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EXPERIMENTAL INVESTIGATION OF COMPOSITE MATERIALS FOR MARINE APPLICATIONS-A REVIEW

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Abstract. Composite materials (Fibre Reinforced Polymers) are lightweight with high stiffness and strength. Polymeric Composite Materials have been used in boats, ships, submarines and offshore structures for the last fifty-five years. This paper overviews the polymer reinforcement of various fibres and the particles are investigated for their impact strength, energy intensity, the efficiency of the composite structure, ultimate strength, deformations, bending strength and impact resistance. After reviewing the natural fibre reinforcement, the fibre structure and its mechanical and thermal properties are reviewed. The paper also discusses Polymeric materials and honey core materials for its uses in light applications such as marine constructions and research development.

INTRODUCTION

Composite materials have been used for thousands of years. They were once used as bricks mixed with mud. They have become a part of our everyday applications. They are defined as a mixture of two or more materials - (Reinforcement, Fillers and Binder) - of different in composition. Composite materials are also called as composition materials. These materials with different physical and chemical properties individually, when joined together make up a whole new property of complex proportions. Its strong load carrying material is known as Reinforcement while its weaker material is known as Matrix. Reinforcement provides stiffness and strength which helps to support thestructural load. Composite materials do not lose their respective identities but still, they relate to the properties of the product of their mixture. The benefits of composite materials include great stiffness and strength. In many cases, the reinforcement is stronger, tougher, harder and stiffer than the matrix. It's applied in automobiles, aerospace, electronic equipment, sporting goods, furniture, medical equipment & Packaging Industry. Composite materials used as an industrial material for their outstanding resistance to chemicals and corrosion. This property is one of its vital characteristics. Some important properties include low mass, lightweight, simple manufacturing & processing possibilities. Complex material bodies are easily produced and the tooling cost is very low as well. Good surface finishes are an integral feature. Composites have four to six times tensile strength as compared to steel or aluminum (depending on the reinforcements). Composites have less noise and lower vibration transmission than metals at times of operations. Composite materials have torsional stiffness and impact properties. They have high fatigue and impact strength, environmentally friendly and simple maintenance, higher fatigue endurance limit (up to 60% of ultimate tensile strength.) Composites exhibit fire and corrosion resistance. They have better surface properties and readily incorporate integral decorative melamine. Other characteristics of composites are low electrical conductivity and thermal expansion. Composite parts can eliminate joints and provide simplification and assembly design compared to non-composite metallic parts. Composite materials are expensive materials, take a long time to develop, and are difficult to manufacture, have low ductility, temperature limits, and suffer solvent or moister attack, hidden damages and damage susceptibility. The Matrix that isused in the composite materials is subjected to environmental degradation. Hence the analysis becomes difficult and hot curing becomes necessary in many cases which require special tooling and hot or cold curing takes time. Materials require refrigerated transport and storage have limited shelf life.

APPLICATION

Kumar S. et al. [1] in his paper discusses rice husk and its ash's industrial and domestic application. They are employed to produce high-quality steels as rice husk have insulating properties like lightweight, high melting point, its bulk density is less, less thermal conductivity, and high porosity. They are used to make blended cement to meet the demands for building material. Extracting silica becomes economical as it has high silica content. Rubber industries make use of silica as a reinforcing agent. They are also used in cosmetics, toothpaste, and in food industries as a caking agent. D. Pathania et al. [2] studied and showed that the constant and dissipation of di-electricity decreases with frequency and increases with temperature. But its loss factor decreases with an increase of its frequency at a fixed temperature and increases with temperature at low frequencies. When chemically treated, the dielectric loss factor decreased. They found that with continuous systematic research, there is an excellent future for Polymer Reinforced Composites for various electrical applications.A.Balaji et al [3] discussed bio-composites material. This material and natural fibers are made from eco-friendly sources. In the future, they can be used as well-designed industrial components which can replace petroleum-based products. By using bagasse fibers for manufacturing bio-composites, the future generation can benefit from it. Different methods are to be adopted to develop the bio-composites which can be widely used for daily requirements like furniture, house, fencing, window, decking, designing, flooring, lightweight automobile components or sporting goods. To aim for a sustainable future, its main advantages like low cost, ease of availability and design should be considered. T. Subash et al [4] discusses blast fibers reinforced green composites for the interior structure of an aircraft. They provide the benefits to create body panels, seat cushions, and cabin linings, parcel shelves etc., Jute, kenaf, bagasse, bamboo, coir, and sisal has proved to be a material with the high strength and is often employed in aerospace and automotive industry. They possess lower density when compared to traditional mineral composites. To reduce the amount of energy consumed in the aerospace application, they have a great capability to lightweight sustainable products.

