A REVIEW PAPER ON COMPOSITE MATERIAL DISCUSSING, ITS STRUCTURAL BASICS, PROCESSING METHODOLOGIES AND APPLICATIONS

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Abstract: Use of composite is though popularise now days, it's never been so new, as traces of using composite discovered, which justifies the use of composite happened a thousand years ago in structure making, bows, arrows, bricks etc. The structure is gaining popularity due to its several advantages such as, high strength to weight ratio, low coefficient of thermal expansion, and list goes un ended. It has no doubt the use of composite in coming decades will rise by the margin twice as it is in the current scenario. And this is enough to attract attentions of many researchers to investigate the material domain more deeply, so the use of material would threshold in more innovative and optimistic way.

The paper describes and discusses the basic of composite structure, its constituents, processing methodologies and application etc.

Index Terms- **Composite, fiber, matrix, lamina, laminate etc.**

1. Introduction: Composite is mixture of distinctly different material, insoluble in each other, differs in form& chemical composition. It is different from any alloying elements. The fiber and matrix though are separate entities, still a structure comprise of these can take combine advantage of both.

Ex. Mortar, Reinforced rubber, Alloys, FRP (Fiber Reinforced Plastics), Fiber impregnated material etc.

For several thousands of years ago, composite material was used in construction application, so the straw reinforced mud bricks, composite bows found during excavation justifies on the same. First fiber boat was built in 1942. Reinforced filament winding used in missile applications. Most of the aircrafts components are made of composite. Composite used in other applications also, such as, medical, sport, pressure vessels etc.

When composite is compared with steel or any isotropic material, then it has high specific strength and specific modulus.

The composite can be considered with few constituent, alteration of which changes the property configuration of structure and made is unable for specific applications. Fiber, matrix, coupling agents, coatings, and fillers can be considered as few such. Fibres are principal load carrying agents, through matrix load is transferred to fibres by means shear, coupling agents facilitates fiber-matrix bonding, and fillers ensure the dimensional stability of structure.

Composite material can be viewed and studied in two forms,

Particulate composite: Particles of various sizes dispersed in matrix. Such composites are quasi-isotropic or quasi-homogeneous types. Ex. Mica flakes with glass, Aluminium particles in polyurethane rubber etc. this type of composites used in electrical applications & welding applications.

Fiber Reinforced Composites: Fibres of enough strength & stiffness embedded in matrix. Few names can be listed under category such as, Metal matrix composites, Polymer matrix composites, Ceramics matrix composites, Carbon-carbon composites etc.

Fibres are strong and stiff element in the structure and also possess low density. Fibres occupy largest volume fraction of composites. Combination of fiber and matrix enables the structure to take compressive, shear, tensile and flexural loads. Stress-strain curve for all fibres are linear up to the failure, by the time of failure it shows less deformation unlike matrix. Mode of fiber failure is brittle.

Fibres can be used in several forms such as, single fiber, chopped strand fiber, woven roving, continuous and discrete etc. woven roving fibres orients in [+45/-45], [0/90] directions. Discrete fibres have low strength and modulus than continuous fibres.

As discussed earlier FRP's widely used in various fields, and those who have not used it ever, are thinking in the prospective of using it in more innovative way. There are few parameters which widen the popularity of this structure such as, high fatigue strength, less coefficient of thermal expansion, better dimensional stability over wide range of temperature, high damping capacity, vibrational energy absorption capacity, non-corrosive behaviour, reduced transmission of noise, light weight structure, less tooling cost etc.

The failure analysis of composite is viewed on two scales majority, i.e. micromechanics and macro mechanics. In micromechanical approach, stresses and respective failure is considered at constituent level such as fiber, matrix and interface. In macro mechanical approach, properties are considered on average basis, and lamina failure is considered as part of analysis.

The composite structure can be analysed in two different forms, named as, Lamina and Laminate. Lamina is formed by combination of large number of fibres in thin layer of matrix. Lamina thickness can be considered between range 0.1 to 1 mm. several such laminas either with same or different fiber orientations when stacked one above the other, the resultant structure formed after called as Laminate. Laminate many be unidirectional or multidirectional. In unidirectional laminate, fibres are oriented in one direction, where, in multidirectional laminate, fibres are oriented in different directions as per the requirement of mechanical and physical properties.

