Innovations in Textile Composite Designing and Their Applications

Rajeev Varshney
Department of Textile Engineering
GZSPTU Campus, Bathinda

Amit Madahar
Department of Textile Engineering
GZSPTU Campus,Bathinda

ABSTRACT

Textile composites are the materials in which the composition and internal structure is changed under controlled conditions so as to match their performance to the most demanding structural or non-structural roles. Textile reinforcement structure can be made of fibers, yarns or fabrics (woven, braided, knitted or non wovens) and are generally flexible. The application of traditional textile technology to organize high performance fibers for composite material applications has provided a route to combining highly tailored materials with enhanced process ability. Many commercially produced composites use a polymer matrix material often called a resin solution. There are many different polymeric materials available depending upon the starting raw ingredients. There are several broad categories, each with numerous variations. The most common are known as polyester, vinyl ester, epoxy, phenolic, polyimide, polyamide, polypropylene, PEEK etc. This paper highlights the innovations in Textile Structural composite designing and their areas of application.

General Terms

Composite structures, Reinforcement materials and matrix materials

Keywords

Braided, Non woven, Matrix, Polymer, Woven, Knitted

1. INTRODUCTION

The Textile composites represent advanced materials which are reinforced with textile performs for structural or load bearing applications. Presently, textile structural composites are a part of a huge category of composite materials: textile composites. Textile composites can be defined as the combination of a resin system with a textile fiber, yarn or fabric system. They may be either flexible or rigid. Flexible textile composites may include heavy duty conveyor belts or inflatable life rafts. On the other hand, Inflexible or rigid textile composites are found in a variety of products termed as fiber reinforced plastic (FRP) systems. These textile composites have been in use since the 1950's mostly in interior and exterior panels and in parts for the automotive and aircraft industry and represent a good alternative for metal and wood applications. Textile structural composite are mainly used as structural materials to resist heavy loads that occur in the basic framework for buildings, bridges, vehicles, etc. They are made of a textile composite perform embedded in a resin, metal or ceramic matrix. The matrix system provides rigidity and holds the textile reinforcement material in a prescribed position and orientation in the composite. The composite perform is obtained from the assemblage of unrigidized fibrous material such as fibers, yarns or fabrics and its structure can vary from a simple planar sheet to a complex 3D net shape.

2. STEP WISE PROCEDURE FOR MANUFACTURING TEXTILE COMPOSITES

With the growth and developments in machinery and textile manufacturing techniques have advanced the science of textiles There are usually four important levels in the manufacturing process of textile composites:

FIBER > YARN > FABRIC > COMPOSITE

The first step represents the choice of the fibers in the fabrication of textile structural composites. To resist high loads in structural applications, textile structural composite products should be made from high modulus fibers, such as glass, graphite, aramid, ceramic or steel fibers.

The second step of the composites manufacturing process consists of grouping together the fibers (or filaments) in a linear assemblage to form a continuous strand having textile like characteristics. The yarns may be composed of one or more continuous filaments, or even discontinuous chopped fibers, and finally, two or more single yarns can be twisted together to form ply or plied yarns.

The third step in the textile structural composites manufacturing process involves bonding and interlocking of the yarns together to produce a flat sheet with a specific pattern. Fabric types are categorized by the orientation of the yarns used, and by the various construction methods used to hold the yarns together.

The four basic fabric structure categories are woven, knitted, braided, and nonwoven.

3. PREFORMS IN COMPOSITES – MANUFACTURING

The reinforcement materials used during manufacturing of composites may be in form of a thick woven cloth or the laminates which are can be combined to get the required thickness. So on the basis of reinforcement material used, The composites can be broadly categorized as:

(A) Laminated Composites

(B) 3-D Composites

(A) Laminated Composites: In case of laminar composites the layers of reinforcement material are stacked in a particular pattern in order to obtain the desired properties in the resulting composite material. These layers are termed as plies or laminates.

The Laminates may be composed of reinforcement materials including

• Woven

• Non woven

• Matt

• Braided

• Fiber reinforced

• Uni-directional fibers

The advantages of laminated composites includes a relatively well defined arrangement of the fibres in the final composite material, higher fiber to volume ratio, higher strength where as their disadvantages includes relatively poor thickness properties and problems of process induced deformations. The unidirectional fibers are mostly used in the form of pre-preg for carbon/epoxy and in the form of non-crimp fabric in case of glass/polyester.