Gururaja M N et al. [5] give a review on applications and future development in the field of hybrid composites. It reviews the composite materials in terms of availability and properties. It also outlines the trends and studies the applications. The Author concludes that the hybrid composite material can be applied in aerospace, marine, automotive, wind power etc. Prof.N.V. Hargude et al. [6] discussed composite material mono leaf spring. Here, we learn that it's possible to manufacturing a leaf spring by using E glass epoxy fiber. Also, weight reduction is possible by using the composite material. When compared to steel leaf springs, they offer comfort and prolonged life. Obilade, I.O. et al. [7] studies the usage of rice husk ash as semi-replacement for cement in concrete. It's concluded that the cement replacement is at a range 0-20% optimum addition of RHA. The compacting factor value of the concrete decreases as the RHA percentage increases. When the percentage of RHA replacement increases, the bulk density of concrete reduces. When the concrete's compressive strength decreases, the percentage of RHA replacement increases. Allen John et al. [8] give a review of the composite materials used as a vehicle bumper for passenger vehicles. The right materials should be selected and it should satisfy the engineer, and also be of low cost. The composite materials are also used as steering, brakes, body panels, suspension, etc. for automobiles. They also include bumper systems, instrument panels, cross wheel beam, intake manifold, leaf springs, drive shafts and fuel tanks. S. Prabhakaran et al. [9] developed the ceiling fan blade using glass fiber reinforced polymer composite. Here, the composite blade is fabricated. They have more strength compared to thepresent fan blade. The existing fan blade weighs about 295 grams whereas the composite fan blade weighs 215grams (28% lesser than theexisting blade.) The existing blade consumes 0.052 units when compared to 0.037 units by a composite blade. The composite ceiling fan blade is Rs.279 (44% less than existing aluminum blade.) Its strength is also high. The study concludes that fiber reinforced plastic material is better for manufacturing composite ceiling fan blade. It also concludes that they can be used as a viable alternative for the reinforced concrete frame at earthquake-prone zones. To construct masonry structure, fiber reinforced cement composites are found to be effective.

PiyooshThori et al. [10] studied the composite materials which are usedfor industrial machinery. The Hybrid laminates are applicable to various industries such as constructions, transportations, marine, aeronautics, naval, automotive and also in the field of electronics. The study is focused on the applications of Hybrid composites to better understand the growth in cutting-edge technology. Md Iqbal Ahmad et al. [11] presents the current scenario, future& applications on earthquake resistant buildings. Aerospace: almost 50% of the components are composites. Composite materials reduce weight and ease assembly. They are vastly used for developing fighter planes, civil aircrafts, satellites, launch vehicles and missiles. Many aircraft components like rudders, spoilers, airbrakes, LG doors, engine cowlings, keel beam, rear bulkhead, wing ribs, main wings, turbine blades, propellers, etc. are made by composites. [12-14].

Automobiles: Composites are used to make safer, lightweight and fuel-efficient vehicles. They consist of a high strength fiber (carbon or glass) in a matrix material (epoxy polymer) which when fused together combines to provide enhanced properties when compared to their individual properties. They are used to make steering wheel, dashboard, seat, instrument cluster, interior and exterior panel, roof, hatch, mats, energy absorber, leaf spring, wheels, engine cover etc.

