Kevlar Based Fibre Reinforced Polymer Composite- A Review

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ABSTRACT: The review article showcased here is to understand the mechanical and tribological characteristics such as tensile, flexural, impact, wear, chemical and thermal properties of various available fibres such as Glass, carbon, Graphite and Kevlar fiber reinforced polymer matrix composites. The characteristics of the various fibre-reinforced polymer composites with reference to their proportion and the areas of usage are discussed. The review looks into the studies on various types of Kevlar composites. It provides an orientation to optimise the present day Kevlar materials and a platform to explore and investigate new combinations

Keywords:, Glass fiber, Kevlar fiber, Carbon fiber, Epoxy resin, characteristics, advanced composites

A. Introduction

Composites naturally found are can be technically synthesised materials obtained from multiple constituents displaying significance in physical, chemical properties, thermal, optical characteristics. They are observed to remain distinct and exhibit uniqueness within the processed product. FRPC's are known as Fibre-reinforced polymer composites are basically called as plastic, is an artificially evolved composite material made of reinforced fibres in a polymer resin matrix. The fibres that are commonly used are glass, carbon, aramid etc and similarly various other reinforcements such as asbestos, paper or wood have been occasionally adopted. The resin to obtain the polymer thermosetting plastic is polyester, epoxy, vinylester and phenolic based

Resins are still in vastly applied. FRPC's are applied in applications such as in automotive, marine aerospace and construction based industries. Most composites usually exhibit strong, stiff fibres in a matrix which is relatively less weak for the same. The purpose is to create a product which is strong and stiff and is of a lower density. Commercially available material such as glass, Kevlar and carbon fibres in matrices based on thermosetting polymers mainly epoxy, vinyl and polyester resins. There are occasions when thermoplastic polymers may be preferred, The cost of based on cost [1]. To emphasise further these composites when fabricated by adding the fibres exhibit complexity. Considerable improvements may be sought in fracture toughness, thermal stability, creep, wear, etc [2].

Fibre-reinforced polymer composites are extensively applied in advanced engineering structure, with their usage ranging from aircraft, helicopters and spacecraft, boats, ships. These can also be used in versatile applications such as automobiles, sports goods. They are also used in civil infrastructure, chemical processing equipment, bridges and buildings etc. Fibre-reinforced polymer composites are steadily growing at a faster rate. These materials are applied in the current markets and gaining importance in new markets such as biomedical devices and civil structures. An essential factor that's led to increase in applications from the recent years is the development of advanced forms of Fibre-reinforced polymer composites. The combination of resin systems and fibres are mouldable after initial production. FRPC's have additional classes of hybrid materials during the initial stages of manufacturing, the cost is impacted by applying carbon nanotubes and nano materials [3]

B. Properties of FRP as a Composite Material

Fibre-reinforced polymer composites are a class of materials system combined of two or more micro-macro-elements that differ in structure, physical and chemical amalgamation. They are distinctively insoluble in each other. Applying Fibre-reinforced polymer composites has a great importance in various technical domains like automotive industry, construction industry, manufacturing industry. The purpose of Fibre-reinforced polymer composites is to finally obtain better properties and ease of production comparing to the existing components. These composite usually refers to a "matrix" material with fiber reinforcement [4].

C. Classification of Composite Materials

Composite Materials are basically classified as Polymer Matrix Composites, Metal Matrix Composites or Ceramic Matrix Composites. They appear or take forms with the type of Fiber- reinforced Particulate, Laminar based composites. The composites in most of the situations are useful materials and in few cases, the downside properties of such materials should be well defined. The general properties of such materials is shown in Table 1

Table 1 .Advantages and Disadvantages

Advantages of Composite Materials	Disadvantages of Composite Materials
• High strength to weight ratio	• High manufacturing costs
• High stiffness to weight ratio.	• Brittle, not ductile failure
• Air condition,corosion and chemicals resistance	• Materials require refrigerated transport and storage and have limited shelf lives
• Lightweight,	• Composites must be completely cleaned of all contamination before repair.
• High workability,	• Composites must be dried before repair because all resin matrices and some fibers absorbmoisture.
• Easy formability	• Repair at the original cure temperature requires tooling and pressure.
• Low transport cost due to lightweight	
• High fatigue and impact strength	
• Low heat conductivity	
• Electrical insulation and conductivity	