(B) 3-D Composites: The textile preforms can be broadly classified as two- and three-dimensional on the basis of extent of reinforcement in the thickness direction. But the three-dimensional textile performs are more attractive as they offer the benefit of near net shape manufacturing with improved damage tolerance.

Three-dimensional textile preforms are basically the fully integrated continuous-fiber assemblies with multi-axial in-plane and out-of-plane fiber orientations. The composites which are reinforced with three-dimensional preforms provides several distinct advantages which are not realized in traditional laminates. Firstly, due to the out-of-plane orientation of some fibers, the three dimensional preforms provide enhanced stiffness and strength in the thickness direction. Secondly, the fully

integrated nature of fiber arrangement in three dimensional preforms eliminates the inter laminar surfaces characteristic of laminated composites. The superior damage tolerance of three-dimensional textile composites based upon polymer, metal and ceramic matrices has been demonstrated in impact and fracture resistance. Third, the technology of textile performing provides the unique opportunity of near-net-shape design and manufacturing of composite components and, hence, minimizes the need for cutting and joining the parts. The potential of reducing manufacturing costs for special applications is high. The overall challenges and opportunities in three-dimensional textile structural composites are very fascinating. As shown in Fig. 1, three-dimensional preforms can be further classed by their manufacturing techniques: woven, non-woven, knitted, braided and stitched.

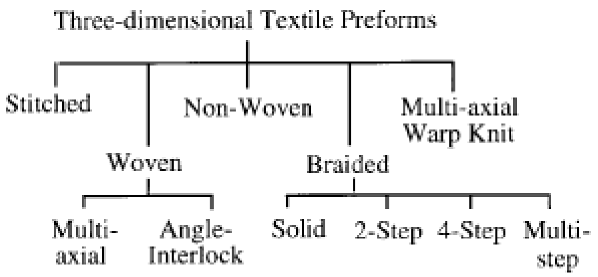

Fig. 1. 3-D Textile performs

The design of a composite structural component illustrates which fiber preform manufacturing technique should be employed.

(a) Woven Preform

The most widely used textile manufacturing technique, weaving accounts for nearly 70% of the two-dimensional fabric produced. The weaving process is suited for the production of panels and woven fabric textiles have been used for a number of years in two-dimensional laminated composites. However, these composites had poor impact resistance, delaminating strength and, since typical two-dimensional weaves only possess fibers in the 0° ie warp and 90° ie. weft or filler directions, reduced in-plane shear properties. To improve the impact and inter laminar properties, through-the-thickness reinforcement material was required. This reinforcement was achieved by angle-interlock weaves which use fibers to either weave together all fabric layers ie. through-the-thickness interlock or weave together adjacent fabric layers ie. layer-to-layer interlock. Although this caused an increase in the through-the thickness properties, these preforms still had poor in-plane shear resistance since the in-plane fibers are only in the warp and weft directions. Thus, In order to improve the in-plane shear characteristics O€-axis (bias) fibers were needed and there has been several multi-axial 3- D weaving techniques developed to introduce bias fiber layers. Fig 2 Shows some of 3-D woven designs.

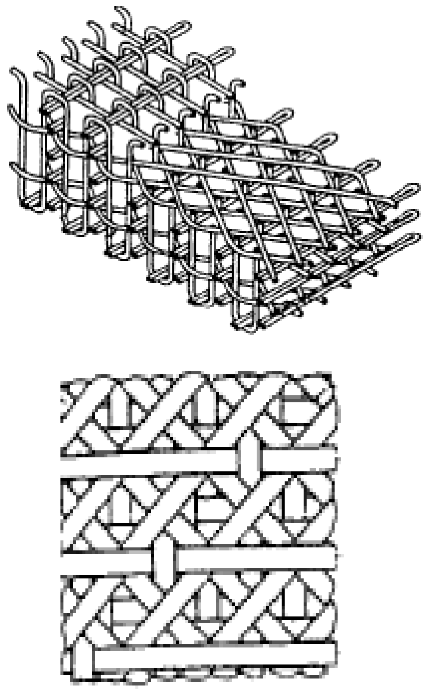

Fig.2. 3-D woven designs.

(b) Stitching/nonwoven preform: Stitching is the simplest technique of fabricating 3-D textile performs. However, stitching also causes significant in-plane fiber damage that results in a degradation of the in-plane mechanical properties of the composite. On the other hand, By using a non-woven through-the thickness reinforcement can be introduce without causing significant in plane fiber damage.

