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# Textile Structural Composite and It's Applications

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**ABSTRACT**
In this paper, textile reinforcement material and composites have been described and briefly explained. The existing technologies in terms of processes and product performance in field of textile discussed. It is pointed out that more research and developments have been concentrated on 3D preform made up by weaving, knitting, braiding and nonwoven techniques to achieved near net shape, improved mechanical performance and light weight which are suitable in high performance application. Moreover, a textile preform architecture can vary from a simple planar sheet to a complex three dimensional shape according to yarn place in the structure and the geometrical arrangements of yarns in the final products. This paper also highlights the innovations in Textile Structural composite designing and their areas of application.

***Keywords –*** Reinforcement, Textile Preform, Resin, Textile Composite

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## I. INTRODUCTION

Whenever advancing technology creates a need for a combination of properties that no single material can provide, composites become the materials of choice. Composites can be defined as a combination of dissimilar materials to perform a task that neither of the constituent material can perform alone. Since hardly any material is used in its pure form today, composites have a broad meaning and usage. There are several form of synthetic composites such as metal-metal, metal-ceramic, metal-polymer, ceramic-polymer, ceramic-ceramic, and polymer-polymer combinations. A common example of synthetic composites is concrete which is reinforced with metal[1].

A textile composite is made of a textile reinforcement and a matrix material. Textile reinforcement can be made of fibres, yarns or fabrics (woven, braided, knit, nonwoven) and are generally flexible. These structure are called textile performs. Textile performs can be in various shapes and forms. Matrix material can be thermoplastic or thermoset polymers, ceramic or metal. The consolidation of the textile reinforcement with the matrix material produced textiles reinforced composites or textile structural composites.

Textile composites can be flexible or rigid. Examples of flexible textile composites are coated fabrics, automobile tires and conveyor belts. Rigid textile composites are widely used in many applications and replaced metal components. Main characteristics of rigid textile composites are high stiffness, high strength and low density. Other characteristics include but are not limited to high temperature resistance, corrosion resistance, hardness and conductivity depending on the product design for specific application. Textile reinforcement composite have higher strength-to-weight ratio than metal composites. Well established textile manufacturing techniques allow near-net-shape manufacturing which reduces cost and material waste considerably. Braiding, weaving and knitting technologies have allowed fibres to be arranged locally in optimized configurations and globally into preforms for conversion processes such as resin transfer molding and pultrusion.

Another advantage of textile structural composites is that they can be made anisotropic. Many structural materials including metals have homogeneous and isotropic properties in general. In isotropic materials, strength, stiffness, thermal and other properties are equal in all directions and at all locations. With use of oriented fibres in bundles or layers, composites can be made anisotropic so that they exhibit different properties along different axes. Strength, stiffness, thermal and moisture expansion coefficient can vary by more than ten times in different directions. As a result, by proper alignment of fibres with respect to loading direction, for example, the weight of the composite can be reduced further.

The strength and stiffness of the composite structure are function of fibre and matrix properties. The functions of matrix materials are to bind the fibrous materials together and protect them from outside effects. Matrices transport the forces and stresses acting on the boundary of the composite to fibres. They also help to strengthen the composites structure.

Application areas of composites are steadily expanding. They have replaced metals and metal alloys successfully in many applications including automotives, aerospace, electronics, military and recreation. Typical application examples are aircraft parts, rocket and missile components, automotive parts, electronic boards, home appliances, construction and sporting goods.

## II. COMPOSITES

Composite materials (or composites for short) are engineered materials made from two or more constituent materials with significantly different physical or chemical properties and which remain separate and distinct on a macroscopic level within the finished structure. They can also be defined as a multiphase materials obtained by artificial combination of different materials to attain properties that the individual components cannot attain[2].

The need of composite arises as many of our modern technologies require materials with unusual combinations of properties that cannot be met by the conventional metal alloys, ceramics, and polymeric materials. This is especially true for materials that are needed for aerospace, underwater, and transportation applications. The most primitive composite materials comprised straw and mud in the form of bricks for building construction. Other examples include road making with steel reinforcement and aggregate reinforced Portland cement or asphalt concrete, plywood, shower stalls and bath tubs made of fiber glass.