Composite materials are mostly classified in fiber or matrix phases as shown in Fig. 1

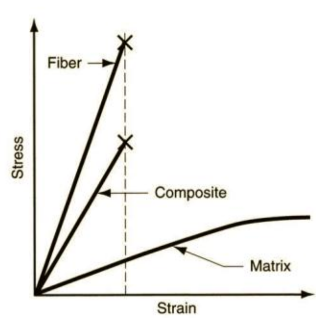

Fig 1. Stress Strain Diagram for Composite Phases

Fibers

Fibers exhibit the nature of effective reinforcements. They comply the defined conditions. They transfer strength to the matrix constituent. By doing this they enhance their properties. The extent of applying of a fiber composite can be gauged by its shape, orientation, and length, composition of the fibers and the mechanical properties of the matrix [5]. The branch of infrastructure engineering give importance to Carbon fibers, Glass, Aramid and Kevlar based fibres. The mechanical properties of the fibers displayed in Table 3 and the stress-strain behavior is showed in Fig.1.

Table 2. Mechanical properties of Fibers

Material	Specific gravity (gr/cm^3)	Tensile Strength (N/mm^2)	Modulus of elasticity (N/mm^2)
Glass Fiber	2.54	2410	70000
Carbon Fiber	1.75	3100	220000
Kevlar Fiber	1.46	3600	124000

Aramid Fibers: It's also known as a Kevlar fiber in the markets as shown in Fig. 5. The structure of Aramid fiber is anisotropic in nature. It usually appears yellow in color. Aramid fibers are costly compared to glass fibre. They exhibit good stiffness. Its good in tension applications such as Cables and tendons, but are more prone to failure in compression. Kevlar has strength, high stiffness high tensile, high modulus. They have low weigh and density. Impact-resistant structures are usually manufactured through these materials. The various types of Kevlar are Kevlar-29, Kevlar-49, Kevlar-100, Kevlar-119, and Kevlar-129

Carbon Fibers: Carbon fibers are basically anisotropic in nature. It is produced at 1300ºC. They exhibit excellent creep level, resistance to chemical effects. They exhibit high strength, low conductivity, low density and high elastic modulus which are beneficial. The drawback is that they are expensive with low compressive strength

Glass Fibers: Glass fibers are basically isotropic in nature. It is vastly applied filament. The various types of glass fibers are E-Glass, S-Glass, C-Glass etc. The identity properties of glass fibers are high strength, water resistant, low cost with and resistance to chemical attack

Mechanical properties of these vary with the orientation of the reinforcing fibers and type of fibres[6]. Continuous and aligned fibers are long, straight and the fibers are oriented parallel to each other. They also appear in Woven Form, Chopped Form in which fibers are short and are randomly and discontinuous arranged as shown in Fig. 2.

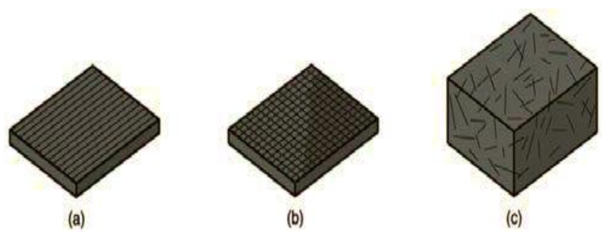

Fig 2: Fiber orientation in a) continuous b) woven and c) chopped form

Matrices form the second biggest percentage of the composite material. They are which classified as shown in Fig. 3. Selection of the relevant matrix impacts the efficiency of the performance in fibers. The matrix is meant to hold the fibers together. It helps totransfers loads to the fibers and protects the fibers from external impacts

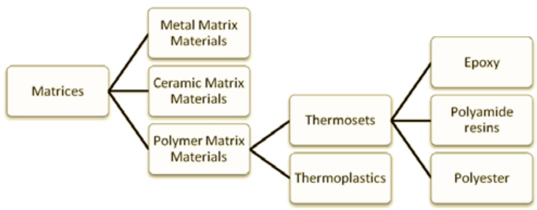

Fig 3. Clasification of Matrix Material

The material properties of moisture need to be considered for the choice of matrix. Shear stiffness, longitudinal compressive strength is given importance. The strain, failure, fatigue, impact is also very important features. The chemical and physical features of the matrix such as melting, curing temperature, viscosity and reactivity with fibers will decide the type of fabrication process. Properties of matrices can be summarized as follows [7]

