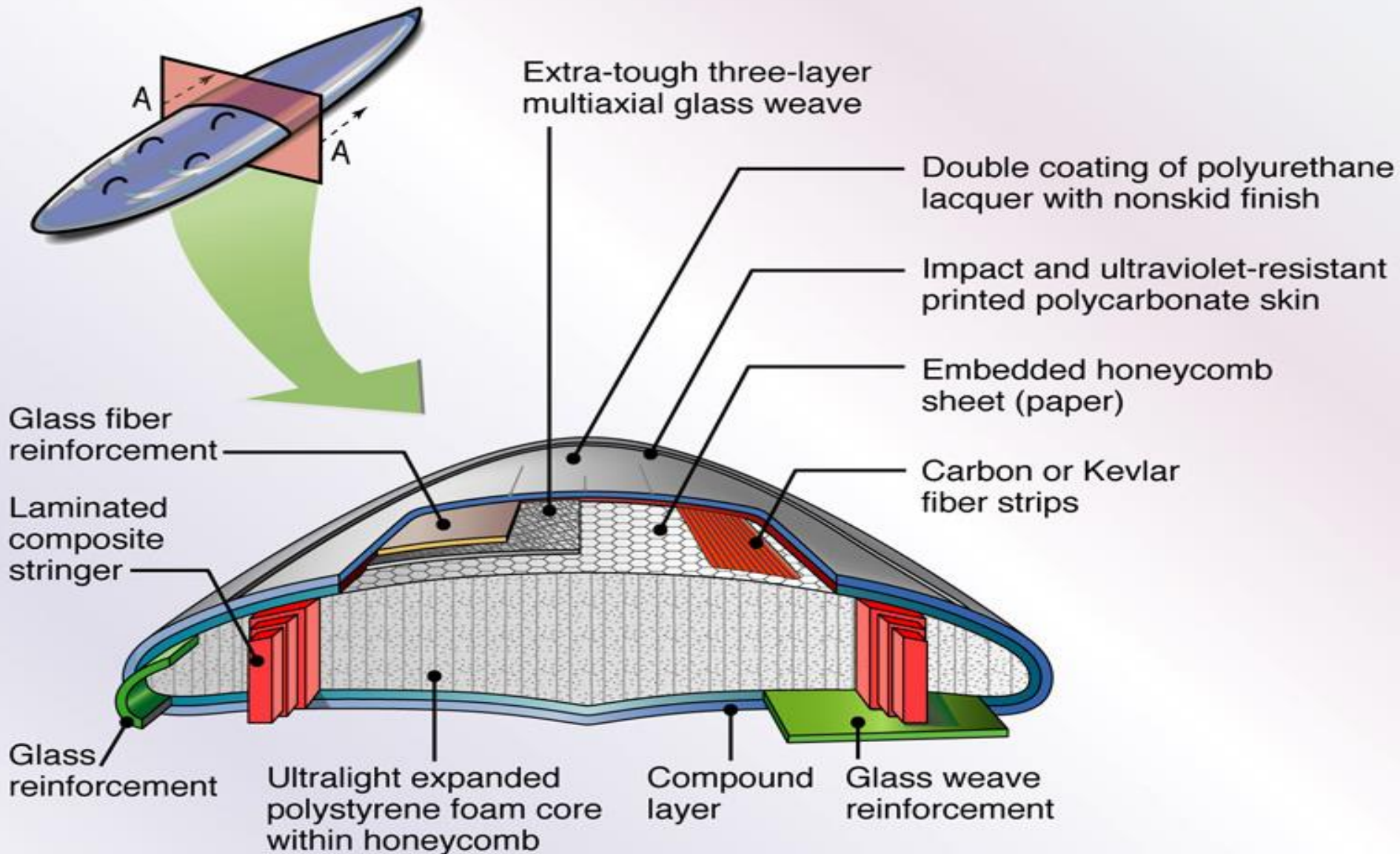
(large military transport aircraft)