A Composite consist of two components viz. Matrix and Reinforcement and at least one portion of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties. A synergism produces material properties unavailable from the individual constituent materials[2].

### 2.1 Types of Composites

Broadly, Composites can be classified as:
1) Particle reinforced composite
2) Fiber reinforced composite
3) Structural composite

### 2.1.1 Particle reinforced composite

Particle reinforced composite as the name suggests have reinforcing elements in particulate form, either small or large. In case of particle reinforced composites the reinforcing particles tend to restrain movement of the matrix phase in the vicinity of each particle. The matrix transfers some of the applied stress to the particles which bear a fraction of the load. Concrete is a common large-particle composite in which both matrix and dispersed phases are ceramic materials i.e. the aggregates are bind by a cement matrix.

### 2.1.2 Fibre reinforced composite

The reinforcing material here is in a fiber form. These types of composite are technically important one and are used where high strength and stiffness properties are requires on weight basis. Factors such as fiber length and orientation inside the matrix are important in deciding the composite properties. It is obvious to say that preferential orientation of fibers in matrix will result in an anisotropic structure.

For better understanding of fiber reinforced composite, some essential information will be discussed here. A fiber-reinforced composite consisting of these fiber and matrix materials will exhibit the uniaxial stress–strain response as shown in Fig. 1.

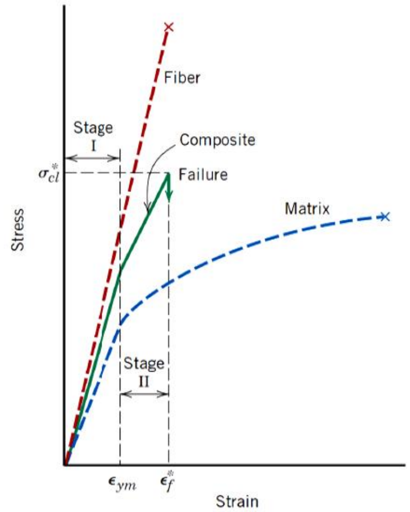


Figure 1: Schematic Stress strain curve for aligned fibre composite (brittle reinforcing fibre ductile matrix)

In the initial Stage I region, both fibers and matrix deform elastically; and the curve is linear. The matrix yields and deforms plastically while the fibers continue to stretch elastically, as the tensile strength of the fibers is significantly higher than the yield strength of the matrix. This process constitutes to Stage where the proportion of the applied load that is borne by the fibers increases. The onset of composite failure begins as the fibers start to fracture, which corresponds to a strain of reinforcing fiber approximately. Composite failure is not catastrophic as, the matrix still remains intact and also shorter (broken) fiber length still remain intact inside the matrix.

2.1.3 Structural reinforced composite

A structural composite is normally composed of both homogeneous and composite materials, the properties of which depend not only on the properties of the constituent materials but also on the geometrical design of the various structural elements. Laminar composites and sandwich panels are two of the most common structural composite.

2.2 Alternate Classification

In addition to above classification another classification based on based on type of matrix also exist.

1) Polymer Matrix Composite
2) Metal Matrix Composite
3) Ceramic Matrix Composite

Although various above mentioned types of composites exist, most commercially produced composites use a polymer matrix composite. It consist of a polymer resin as the matrix, with fibre as reinforcement medium. These material are used in the greatest diversity of composite applications, as well as in the largest quantities, in the light of their room-temperature properties, ease of fabrication, and the cost. It is often called a resin solution. The most common are known as polyester, vinyl ester, epoxy, phenolic, polyimide, polyamide, polypropylene, PEEK, and others.

This class is subcategorized into thermoset and thermoplastic polymer matrix composites.

2.2.1 Thermoset polymer matrix composite

Thermosetting plastics (thermosets) are polymer materials that irreversibly cure to a stronger form (due to cross linking of polymeric chains). The cure may be done through heat, through a chemical reaction, or irradiation.

Thermoset materials are usually in liquid form prior to curing and are hence can easily be used as a matrix for composite structures. The curing process transforms the resin into a plastic or rubber by a cross-linking process. Molecular chains reacts at chemically active sites (unsaturated or epoxy sites, for example), linking into a rigid, 3-D structure. The cross-linking process forms a molecule with a larger molecular weight, resulting in a material with a higher melting point and the material forms into a solid material.