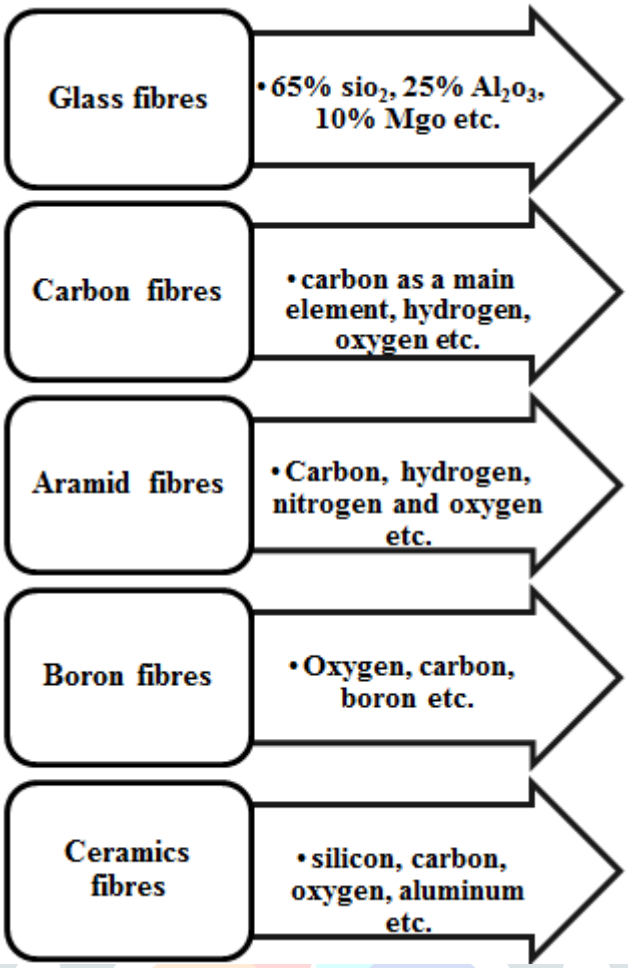
Few of the fibres which are widely used in composite structure are discussed below along with their applicability, advantages and limitations etc.

2. Attributes of the composite fibres: Based on microstructure; the behaviour of composites can be analysed on the basis of two different scales namely, Micromechanical and Micromechanical. In micromechanical analysis interaction between constituents and their overall impact on properties and behaviour of composites is taken in to account, where, in macro-mechanical analysis the impact of constituents are considered to obtain average properties of composite structure, the structure is considered as homogeneous in macroscopic scale of evaluation and judging of structure performance.

Manufacturing of composites can be proceed by different methods, the selection of process of manufacturing is the function of type of geometry, its complexity, material chosen for manufacturing, process requirement etc. the few methods can be enlisted as, Filament Winding, Pultrusion, Hand Lay-Up, Spraying up, Resin Transfer Molding, Autoclave Moulding etc. Pultrusion is recommended for continuous and long structural manufacturing.

Hand lay-up is manual technique of forming the lamina and thus laminated structure. In spraying techniques, the mixture of fibre, matrix and resin is sprayed in mould which defines shape and geometry of product to be manufactured. The flow chart below depicts the process of moulding the final composite product from basic raw materials.

"Fiber constituents"



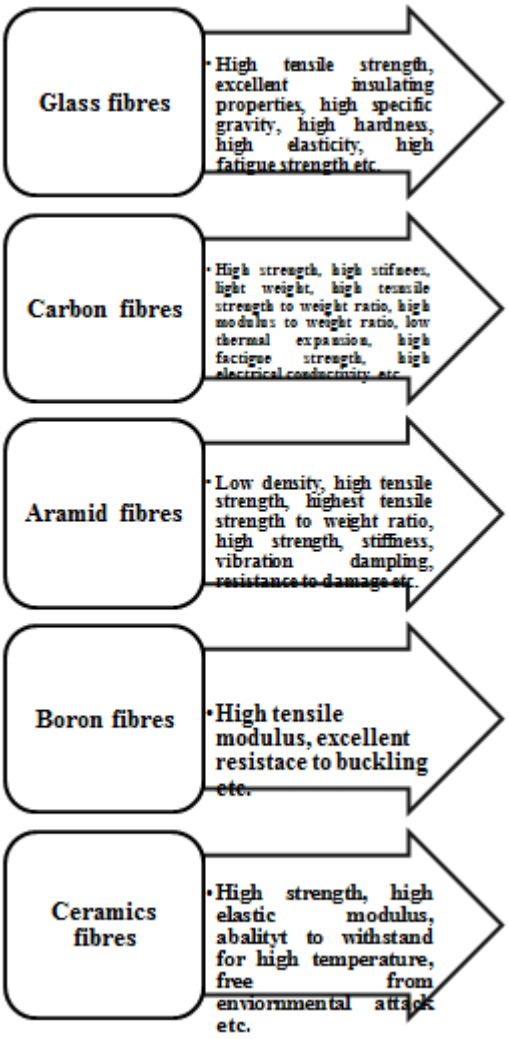
Fibre diameter 12 to 19 micron is recommended in to use. The fiber orientation holds the unique importance, as 0 degree lamina are good in longitudinal loading, 90 degree lamina are good in lateral or transverse loading, and 45 degree lamina are good in shear loading.