- It leads to reduction in moisture absorption
- It displays less shrinkage and coefficient of thermal expansion
- Sufficient modulus, strength and elongation
- Must be elastic to transfer load to fibers
- It retains high strength at elevated temperature and displays chemical resistance
- It needs to have ease of processing and good dimensional stability

Adhesives

The purpose of the adhesive is to fix the composites to solid and stable surface. It provides a shear load path. The structural adhesives which are commonly found are Epoxy, Vinvl Ester and Polyester which are the polymer matrix material. Properties of Epoxy and Polyester adhesives are shown in table 3

Table.3. General Properties of Epoxy and Polyester

Properties of Epoxy Adhesives	Properties of Polyester Adhesives
• High cost • Good electrical properties • High bond strength and flexibility • High temperature resistance, • Low shrinkage during curing • Better adhesion between fibre and matrix • Resistance to chemicals , solvents and water • Resistance to creep and fatigue • Limited temperature application range upto 175°C • Moisture absorption affecting dimensional properties • High thermal coefficient of expansion • Extremely harmful to the skin	• Low cost • Good mechanical strength • Good electrical properties • Low viscosity and versatility • Good heat resistance • Cold and hot molding • Curing temperature is 120°C • Good handling properties • Poor chemical resistance • High curing shrinkage • Fair weatherability

The previous decade has witnessed the use of polymers as reinforcement. They are increasingly extended to wide applications for structural strengthening in construction related applications. Fibre-reinforced polymer composites strength enhancement is dependent on the blending and fabrication of the FRP material. Laboratory tests are done to check the laminate strength. Elongation tests are performed to understand the bondage with the surface items should be considered during construction to succeed in Fibre-reinforced polymer composites applications [8]

D. Aramid fibres characteristics

They are basically used as reinforcements in high tensile modulus and strength based applications. These fibers have 5-10% higher mechanical properties when compared to other fibres. They perform better than steel or glass on equal weight basis. They also exhibit excellent heat and wear resistance.

Kevlar fibres are identified by medium to high strength, low elongation, and high modulus. They exhibit densities ranging from 1.35g/cm^3 to 1.45g/cm^3. They display high specific tensile strengths over twice that of nylon and polyester. It's five times higher compared that of steel wire. The specific ultimate tensile strength of Fibre-reinforced polymer composites is generally higher than that of inorganic fiber composites with high strength. The specific modulus of Kevlar reinforce epoxies are three times higher than that of S glass-epoxy and is equivalent to that of graphite fibers and one-third that of boron epoxy. Kevlar has five times the strength of steel wire. They have fatigue life cycle of 10^7 cycles. The exhibit a creep behavior at 50% of the break load and at10^7 cycles is around 0.3%.

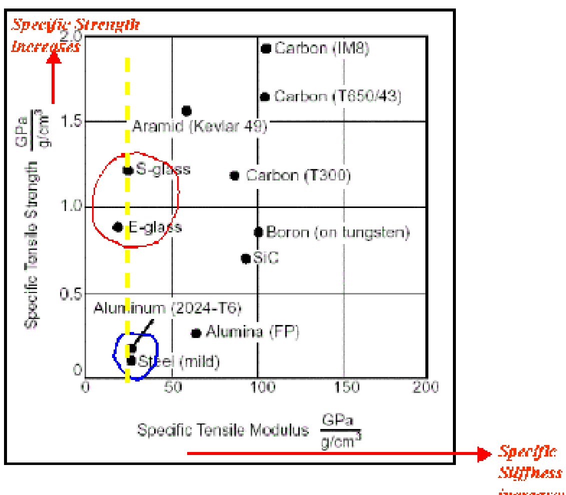

Fig.4. Specific tensile modulus and strength of reinforcements

Thermal Properties

Fibre-reinforced polymer composites are dependent upon the selection of resin systems. Kevlar composites have a useful temperature range from -320 to 400°F (-196 to 204°C). They retain strength modulus at a temperature in excess of 300°C to 640°C.