Reheating of the material results in reaching the decomposition temperature before the melting point is obtained. Therefore, a thermoset material cannot be melted and re-shaped after it is cured. This implies that thermosets cannot be recycled, except as filler material.

Thermoset materials are generally stronger than thermoplastic materials due to this 3-D network of bonds, and are also better suited to high-temperature applications up to the decomposition temperature of the material

But an important aspect here is that sufficient adhesive strength must be developed at every point along the matrix polymer-reinforcement (glass) interface so that the maximum stress can be transferred from the polymer matrix to the reinforcement. Thus there arises a need of the coupling agents which serve as an intermediate layer between the matrix and the reinforcement, and can be applied directly to the reinforcement surface or as an integral blend with the matrix.

Examples include Glass-reinforced plastic (GRP), using polyester, vinylester or epoxy matrix and Carbon fiber reinforced plastic (CFRP or CRP), again using polyester, vinylester or epoxy thermoset matrix.

2.2.2 Thermoplastic polymer matrix composite

A thermoplastic is a plastic that melts to a liquid when heated and freezes to a brittle, very glassy state when cooled sufficiently. Most thermoplastics are sufficiently high molecular weight polymers whose chains associate through weak Van der Waals forces (polyethylene); stronger dipole-dipole interactions and hydrogen bonding (nylon); or even stacking of aromatic rings (polystyrene).

The problems associated with thermoplastic processing is that they are not in a liquid low viscosity stage as compared to thermoset resins and hence for proper distribution as a matrix needs to be melted, still remaining into a highly viscous form. Lowering of viscosity can be achieved by increased temperature, but the polymer degradation must be kept in mind. Reduced molecular weight helps in reduced viscosity but then the strength of the matrix is largely reduced. Various methods have been derived for uniform matrix formation such using thermoplastics in powder form during composite making. Here also coupling agents are needed in case of incompatible matrix and reinforcements.

The advantages gained by thermoplastic matrix include heat welding for joining two components and the biggest one, recyclability, which is now becoming increasingly important from ecology point of view.

Use of thermoplastic matrix has opened a new division of composites called all thermoplastic composite which is better known single polymer composite, which give the best recyclability options.

## III. CLASSIFICATION OF TEXTILE REINFORCEMENT STRUCTURES

Textile reinforcements are classified based on the preform structural parameters, such as dimension, direction of reinforcement, fibre continuity, linearity of reinforcement, bundle size in each direction, twist of fibre bundle, integration of the structure, method of manufacturing and packing density. By using conventional textile manufacturing techniques such as weaving, knitting, braiding and stitching it is possible to produce a wide range of two and three dimensional preforms as shown in Fig. 2.

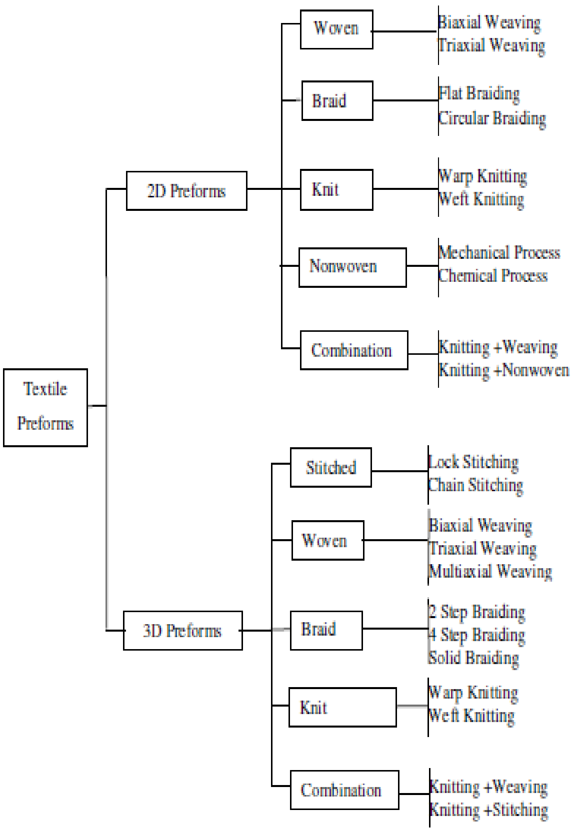


**Figure 2:** Various techniques of manufacturing textile fibre performs[3]

## IV. APPLICATION OF TEXTILE STRUCTURAL COMPOSITE

The advantages of textile composites can be summerized as follows[4]:

