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Textile Composite Materials

A review

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l. Textile -Materials:

1.1: General:

Textile materials have been known to have two main areas of applications. These are domestic and industrial uses. Every field of application is dictated by the end use of the product, which in turn decides the raw material to be used. Hence, a plan is to be put in advance for the selection of the appropriate raw material to be used with their different properties put in -mind. The raw materials for textile products are fibre produced from natural origins, synthetics or regenerated chemically. These different kinds of fibres have different properties each of which suits an end use of a product. Each end-use requires a complete line or different processes depending on the physical and chemical properties of the fibres.

I .2: Definition of fibres:

Fibres are defined as materials characterized by their high length to width ratio, fineness and elasticity. For the textile industry, in general, they should acquire other characteristics, They should have a minimum amount of tensile strengths a high degree of orientation, and thermal and dimensional stability. Textile fibres are found in a staple length of or in a continuous filament forms. They should be tested for their quality before being processed so that they can meet the requirements of their final products end use.

1.3: Forms of textile materials:

Textile materials have a wide range of different forms and shapes (Datoo, 1991). They can be:

1- Single form fibres:

2- Yarns: which are collection of single aligned fibres with different characteristics and properties and they are made by different techniques of spinning processes.

3- Fabrics; which are woven, non- woven, or knitted owing different characteristics and properties and made by different techniques of fabric formation.

These different kinds of textile materials can be used domestically or industrially after further processing and fabrication.

2. High performance fibres:

2.1. Introduction:

It is well known that fibres are stronger along their lengths than the same material in bulk form. This is because of their small cross-sectional dimensions, thus minimizing the inherent presence of molecular imperfections, flaws and dislocations. The commonly used fibres in engineering applications are glass, carbon, and Kevlar (aramid) fibres which are characterized by:

I - A high modulus of elasticity in the direction of the fibre.

2- A high ultimate strength in the direction of the fibre.

3- A low variation of mechanical properties between individual fibre.

4- Stability and retention of mechanical properties during handling and fabrication.

5- A uniform fibre cross-section.

These fibres are useless structural engineering applications unless they are bound together to form a structural element capable of withstanding loads known as composites.The composites formed by fibres are called fibrous composites.

2.2. Reinforcing fibres:

There are basically two kinds of glass fibres; E (electrical) -glass and S (silica)- glass fibres. E-glass is mostly used as it has satisfactory strength and stiffness values, S-glass has superior strength and stiffness properties but is very costly to produce.

Kevlar (aramid) fibres have good impact resistance. Properties, but poor compressive strength, so it is mainly used for impact resistance applications. There are two basic variants of Kevlar; one of a low modulus type (~60 GPa) like Kevlar 29 and another of a high modulus type (~120 GPa) like Kevlar 49.

All of these types have similar tensile strengths of about 3 GPa. Kevlar 149, however, being the recent aramid type, is much stronger. Kevlar 29 is mainly used for ropes, cables and webbings while Kevlar 49 is used for high performance fibre- reinforced composites. The poor compressive performance is compensated in their use in hybrid constructions with glass and carbon to utilize their high tensile properties and toughness.

Carbon fibres are found in a variety of strength - modulus characteristics. They range from high modulus-low strength to low modulus-high strength characteristics, Intermediate ranges of fibres, combining the stiffness and strength characteristics of the fibre, are also available and are widely used. These high performance fibres used to strengthen materials (reinforcements) are available in various types:

1- Chopped strands
2- Woven cloths
3- Prepreg forms,

The cross - sectional dimensions of these fibres are very small (typically 10µm) and therefore individual fibres are drawn together to form strands. Which in turn bundled together to form roving, or twisted to form yarns for further processing. Prepregs arc the forms of the fibres where are laid in a tape form having retained their shape by a binder (usually the resin matrix itself which is used for the composite manufacture).

2.3. Tensile Properties:

For primary and secondary load bearing materials, the structural materials should be made of high modulus fibres or yarns. High modulus yarns exhibit extremely high stress-strain behaviour during tensile deformation (Tsu- Wei et al 1989). The term high modulus refers to the high initial modulus or sharp slope of the stress-strain curve, which indicates a great resistance to extension of the material. Compared with yarns for apparel applications, high modulus yarns are much stiffer and exhibit much higher tensile strength and much lower elongation to break. Table (l) below gives a comparison of the tensile behaviour of the most important high modulus yarns to that of steel

Table 1: Tensile behaviour of high performance fibres

Material	Density g/ C^3	Stress GPa	Strain	Modulus GPa
Glass	2.54	1.92	0.018	97
Carbon	1.77	2.74	0.009	254
Kevlar	1.45	2.86	0.024	114
steel	7.8	2.76	0.014	200

The outstanding features common among these materials during tensile deformation are very high stress, very low strain, and extremely high modulus.