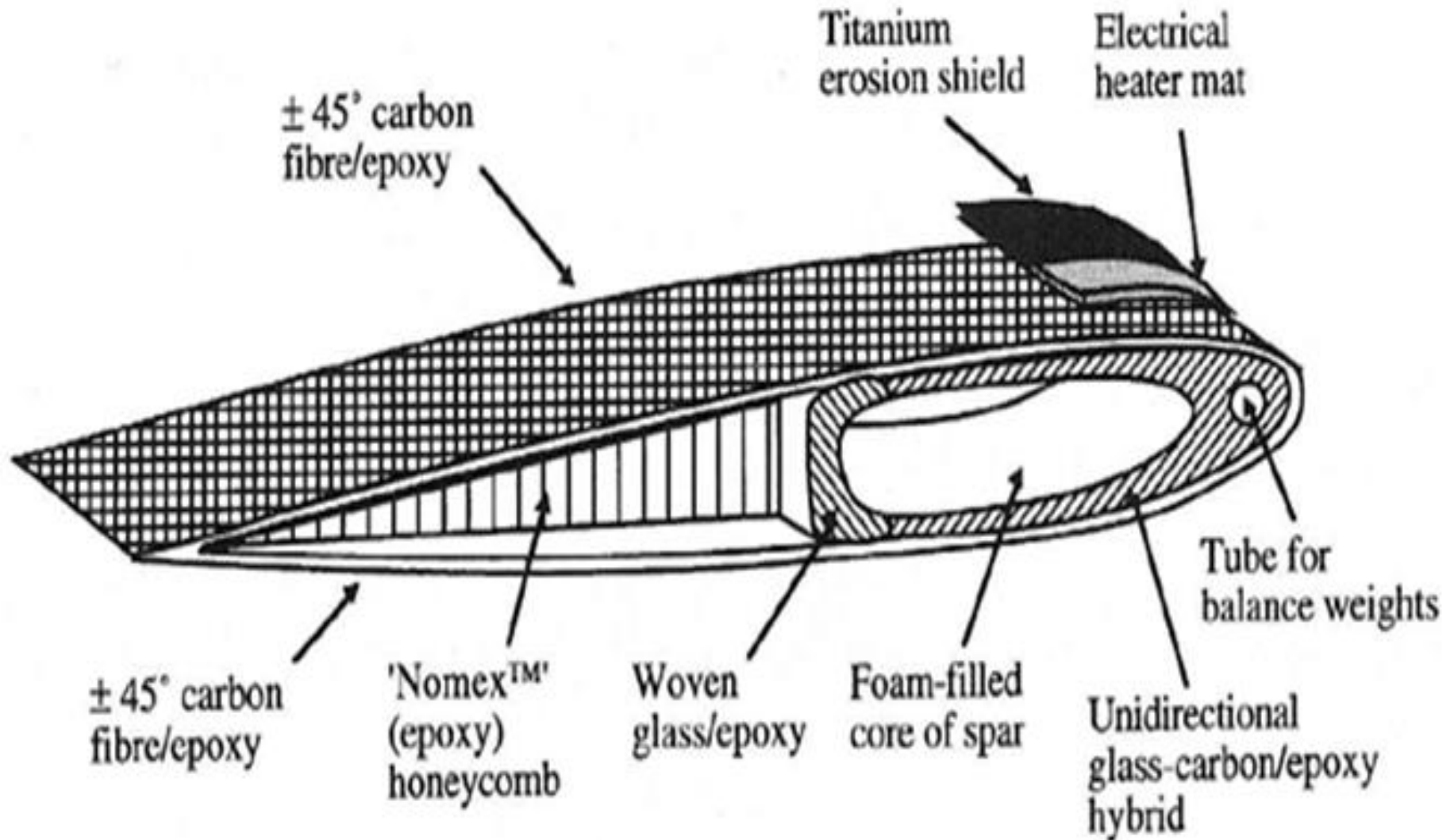
- | | |
|---|--|
|  Carbon/epoxy |  Aramid/DuPont Nomex |
|  Carbon/aramid/epoxy |  Aramid/foam core |
|  Glass-fiber reinforced plastic |  Carbon/DuPont Nomex |

Cross-section of a composite sailboard.

Source: K. Easterline, *Tomorrow's Materials* (2nd ed.), p. 133. Institute of Metals, 1990.



Helicopter rotor blade



Schematic section through a typical composite construction for a helicopter rotor blade. (Courtesy of Westland Helicopters.)



Wing Panel



Automotive structure



Aerospace parts

Sporting goods



Delta IV Rocket faring mandrel



Disadvantages and Limitations of Composite Materials

- Properties of many important composites are anisotropic - the properties differ depending on the direction in which they are measured – this may be an advantage or a disadvantage
- Many of the polymer-based composites are subject to attack by chemicals or solvents, just as the polymers themselves are susceptible to attack
- Composite materials are generally expensive
- Manufacturing methods for shaping composite materials are often slow and costly