Medicine: Composites are made to interact with the biological system and are also a nonviable material in medical instruments. Technology has been advancing in the field of composite materials for years and they are widely used in surgical technique and sterilization methods. Composites implants in the form of heart valves, intraocular lenses, dental implants, pacemakers, sutures, bone and joint replacements, vascular grafts, biosensors, artificial hearts etc. are widely used to replace or restore the damaged organs and thus improve the patient's health [18-19].

Electrical: Composite materials own strength and high modulus. When used for electrical applications, they emphasize high thermal conductivity, low thermal expansion, low dielectric constant and high/low electrical conductivity. They use expensive fillers, such as silver particles, which provide high electrical conductivity. Applications include interlayer dielectrics, die attachment, lids, thermal interface materials, printed circuit boards, electrical contacts, connectors, heat sinks, housings etc. [20-22].

Sports: Sporting goods make use of composites as they less maintenance, lightweight, easy to carry and are durable. Woods were normally used at the beginning but they had poor properties. Composites have characteristics like friction resistance, abrasion, fatigue resistance break resistance, superior thermo-stability, and resistance and vibration attenuation. They are also used to make tennis rackets, badminton rackets, softball bats, ice hockey sticks, bows and arrows etc. [23, 24].

Chemical Industry: Composites are resistant to fire and they are lightweight. They are widely used in exhaust stacks, pumps & blowers, structural supports, storage tanks, columns, reactors industrial gratings, scrubbers, ducting, piping, etc. Other usages include fan blades, ducts, stacks, underground storage tanks, casings. Internationally, composite applications in chemical industry are relatively small.[25].

Other- Composites are used in constructions of industrial supports, buildings, roof structures, tanks and bridges. They offer excellent resistance to marine environment. We can make light doors, windows, furniture, etc. for domestic purposes [26].

They are used as an industrial material for their outstanding resistance to chemicals and corrosions. It is one of the most important properties. There also have less mass, lightweight, simple manufacturing and processing possibilities, ease to make complex bodies which are appropriate to very small products and large product. The tooling cost is very low and good surface finish can be obtained. [27, 28].

Basalt is a material found in volcanic rocks which originate from frozen lava and have a melting temperature between 1500° and 1700 °C [29],[30]. Its state is strongly influenced by the temperature rate of quenching process which leads to more or less complete crystallization. 80% of basalts are made by two essential minerals; i.e. plagioclase and pyroxene. After analyzing the chemical composition, it is observed that SiO2 is the main constituent and Al2O3 is the next. [29], [30]-[32]. Basalt fiber, which was developed by Moscow Research Institute of Glass & Plastic in 1953 and 1954, is a high-tech fiber invented by the Soviet Union after 30 years of research. Its industrial furnace adopted 200 nozzles drain board combination oven. The bushing process was completed in 1985 at Ukraine Fiber Laboratory [33]. The base cost of basalt fibers varies according to the quality, type of raw material, production process and characteristics of the final product. The chemical and mechanical properties depend on the composition of the raw material. Differences in terms of composition and elements concentration, it gives the difference in thermal and chemical stability and more or less good mechanical and physical properties [34].

Liu et al investigated that the tolerance of basalt-fiber-reinforced epoxies composites towards saltwater immersion, moisture absorption, temperature and moisture cycling. [35]. The authors used two twill fabrics (i.e. basalt and glass) having same weave pattern and yarn ratio in both warp and weft directions and two polymers (i.e. epoxy resin and vinyl ester) as a matrix, thus manufacturing four composites having the same fiber volume fraction (i.e. 37.7%). The authors selected these epoxy and vinyl ester resins because they are low cost, and have high heat resistance (i.e. heat distortion temperature of epoxy resin equals to 74°C, glass transition temperature of vinyl ester equals to 99°C). Epoxy resins are expensive but show better mechanical properties and higher resistance to moisture absorption, corrosion and to environmental agents when compared to vinyl ester resins. The epoxy resins have low shrinkage during the curing process: i.e. the vinyl ester resins shrink up to 12% in volume whereas epoxy resins shrink less than 5%. Due to the absence of styrene, the epoxy resins have less toxic emissions than vinyl ester during the curing process, making it possible to use them with "open-mould" manufacturing technologies (e.g. hand lay up or vacuum bagging). For seawater resistance, the vinyl ester resins show better behavior than epoxy. Tensile and short beam tests were carried out showing that after 240 days of ageing in salt water or water, a slight but significant decrease in Young's modulus and tensile strength of basalt composites were found. The freeze-thaw cycle of up to 199 cycles did not change the shear strength but ageing in hot (40 °C) saltwater or normal water made the shear strength of basalt decrease. The ageing results indicated that both the interfacial region in basalt composites can be more vulnerable to damage than glass composites. The interfacial region of basalt composites requires modification before using it to long-term applications involving exposure to water.