The unidirectional laminate has several laminas stacked one above the other; with fibre orientation of all laminas marinated same. In multidirectional laminate, fibre orientation varies from lamina to lamina, and becomes the function of laminate average property requirement.

Composite material is the combination of two or more physically distinct and mechanically separable materials, sometime it included more than two materials and requirement varies from application to application. Few examples of composites can be given as, concrete and mortars used in construction applications, rubbers, plastics and many metallic alloy combinations.

Composite structure can be classified and studied well based on types of matrix and fibres used in its making.

"Fiber Properties"

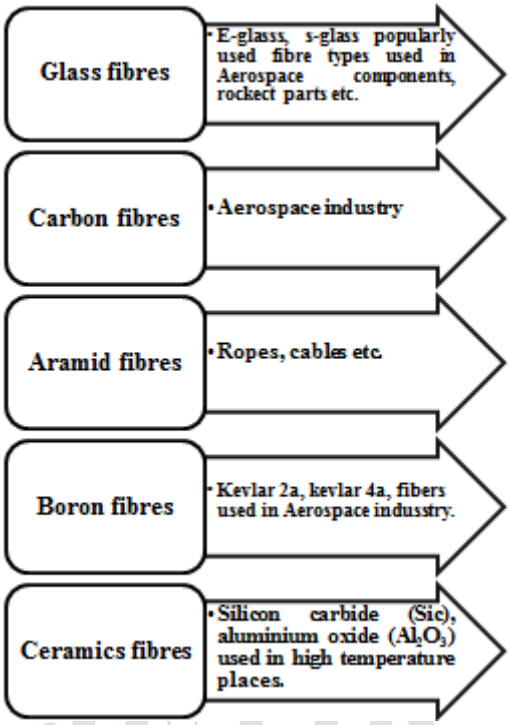


Classification of composite material: Based on types of fibre, they can be studied as, Particulate and Fibre Reinforced Composites.

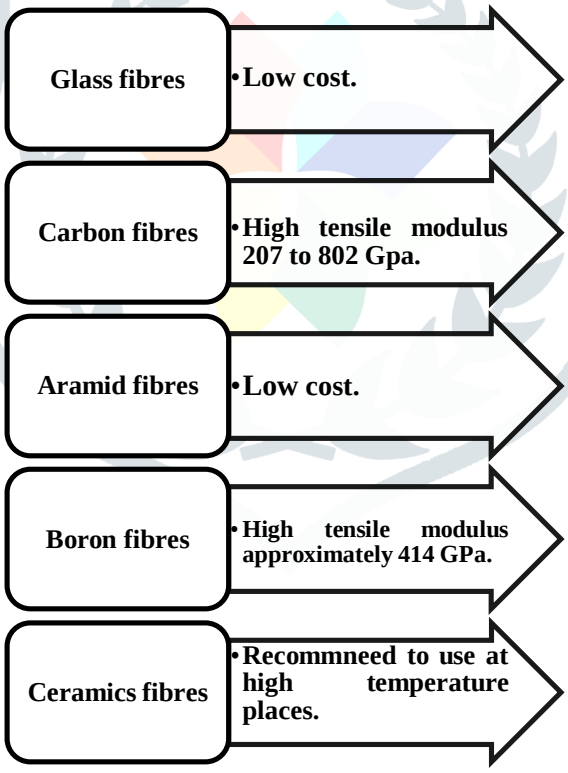
- **Particulate composite:** Particles of different shapes and size dispersed in matrix at random leads to form Quasi-Homogenous structure. Ex. Aluminium particles dispersed in rubber matrix.
- **FRP (Fibre Reinforced Polymer):** Fibres, may be short or continuous dispersed in to matrix with distinct boundaries maintained, the packing of fibres is scientific and not random like particulate composites. Arrangement of fibres follows triangular or rectangular pattern. The maximum percentage of fibres can be packed in to matrix is 80%, in the case off cylindrical fibres this percentage reach up to 90% sometimes. Continuous fibres are more efficient compared to short fibres such as whiskers.