3. Composites Materials:

3.1. Introduction:

The word composite means "a made of two or more different parts or phases" i. e. it consists an assemblage of two materials of different natures completing and allowing obtaining a material of which the set of performance characteristics is greater than that of the components if taken separately. The constituent materials are reinforcement and matrix. Accordingly the properties of the composite materials result from the following:

i- the properties of the constituents

ii- their geometrical distribution

iii- their interaction

Thus composite materials are composed of a reinforcing structure surrounded by a continuous matrix, which is the material that gives body and holds the reinforcements together (Terry, 2001). Composite materials are mainly characterized by their high strength to weight ratio, a characteristic that is an advantageous factor over the other bulk materials. This in turn enhances the wide range of applications that composites can be used in since the physical properties of composites can be tailored to meet the end-user requirements of a specific sort of application.

3.2. Advantages and disadvantages of composites:

The followings are the advantages of composite materials (Kathleen, 1998):

i- high strength to-weight ratio or- modulus - to- weight ratio
ii- reduced weight
iii- properties that can be tailored made with each composite type
iv- reduced path loads (fibre to fibre).
v- longer life (no corrosion).
vi- inherent damping

Whereas the disadvantages can be summarized to be the following:

i- high cost of raw materials and fabrication.
ii- possible weakness of traverse properties (non-isotropic).
iii- weak matrix and low toughness.
iv- environmental degradation of matrix.
v- difficulty in attaching.
vi- difficulty with analysis.

The following Figures (l -3) give a general view of the advantages of composite materials
compared to steel and alloys.

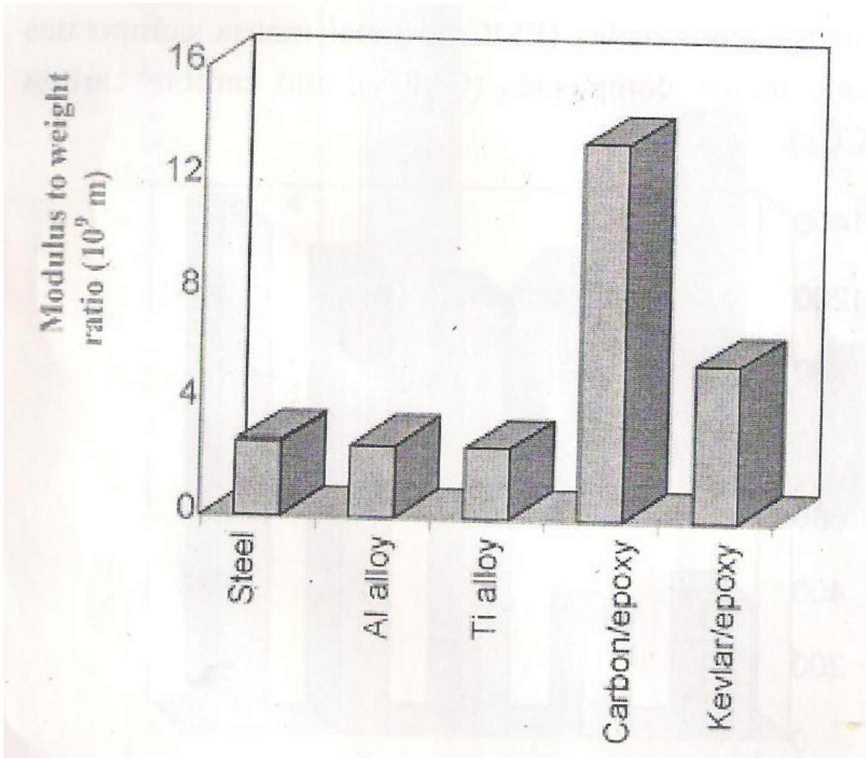

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Figure l: Comparison of modulus to weight rati

3.3. Classification of composite materials:

Composite materials are classified according to the form of constituents and the nature these constituents. Amongst the first classification lies the division of fibre composites. Other categories are the particulates and the laminates. The other classification that depends on the nature the constituents is divided into four groups viz.; polymer matrix composites (PMCs), metal matrix composites (MMCs), ceramic matrix composites (CMCs), and carbon/ carbon Composites (CCCs).