He et al. [36] studied the impact damage modes and the mechanical properties, post-impact of three epoxy-based composites; reinforced S-2 glass, aramid and basalt fibers. All the unidirectional laminates were produced by hot-press molding procedure and it obtained the fiber volume fraction of 60%. The Charpy pendulum machine induced the impact damage to the un-notched specimens. The post-impact were analyzed by conducting three-point bending tests to the specimens in the directions of impact face and back face. The results showed that, under low-velocity impact, glass reinforced beam have a mutational damage evolution. At the initial stage, damages were similar in basalt and glass beams. At the high impact energy, basalt laminate exhibited a progressive damage to the fibers as the back face tension fractured layer by layer. Aramid beam also displayed a progressive evolution. The reduction in residual flexural modulus is slightly larger than the strength, especially for aramid reinforced beam. The discrepancy between the reductions in the flexural properties at the direction of the back face and those of the impact face was larger for aramid beam than glass and basalt. However, all these three composites beams showed a similar variation to the law in residual flexural properties as a function of impact energy.

The degradation in seawater of epoxy composites reinforced with basalt and glass plain weave fabrics. They were fabricated using hot-pressing process and were compared and monitored the mass gain and strength maintenance ratio [37]. The samples were immersed in artificial seawater. They are prepared by mixing the sea salt with distilled water. The salt concentration was at a weight of 6 %, and at a temperature of 25 °C for up to 90 days. They showed that the anti-seawater corrosion property of the basalt fiber reinforced composites was almost the same as that of the glass fiber reinforced. (Figure 7). Based on these results, the authors explored possible corrosion mechanisms and found that by effectively lowering the Fe2+ content in the basalt fiber, it could lead to a higher stability for the basalt fiber reinforced composites at a seawater environment.

Wang et al studied the chemical durability of unidirectional basalt fiber reinforced epoxy composites [38]. Composites were immersed in eight kinds of chemical mediums (i.e. 30% vitriol, 5% hydrochloric acid, 10% ammonia, 5% nitric acid, 10% sodium hydroxide, saturated sodium carbonate solution, acetone and distilled water) for 15, 30, and 90 days at room temperature. The monitoring of the flexural properties was carried out after each period of immersion. Results showed that the corrosion behavior of the composites differed greatly due to the different corrosion mechanisms of basalt fiber in acid and alkali mediums. In particular, in alkali mediums, the flexural modulus is closer to the original value while the flexural strength declines gradually. In acid mediums, the flexural strength and flexural modulus decline in the same way.
De la Rosa Garcia et al. [39] proved the good behavior of epoxy-based composites when reinforced with basalt unidirectional fiber as bending reinforcement for pine timber beams.

Kim et al. [40] found the effect of the silane and acid treatments of multi-walled carbon nanotubes on the flexural and fracture behaviors of epoxy/basalt composites. Here, flexural and mode I fracture tests were performed by using acid-treated and silane-treated carbon nanotube, epoxy, and basalt composites respectively. Results showed that the flexural properties and fracture toughness of silane-treated carbon nanotube, epoxy and basalt composites are higher than those of acid-treated carbon nanotube, epoxy and basalt composites. SEM examination showed that the improvement in the flexural and fracture properties of silane-treated carbon nanotube, epoxy and basalt composites appeared due to enhanced dispersion and interfacial interaction between the silane-modified carbon nanotubes and when the epoxy resin was used as the matrix.

Lee et al. [41] showed the better tensile and thermal properties of salinized carbon nanotube, woven basalt and epoxy composites in comparison to unmodified and acid modified carbon nanotube-based composites.