The wide variety and availability of composites enable one to use it in different applications, few of them are depicted below in smart picture.

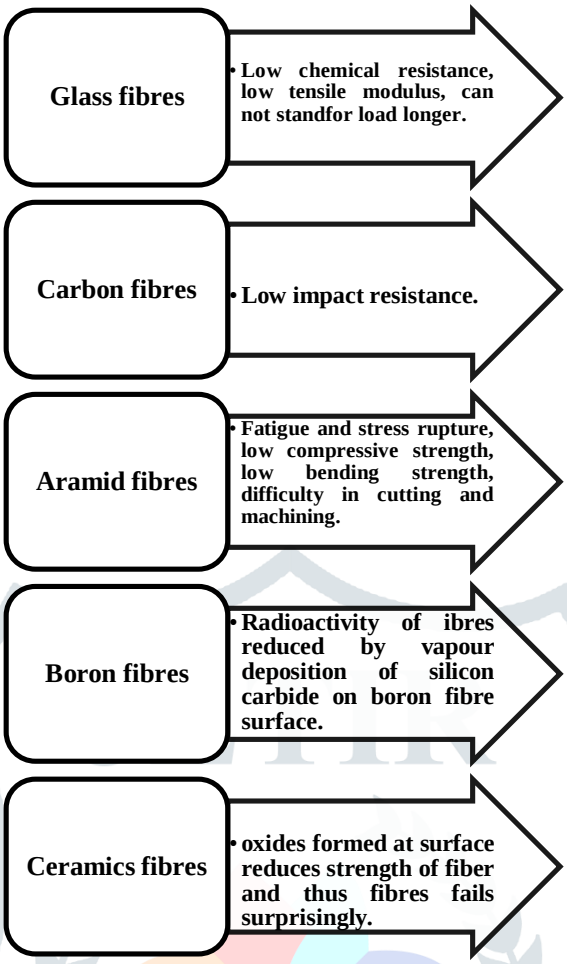
"Fiber Applications, examples"



"Fiber benefits/Advantages"



"Fiber Limitations/Disadvantages"



Matrix is another element of composite structure which receives the load and transfer to fibres by means shear.

Two types of matrix used popularly, and named as, thermoset and thermoplastic. Thermoplastic has good fracture toughness in the comparison of thermosets. Thermoplastics can be used for temperature range between 100 to 300 degrees. Thermoplastics can be used at ambient temperature. Viscosity of thermoplastics is high which creates problem when mixing with fibres at normal temperature, but thermosets can mix with fibres easily. Thermosets have good thermal stability and chemical resistance. Thermosets exhibits low strain value at failure. Thermosets can further classified and listed as, polyester resin, epoxy resin, vinyl ester resin, phenolic resin, high performance resin etc.

3. Composite processing methodologies: Selection of processing method for composite is function of shape, cost, performance, number of components to be produced etc.

The composite can process through various methods, and few of them can enlist and named as, compression moulding, contact moulding and filament winding etc. in compression moulding, material to be shaped is pressed between heated and matched dies. In filament winding, structure in the form of bodies of revolutions can be fabricated.

3.1 "Contact moulding"

Steps: Processed in three stages, (1) Mould preparation (2) Spray up (3) Hand layup.

Procedure: Mould which is made of plug wooden construction finished in GRP assembled with external shape which defines structure of shape to build. Mold is polished with wax. Glass fibres chopped for 25 mm length spray with resin, and mixture is pressed between dies for said pressure.

In last stage, resign mixed with catalyst applied on structure by roller dispenser, brush or spray gun etc.

Limitations: Only difficulty working with method is, it is difficult to release trapped air, and thus thickness control goes uneasy.

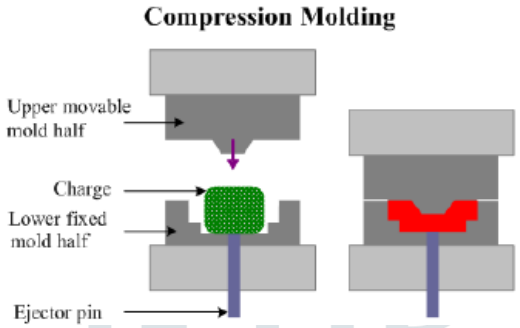
Applications:

- Fabrications of large structure ship hulls.
- Complex, large structure in small quantities.