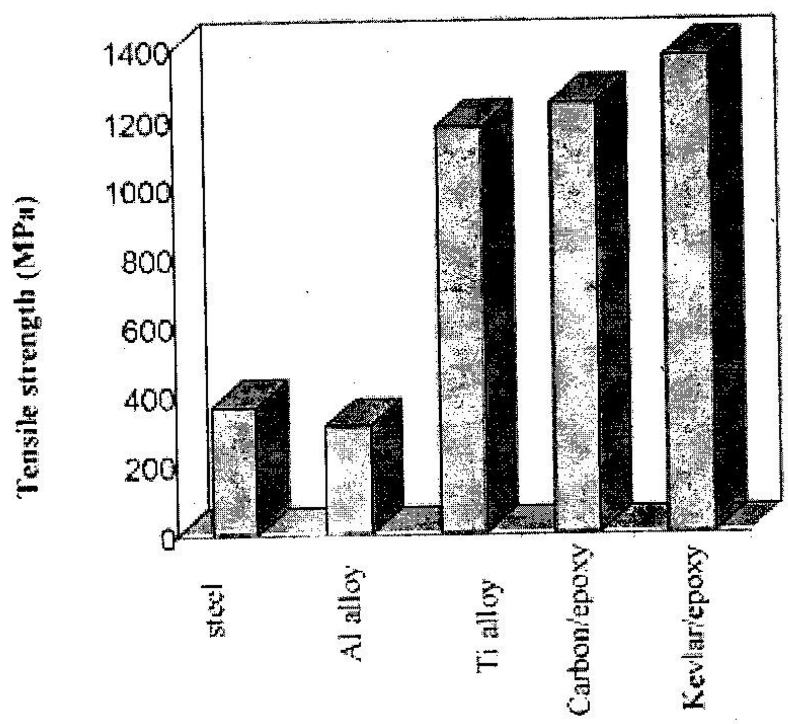

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Figure 2: Comparison of tensile strengths

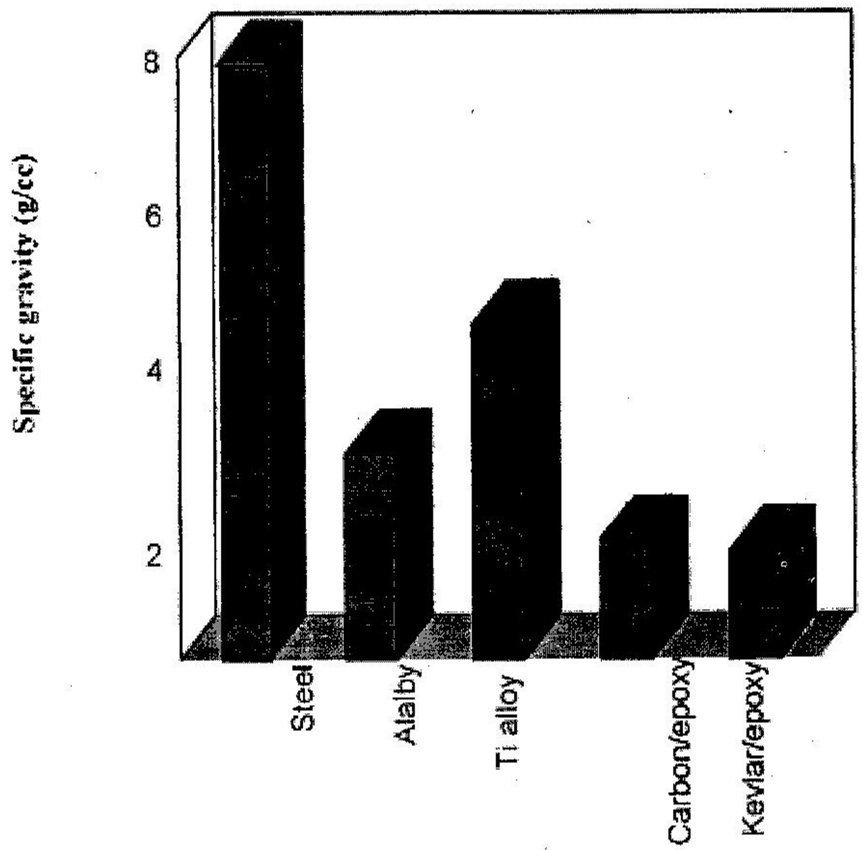

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Figure 3: Comparison of specific gravities