Bashar et al studied the effect of Nano-reinforcements on mode-I interlaminar fracture toughness of quasi-uniaxial basalt fiber-reinforced by epoxy laminates. They were manufactured by filament winding method followed by vacuum bag to consolidate the part and bleed out excess resin [42]. A 50 mm thin ethylene tetrafluoroethylene film inserted at the mid-plane of each laminate and were investigated as a crack initiator. From the different nano-reinforcements available, an organically modified sodium-montmorillonite Nano clay and an acrylic based tri-block-copolymer were studied. The authors showed that the fracture energy of the bulk epoxy nanocomposites was significantly increased with acrylic triblockcopolymer addition but remained unchanged with the incorporation of nano-clay. However, delamination fracture toughness was not influenced by the presence of nanoparticles in the matrix. Decreasing fiber volume fraction significantly improved the interlaminar fracture energy since the rigid fibers in these composites constrict the stress field ahead of the crack. Hence, increasing the resin content improved the composite delamination energy by increasing the capacity for matrix deformation.

ArySubargia et al. [43] studied the effect of different tourmaline Micro/Nanoparticle loading, with and without a surfactant to better disperse the tourmaline particles, on the mechanical properties of the epoxy composite which are laminated and reinforced with basalt fibers. Here, all the composites investigated were manufactured by a vacuum assisted transfer resin molding by using a reinforcement woven basalt fabrics having an area density equal to 210 g/cm2. The experimental results showed that significant improvement in both tensile and flexural strength and modulus was achieved when tourmaline particles were incorporated in the basalt/epoxy composite. The best result was obtained at 1% in weight of tourmaline loading with a surfactant. The authors stated that the enhanced performances of the laminates were due to a good dispersion of tourmaline particles in the epoxy matrix that provided an increased surface area for strong interfacial interaction and good load transfer.

Varley et al. [44] studied and compared different modification methods to understand the influence of matrix-fiber interaction on the mechanical properties of epoxy-basalt composites. They employed two basic strategies. They first applied colloidal silica to increase the surface roughness of the fiber. Then, they chemically attached an epoxy silane to the fiber surface using sol-gel methods. They also did a hybrid approach which combined two strategies. Finally, the hybrid functionalized surface of the fiber was modified through the addition of triethylenetetramine. To use basalt reinforced composites for structural applications, some authors have compared the use as matrices of epoxy resins and vinyl ester ones.

Czigany et al. [45] investigated the mechanical failure of basalt fiber mat-reinforced composites with vinyl ester and vinyl ester/epoxy hybrid resins as a function of resin hybridization and treatment for basalt fiber surface. The composites with a weight fiber content equal to 30% were produced by resin transfer molding method. Two coupling agents were used to improve the adhesion of basalt fibers towards the resins used. The first contained epoxy functional groups while the second had vinyl functional groups. In the hybrid resin system, the vinyl ester/epoxy ratios were set equal to 1 to 3, 1 to 1 and 3 to 1, respectively. The results showed that the toughness of the brittle vinyl ester was effectively improved by hybridizing it with an appropriate epoxy resin. The authors stated that the hybrid resin systems in the studied range possess an interpenetrating network structure, which may be very advantageous in fiber-reinforced composites. It was established that for the ratio of 1 to 1 vinyl ester/epoxy hybrid resin-based composites both strength and toughness could be enhanced at the same time when using surface-treated basalt fibers. The authors also proved that the shape and size of the damage zone in the composites, detected by the location of the acoustic emission activity, are independent to both types of treatment of basalt fiber surface and the resin composition.

Colombo et al. [46] studied the static and fatigue properties of basalt fiber composites by using vinyl ester and epoxy resins as a matrix. The technique used composites manufacturing the vacuum infusion process. Both the panels showed fiber volume ratio is equal to 50%. Varied type of mechanical tests is performed: static delamination tests, classical, static tensile and compression tests, and stepwise fatigue tests. The epoxy composites showed higher mechanical properties with respect to vinyl ester. The failure mode is compact since fibers do not tend to explode, as shown in Figure 9. By considering fatigue curves, it is evident that similar trend of fatigue curves of two composites compared specimens. Vinyl ester resin has been widely used as a matrix for basalt fiber reinforced composites.