- The availability of a wide range of fibres, yarns, fabrics, matrix materials and manufacturing processes for reinforcement fabrication and composite consolidation allows flexibility in designing various components and structure.
- Energy saving are important – low energy cost during manufacturing and long-term energy saving due to lighter components. The energy cost of producing composite automobile body is 40% less than that of a steel body.
- Due to anisotropic design, directional properties could be obtained.
- Good fatigue resistance and high degree of damage tolerance are seen.
- Corrosion resistance is an advantage.
- Composite parts can be designed with varying degree of electrical and thermal conductivities.

The current application of composites in automotives includes drive shafts, side rails, doors, cross members, oil pans, suspension arms, leaf springs, wheels, quarter panels, trunk decks, hoods, hinges, transmission supports, bumbers, seat frames and wheels.

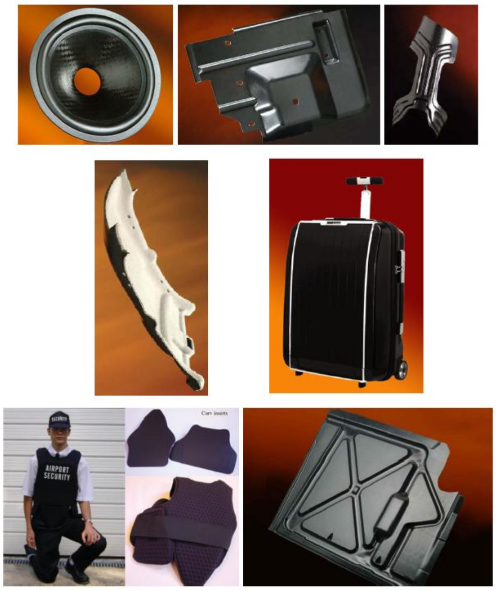

Figure 3: Top row: (L to R) loudspeaker cone, body panel for automobiles, Nike Shinguard; Middle row: (L to R) Headliner for cars, Samsonite luggage bag; Bottom row: (L to R) protective inserts, under shield for automobiles[6]

In the defense industry, composites are ideal material for light weight mobile, easily transportable vehicles for tactical shelters, ballistic combat and logistic applications. Composites are ideal materials for aircraft and aerospace application where high strength-to-weight ratio is required. For example, glass fibre composite is five times higher than that of aluminium. Graphite and boron epoxy composite stiffness is five times higher than that of aluminium. In aircraft applications, usually carbon, aramid, glass fibre or filament reinforced epoxy based textile structural composites are used. Woven, knit filament wound and braided textile structures are used for reinforcement.

Many products have been made using these hot compacted PP composite sheets. Loudspeaker cone, Helicopter radome cover, Nike shinguard and automotive under tray are some of these products. Big companies like samsonite have already launched products using these composite sheets. Some products developed using the pp composite sheets are shown in group of figures under the title fig. 3. This material is increasingly gaining popularity and many end uses are being thought off and worked out viz. sporting goods, personal protection, luggage, packing and various cold temperature application[5].

## V. CONCLUSION

Composite materials allow the designer to select the optimum combination of textiles reinforcement and resin and to develop a material especially designed for a particular application. In the past decades, research and engineering interest has been shifting from monolithic materials to textiles reinforced polymeric materials. These composite materials now dominate the aerospace, leisure, automotive, construction and sporting industries. Application areas of composites are steadily expanding.

Even though, Manufacturing of textiles reinforced composite with well established manufacturing techniques like braiding, weaving, knitting and nonwoven technologies have allowed fibres to be arranged locally in optimized configurations and globally into preforms for conversion processes such as resin transfer molding and pultrusion. It is also possible to produce near-net-shape of products.

Now a day, many products are available which gives high performance. But to achieve same performance at lower product cost and able to produce in mass production are main aim of this research work.

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