A fibre is any material in an elongated form such that the ratio of its minimum length to its maximum average transverse dimension is large "ratio 10:1" (Gill 1972), with a maximum cross-sectional area of 7.9X 10^{-5} in ^{2}. Fibres that are used as reinforcement materials include glass fibre, carbon fibre, boron filaments, steel wire, aramid fibres and others (Kostikov 1995). The following diagram (Fig. 4) shows the relative strength and modulus values for a number of reinforcing materials:

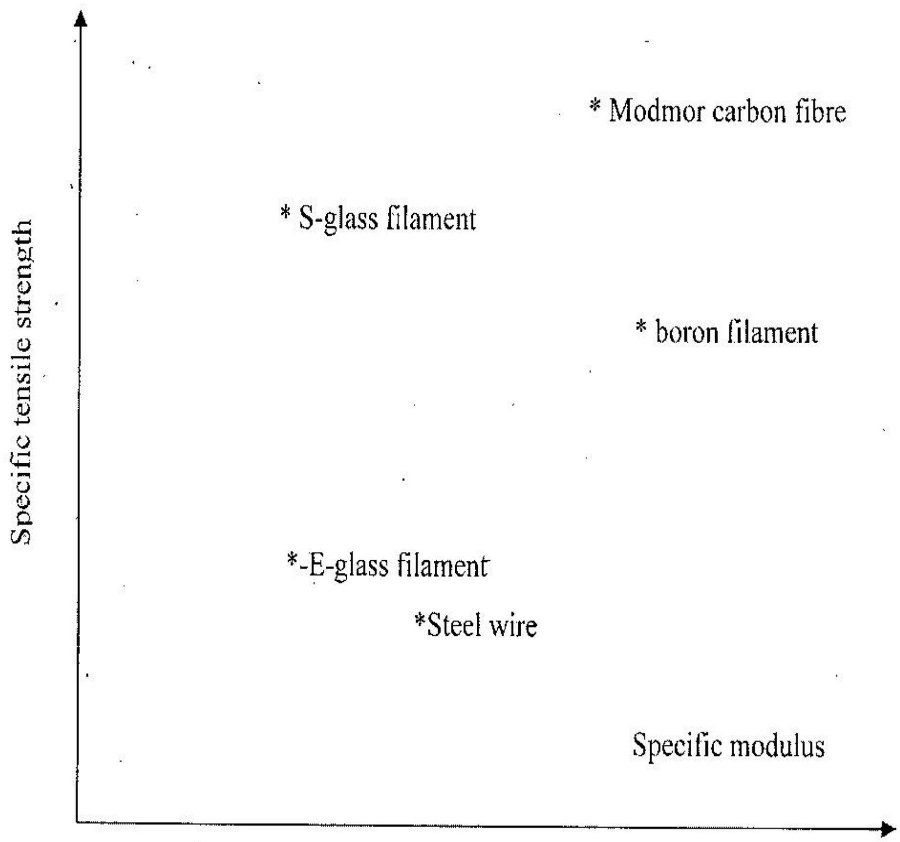

Figure 4: Comparison of different reinforcing fibres

Table (2) below shows the specific mechanical characteristics of materials made in the form of fibres:

Table2. Specific mechanical characteristics of materials made in the form of fibres

Fiber	Moduls E(GPa)	Ultimate Strength σ_{μ}(GPa)	Density P(Kg/m3)	Specific Modulus E/P (MNm/Kg)	Pecific strength σμ (KNm/Kg)
E –glas S-glass	72.4 85.5	3500 4600	2540 2480	28.5 34.5	1380 1850
Carbon with -high modulus -high strength	 390 240	 2100 3500	 1900 1850	 205 130	 1300 1890
Kevlar (Aramid)	130	2800	1500	87	1870
Boron	385	2800	2630	146	1100