Impact properties

The aramid based Fibre-reinforced polymer composites resist shattering upon impact. The relevance of the fibers stops the crack propagation. Impact strengths of Fibre-reinforced polymer composites transverse to fiber alignment are in the middle of E glass- epoxy and graphite-epoxy composites. [9]

Chemical Properties

The various particulate materials such as Na_2SO_4, Na_2CO_3, and compounds of their mixtures is observed by x-ray diffraction. Due to the ash being found high in Na_2SO_4, it contributes to water absorption. Only 6 to **10%** of the total sodium in the fibers is dissolved after 15 days, and more than 50% is dissolved within 6 h of exposure to water and it was subsequently noticed that differences in the sodium dissolution and the percentages of the sodium dissolved in water suggest that either sodium is distributed in a disorganised manner throughout the fibers. It is found to be residing mainly in the interior regions, or that the fibers differ in their porosities *to* water.

On a closer examination by x-ray photoelectron spectroscopy of Kevlar-49 and Kevlar-29 fibers to understand the nature, it was noticed that the first few atomic layers of the fiber is found to exhibit surface composition different from the theoretical composition of bulk PPTA

No major differences between Kevlar-29 and Kevlar-49 were found. There is also no evidence of an exudates caused by exposure to high temperatures. Fibers containing residual H_2SO_4 will rapidly darken, particularly at elevated temperatures which are found to have 25% loss in strength. [10]

E. Advanced Composites

The latest combination of thermosetting composite materials using Boron and Kevlar-49 fibres will be strengthened by establishing their mechanical properties related to the production economy. This clearly investigates the aim to characterise these Fibre-reinforced polymers based on the performance. Its economic impact is instantly deployed by manufacturers and designers. Fibre-reinforced polymer composites with polyimide and polyester thermosetting plastics were prepared and tested for various mechanical aspects. Accumulated and comprehensive results state that tensile strength is comparable similar to respective fibre composites due to its dominant fibre characteristics. The compressive strengths is found to be less and emphasises on matrix dependent. Based on the economics of production, Boron-polyester composite provides the best performance in terms of cost per unit tensile properties in comparison to the Boron-polyimide composite. It exhibited better results in terms of cost per unit compressive and flexural properties. The results of the boron based fibre-reinforced polymer composites tend to serve as dependent reference to designer. It helps in choosing a better characterized composites more specifically during preliminary engineering design stage.[11]

F. Advanced composites application

- Aramid reinforced composites absorb 2-4 times more load than fibre such as carbon and glass.
- Pressure vessels were tested to successfully withstand 25-30% in excess in comparison to glass and carbon fibre
- In combination with hybrid Kevlar and carbon fibre is found to have extensive usage in planes, aircrafts and space equipments.
- Aramids are adopted in construction of beams and also for the reinforced concrete materials
- Ropes, cables and high strength wires deploy Kevlar 29 considering its specific strength is 7 times more than steel and 20 times especially more in sea conditions. Hence adopted for electro mechanical cables and fibre optics
- Based on its high temperature characteristics and fire resistive property its deployed to manufacturing protective clothing in fire proof apparels and gloves
- On the basis of its excellent impact behavior its applied in ballistic kits
- Wear applications use short fibres are employed in the production of brake pads and clutches [12]
- Upon the replacement of asbestos with 10% of Kevlar pulp it was noticed that the life got extended by 3 to 5 times.
- Printed and Electronic circuit boards can be made lighter and thinner by incorporating low specific weight and high density properties of Kevlar materials [13]

G. Conclusion

By the review paper we can express that the Kevlar fibre with LY-556 Epoxy resin was found to display good tensile strength, flexural strength and impact strength. It also finds vast applications which are relevant in aircraft and automobile bodies considering a fact that it reduces weight and gives more strength. The studies further showed that with the variation in the fibre type and fillers used has a significant effect on the tensile and flexural properties of the specimens, the three varieties of fibres used are plain bi-woven glass fibre reinforced laminate, plain bi-woven graphite fibre reinforced laminate and plain bi-woven Kevlar Fibre reinforced laminate.

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