Carmisciano et al. [47] carried out a comparative study on basalt and E-glass woven fabric reinforced epoxy based vinyl ester resin. The authors used fabrics with a specific area density of 220 g/m2. The laminates were manufactured by resin transfer molding method thus achieved a fiber volume fraction equalling to 0.28 for both composites. The mechanical properties of the composites were evaluated by carrying out three-point bending and short beam tests. The electrical properties carried out measurements of the complex permittivity of the materials versus frequency. The experimental results showed higher flexural modulus and apparent interlaminar shear strength in comparison with E-glass but also lower flexural strength and similar electrical properties.

The compression behaviours of plain woven basalt/vinyl ester resin composites under high strain rates have been studied by finite element analyses by Zhang et al. [48]. The authors concluded that the plainly woven fabric structure and the rate dependent behaviours of the matrix are the key factors which affect the strain rate sensitivity of the compressive properties.

De Rosa et al. [49] studied the post-impact performances of two vinyl ester based composites: i.e. woven fabric basalt fibers and woven fabric E-glass fibers. The basalt and E-glass fabrics were plain weave fabrics with specific area weight equalling to 220 g/m2 and the matrix used was a Bisphenol-A epoxy-based vinyl ester resin. The laminates were manufactured by a resin transfer molding method. The fiber volume fraction for both composites is equal to 0.38. The non-impacted specimens were subjected to interlaminar shear stress and flexural tests. Then, mechanical tests were repeated on laminates by impacting a falling weight tower at three impact energies (i.e. 7.5, 15 and 22.5 J). They were also monitored by using an acoustic emission analysis of signal distribution with load and with distance from the impact point. Results showed the damage tolerance to impact and also their post-impact residual properties after impact did not differ much with a slight superiority for basalt fiber reinforced laminates. The authors stated that the principal difference is represented by the presence of a more extended delamination area on E-glass fiber reinforced laminates than on basalt fiber reinforced.

Yusriah et al. [50] studied the effects of hollow polymeric microspheres on specific mechanical and thermal properties of glass, basalt, and carbon weaved fabric reinforced vinyl ester composites. The experimental results showed that the specific flexural and specific impact strength of the composites were marginally increased with the addition of hollow polymeric microspheres. It was also found that a reduction was found at the flexural modulus. The thermal stability of the neat vinyl ester was improved with the addition of woven glass and carbon but was consequently reduced with the further inclusion of hollow polymeric microspheres. On the basis of the experimental data, the authors found that the major reinforcing effect of the woven fiber reinforced vinyl ester composites was governed by the type of fiber used. Also, the addition of hollow polymeric microspheres enhances the ductility of the composites.

Manikandan et al. [51] studied the effect of fiber surface modifications on the mechanical properties of unsaturated polyester reinforced with basalt and glass fabrics. Composites with and without acid (H2SO4) and alkali (NaOH) treatments of the plain weave fabrics with area weight equalling to 220 g/m2 were manufactured by using the hand layup technique at room temperature. Tensile, shear and impact tests were investigated on the composites. The results showed the performance of basalt fiber reinforced composites with unsaturated polyester and were found to be superior to the glass fiber reinforced composite. The acid-treated basalt fiber reinforced composite showed that the higher tensile strength value. The glass fiber composite is a lot more affected by the alkali treatment than the basalt fiber reinforced composites.

Gideon at al. [52] studied the damaging behaviours exhibited by plain-woven basalt-unsaturated polyester laminates under low-velocity impact by varying the impact energy and finite element approach. The finite-element method results were in good terms with the experimental results regarding peak force, maximum energy absorbed and damage area.