5. Fibre composites:

These are the composites in which the reinforcement material is in the form of a fibre, which can be in continuous form, chopped form, short fibres, etc. The physical and mechanical characteristics of the composite will vary depending on the technology of introducing the fibrous filler into the matrix. Thus the arrangement of fibres and their orientation make it. possible to tailor the mechanical properties of the composite to meet a special requirement. The fibre composite is made by incorporating the fibre in a polymer matrix, thus a new material is born with new characteristics. To describe a fibre composite material, it will be necessary to specify:

The nature and properties of constituents

- Geometry and distribution of fibres
- The nature of fibre – matrix interface

These parameters are combined to determine the properties of the composite. For different engineering purpose, metal ceramic, glass and chemically derived synthetic fibres are used in composites with more significance .Their uses differ from a type to another according to the end use of the composite. Metal and ceramic fibres are used in high strength, high temperature, and lightweight composites, The most widely used fibres for reinforcement of plastics are glass fibres with good electrical and mechanical properties and high heat resistance. Carbon fibres offer the widest range of stiffness of any material because they add considerable strength and stiffness to resins. Aramid fibres are characterized by excellent environmental and thermal stability; static and dynamic fatigue resistance and impact resistance. Thermoplastic fibres are also used to reinforce composite materials and they are effective where high - shear processing would degrade conventional glass fibre reinforcement there by reducing performance of the composite. .AII of these. fibres are characterized as high performance materials that used for production of advanced composite.

Concerning the mechanical properties of composite materials made of fibres; the fibrous filler bears the main load in the composite material so the material strength depends substantially on the arrangement of the fibres i.e. their orientation. Thus. the fibres can be introduced in the form of filaments, tows, tapes, fabrics and multidimensional structures into the matrix. Wang et al (2010) slated that the ultimate strength of composites is influenced by fiber strength statistics and stress distribution due to progressive micro-damage.

Fiber – reinforced composites are being increasingly used as alternatives for conventional materials primarily because of their high specific strength, -specific- stiffness and tailorable properties.

In addition the visco - elastic character of composites render them suitable for high performance structural applications like aerospace, marine, automobile, satellites, sport goods, robots, and thermal insulation structures (Aramide et al , 2012).

6. Textiles in composites:

The first use of textiles in composite materials is what so-called Flexible textile, composites with many uses ranging from conveyor belts to human heart. valves (John, 1994). Natural fibres have been used a long time ago in composites, but because of their shortcomings, other materials have been introduced (Rick, 2000), although recently, much research is being carried for the use of natural fibres for technical composites . The turn on fibres for reinforcement of materials came as a result of their strength and lighter weight since their alignment along an axis gives the material additional strength and stiffness i.e. the increased tensile strength is effective only in the direction of fibre axis. Textiles are used in composites with different routes ranging from the use of random fibres to integrated three dimensional (3-D) forms. Woven fabrics resist extension along the warp and weft directions, but .they are looser at 45^0 angle since the intersection and interlacing of warp and weft threads, for fabric formation, is at right angles i.e. perpendicular to each other, knitted fabrics are easier to stretch in all direction while nonwovens suffer from anisotropy (John W. Hearle, 1994; 1995). For composites, stiffness and strength are wanted in all directions. Different textile performs are being used for composites production using different reinforcing fibres like glass, carbon. aramid, ….etc, Their mechanical properties made them more suitable for composites in many use aspects, and the fibres can be introduced industrially in different forms as follows:

l- Linear forms (strands, yarns, rovings)

2- Surface tissues (woven fabrics and mats)

3- Multi - directional forms (preforms and complex cloths),

The use of textiles in composites gives them the improvement in the Inter – laminar shear strength, damage tolerance, and though - shear thickness properties (Raman, 1997).

Textile composites offer adequate structural integrity as well as shape ability for near net-shape manufacturing. Fibre preforms can be produced in different structures by using conventional techniques such as weaving, braiding, knitting , and stitching, Two and three dimensional textile preforms offer the potential of low-cost, mass-produced composite structures when coupled with a cost -effective manufacturing method such as resin- transfer molding (Ryuta el al, 2000). Figure (5) below shows the various techniques of manufacturing textile fibre preforms:

In all of these techniques, the goal is to develop process that can produce neat-net, cornplex shaped preforms that lead to improved performance of the composite material. Weaving process can be modified to produce flat, multiplayer fabrics in a wide variety of architectures to improve impact performance. They can be woven using any type of yarn including glass, carbon, aramid and ceramic fibres, or even combinations of these yarns for tailoring the required properties of the composite for a specific application (Michael, 2001). The disadvantage is that it is not possible to produce fabrics that contain in-plane yarns at angles rather than 0 and 90^0 which result in structures with low shear and torsion properties. Some recent research developed the ability of producing fabric with + 45^0 fibres, or even with 0, ±45, and 90^0 fibres. The braiding process in capable of' forming quite intricate preforms and has been used successfully with glass. aramid, carbon, ceramic, and metal fibres. The standard braiding process can produce preforms with fibres running in the $\pm 45^0$ direction. The limitation of this process is that the produced preforms have small dimensions depending on the machine size. The process of stitching is the simplest. process form complex structures from stitching of 2-D fabric by joining multiple layers of reinforcement fabrics and holding them into the required shape. The main disadvantage of the stitching process is the action of the. stitching needles, which causes damage to the in-plane yarn and distortion which reduces the in-plane mechanical properties. The process of knitting is characterized by its high productivity together with low amount of waste. It gives a highly curved architecture of the yarn in the preform resulting in a very elastic, flexible structure. Multilayer fabrics can be produced with straight, relatively un- crimped fibres stacked in the required orientations, which can improve mechanical performance.

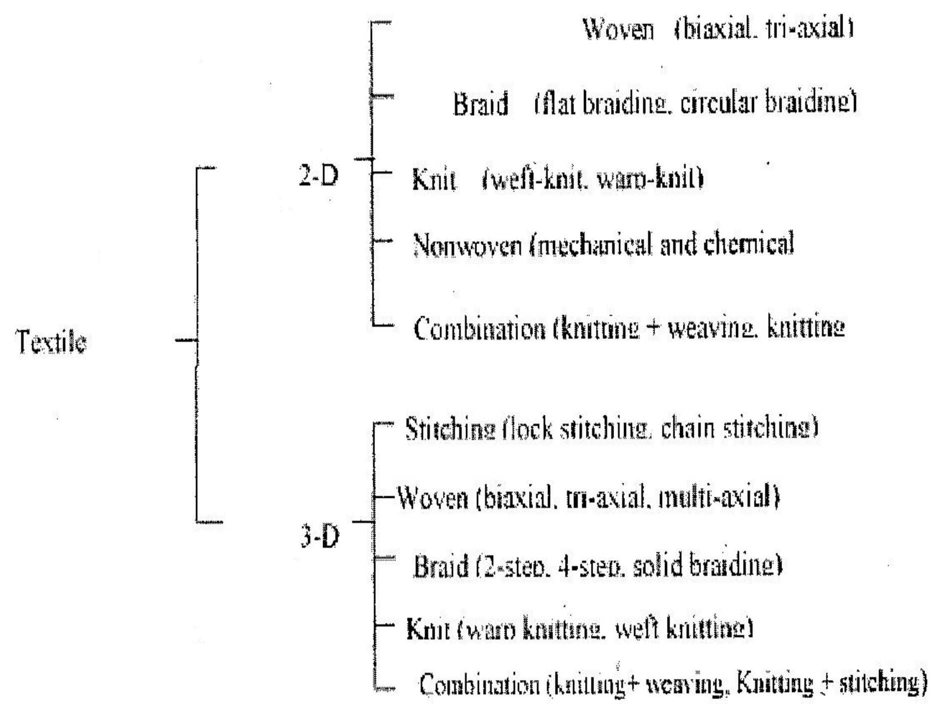

Figure 5: Various techniques of fabric formation

Summary:

Textiles have a lot to do in the manufacturing of composite materials. The challenge is -how to -make a textile preform that suits a special composite material manufacture for a specific requirement of applications which is composed of too many areas. The high performance materials like glass. Carbon and aramid fibres can be used in textile composites manufacturing being made in different structures and preforms to give the most popular properties. They can be used separately or in a combination to provide the optimum or even the most acceptable balance of properties dealing with strength and stiffness through the fibre axis or in different directions according to their end – use. The matrices should also be selected carefully to suit the requirement of the end-use of the composite and their life time should be put into account. Since composites can be made to suit any application by tailoring their properties, textile preforms with different structures can be produced as a raw material, with the most popular properties being guaranteed in the first steps of design of the preform. Natural fibres can also be to used to make composite materials making benefit from their different properties, with specified matrix materials of synthetic or natural origin.

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