3.2 "Compression moulding method"

Procedure: Material pressed between heated metal dies, and thus material starts flowing in to the die contour (usually negative) with respect to applied pressure. As soon as drop in temperature happens, stabilized material injected out of the die by injector pins or some injecting mechanism.

Pressure 50 MPa defines material flow. Time of moulding depends on feed material, material preheating and product dimensions to be obtained etc.

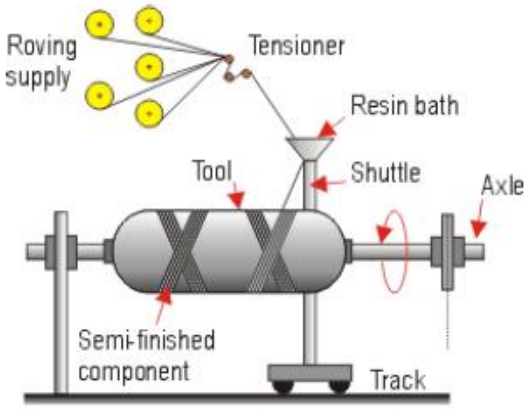


Limitations: Mould material don not have high temperature properties, for large components it takes several days to manufacture. Equipment's are expensive.

Applications:

- Process used in long production runs to manufacture the complex shapes and large components.
- Process facilitates the manufacturing with avoiding need to high cost tools and equipment's.
- Process used in small domestic items manufacturing such as doors, windows.
- Cab panels to large commercial vehicles etc.

3.3 "Filament Winding"

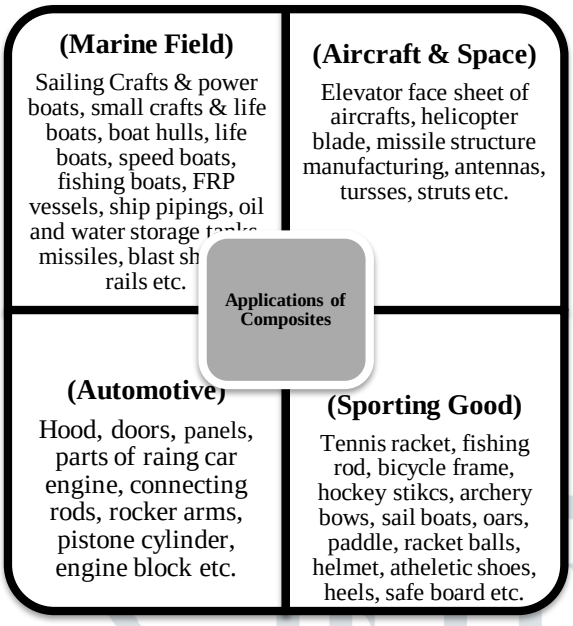


Procedure: Fabrication carried out by winding reinforcing fibres in the form of continuous roving. Fibres impregnated with resin prior to winding. Fibres wind around mandrel which defines internal geometry of product to be manufactured.

Limitations: Maintaining of constant winding speed and filament tightness during wrapping is bit difficult, and any deviation occurred produces unwanted shapes.

Applications: Underwater pipelines, ship pipe works, oil and water storage tanks, air bottles, hulls, helicopter blades etc.

4. Applications of composites: The use of composites can be extended in domains such as, Aircraft, automotive, sporting good, marine etc. the detailed use of composites in particular domain with specific application is depicted below,



5. Conclusion:

1. Use of composite is not new but practice has initiated thousands of years ago, the use of composite in making of bricks, bows justifies on the same.
2. Composite is mixture of two physically distinct phases of material, which despite being separate from each other, composite can gain combine advantage of both.
3. The strength of composite is function of volume fraction of matrix and fiber.
4. The composite is mixture of fiber, matrix, resin, coupling agents etc.
5. Composites have low coefficient of thermal expansion, high strength to weight ratio, high stiffness etc.
6. Composite materials are brittle in nature and show little strain by the time of failure.
7. Matrix is ductile element which receives the load and transfer to the fibres by means of shear.
8. Use of composites gaining popularity in fields such as medical, sport, construction etc.
9. Use of glass, carbon, aramid, boron and ceramics is popular now days.
10. The different orientations of fibres helped to achieve set of desired properties to fulfil the said requirement.
11. For the manufacturing of hollow composite geometries filament winding methods are recommended.
12. In coming decades the composite will be chosen as alternative for every isotropic material and going to capture the highest market share.

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