(c) Knitted Preform: Knitting is a fast process with which multi-axial fabrics can be produced on commercially available multi-axial warp knitting machines. Several three-dimensional knitted fabrics are also produced by using knitting needles to stitch together the in-plane fibers that can be oriented at 0° and 90°.

(d) Braiding: The braiding is a process suitable for the production of cylinders, rods, beams of various cross sections and more elaborate structures when coupled with the use of a mandrel. Track and column braiding processes such as two-step, four-step and multi step have all been successfully used to produce a variety of performs. Produced by intertwining three or more yarn groups in a maypole type fashion, traditional solid braiding has been limited to simple cross-sectional shapes. However, recent advances have allowed for the production of complex 3-D shapes.

4. SELECTION OF RESIN/ MATRIX MATERIALS

The composites can be classified into two categories depending upon the type of resin used:

(A) Thermoplastic Composites

(B) Thermosetting Composites

(A) Thermoplastic composites

These are the composite materials with thermoplastic resin like polyester, HDPE etc. However, they are lesser used as high-tech materials due to their higher viscosity which cause problem during their penetration into the reinforcement. Their manufacturing requires the equipment which may withstand at high temperature and pressure conditions that causes an increase in the manufacturing cost. However, they offer some advantages such as non toxicity and recyclability.

(B) Thermosetting composites

These are the composites in which thermosetting polymers like epoxy, unsaturated polyester and vinyl-ester are used as resin. These are most used type of composites materials in automotive, naval, aeronautical and aerospace applications. They are preferred over thermoplastic resin due to their lesser viscosity thermoplastics which help them to penetrate in reinforcement easily even at room temperature. Moulding equipments used are relatively cheaper as there is no need to rise till very high temperature and pressure. However, the disadvantage is that they are toxic, non-recyclable and lesser availability for penetration time once polymerization starts.

5. APPLICATIONS & ADVANTAGES OF TEXTILE STRUCTURAL COMPOSITES

The worth of textile composites originates from many advantages, such as speed and ease of manufacture of even complex components, consequent economy compared to other composite materials, and out-ofplane reinforcement that is not seen in traditional laminated composites. Further, textile composites do not lose the classically valued advantage that composite materials possess over their metal or traditional counterparts, in that textile composites have an inherent capacity for the material itself to be adapted to the mechanical needs of the design. This is to say that the strength and stiffness of the material can be oriented in needed directions, and no material weight is wasted in providing reinforcement in unnecessary directions. For a conventional laminated composite, this is accomplished by oriented stacking of layers of unidirectional resin impregnated fibers, such that fibers are aligned with any preferred loading axes. A textile composite may also be so adapted by several methods including unbalanced weaves. The woven fiber tows in a preferred direction may be larger (containing more constituent fibers per tow) than in other directions. Also, an extremely diverse set of woven or braided patterns may be employed, from a simple 2D plain weave to an eight-harness satin weave or a 3D orthogonal weave pattern, any of which may exhibit a useful bias in orientation of material properties. The economy of textile composites arises mainly from the fact that manufacturing processes can be highly automated and rapidly accomplished on loom and mandrel type machinery. This can lead to easier and quicker manufacture of a finished product, though curing times may still represent a weak link in the potential speed of manufacture. Composite materials have been used for the past 30 years in many sectors such as aeronautics, space, sporting goods, marine, automotive, ground transportation and off-shore. Due of their high stiffness and strength at low density, high specific energy absorption behavior and excellent fatigue performance these materials have emerged in such areas.

6. CONCLUSION

Thus, The Textile Composite are composed of a matrix material which surrounds and supports the fiber re-enforcement material and the re-enforcement material itself imparts its special characteristics to the matrix material in a composite structure. The unique combination of two material components leads to singular mechanical properties and superior performance characteristics not possible with any of the components alone. The combination of the matrix material and the reinforcement material helps us in achieving the desired characteristics for a specific end use of the final product. Additionally composite materials are often quite superior to other materials (e.g. metals) on the basis of strength-to-weight or stiffness-to-weight. With this reassurance, the range of applications for composite materials appears to be limitless. With the advances in textiles and polymer technology, textiles reinforced composites have attracted a substantial amount of interest. When coupled with a cost-effective manufacturing method such as resin-transfer molding, two- and 3-D textile preforms offer the potential of low cost, mass-produced composite structures. Thus they provides huge possibilities and benefits of making the new and innovative products subjected to some variations in the matrix material and the reinforcement material to form a product at a low cost and with a good performance.

7. REFERENCES

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