The mechanical properties and the thermal stability of basalt fiber reinforced poly (butylene succinate) composites were studied by Zhang et al. [53]. Composites with a fiber content of up to 15% in volume were fabricated by injection molding method. The good thermal stability of basalt fibers allows applying an additional heat treatment (Partial Pyrolysis in nitrogen at high temperatures) to a polymer matrix composite, which yields a ceramic matrix composite with enhanced resistance to oxidation. Černý et al used polysiloxane resins as matrix precursors in several recent works [54]- [57]. It is noted that total pyrolytic transformation (i.e. the transformation of an organic into an inorganic material) of siloxane takes place only above 1000 °C. The exposure of the basalt fibers to this temperature is inappropriate since the amorphous fiber showed a creep and the formation of crystalline phases causes brittleness of the fibers in the temperature range of 600–700 °C [54]. Hence, the process of partial pyrolysis (i.e. partial transformation of the matrix from polymer to refractory silicon oxy-carbide) must be developed at the temperature of 750 °C.

They studied the heat resistant to composites reinforced with continuous basalt fibers made by incomplete pyrolysis of a polysiloxane matrix. They also analyzed the effect of the fiber lubrication [55]. To this aim, unidirectional composites were fabricated by the wet-winding method. The obtained polymer–matrix composites were further pyrolyzed in a nitrogen atmosphere with a temperature between 650 °C or 750°C. In order to assess their thermal stability, some specimens were exposed to hot air at 650°C or 750°C for up to 240 h prior to measuring their properties. The experimental results showed that the flexural strength of composites is sensitive to the presence of fiber lubrication and to the pyrolysis temperature. (i.e. removal of lubrication and increasing of the heat treatment temperature from 650 to 750°C were found to diminish the flexural strength.) Also, the pyrolysis temperature was a lot more determining for matrix-governed elastic properties (shear modulus) than for those dominated by the fibers (Young's modulus). It was also shown that a short exposure to hot air (750°C for 4 hours) deteriorated the flexural strength of the composites and changed the failure mode to brittle fracture.

Lopez De Vergara et al. [58] studied the impact behavior of basalt fiber reinforced furan composites which are manufactured by microwave technology. It shows the microwave cured composites presents a higher value for delamination threshold force, maximum load, interlaminar shear strength, and penetration threshold than the conventionally cured ones.

A study on the tensile properties at various temperatures of clay reinforced polypropylene, nanocomposites and chopped basalt fiber reinforced, polypropylene-clay nanocomposites was done Eslami-Farsani et al. [59] They showed that by adding nano-clay, the yield strength and Young's modulus were improved. But the ultimate tensile strength of polypropylene-based composites was reduced. Also, the addition of chopped basalt fibers improved Young's modulus of the composites.

The effect of temperature, adhesion time, and surface treatment of basalt fibers for the mechanical properties of composites based on a high-density polyethene and a copolymer of 1,3,5-trioxane with 1,3-dioxolan reinforced with basalt fibers was studied by Bashtannik et al. [60]. The results showed that the surface modification of basalt fibers in acidic and alkaline media intensified the adhesion of thermoplastics to it. Also, it was revealed that the treatment in the acidic medium is more efficient and considerably improves the mechanical properties of composites.

Czigany [61] analyzed the mechanical properties of polypropylene which were reinforced with basalt, hemp, glass and carbon fiber and by basalt hybrid composites. To achieve better interfacial adhesion, the fibers were treated with a reaction mixture of maleic acid anhydride and sunflower oil. The results showed that the mechanical characteristics were improved in each case when compared to pure polypropylene matrix. It was revealed that basalt fiber hybridization resulted in a slight increase in the mechanical properties of the hemp fiber composites. For carbon fiber and primarily glass fiber composites a significant improvement was observed.

Chikhradze et al. [62] proposed usage of hybrid epoxy composites reinforced by carbon, basalt and E-glass fibers for manufacturing wind turbines. A study on the influence of the substitution for carbon fibers by basalt fiber was conducted and showed that at 20% and 40% substitution gives approximately the same deterioration of the strength and the elasticity characteristics. Hence, it is accepted as an economical solution.

Cao et al. [63] presented a study on the tensile properties of hybrid carbon/glass and carbon/basalt reinforced polymers. To verify the thermal behavior of the composites, the tensile tests were performed at different temperatures. A similar reduction of the tensile strength of carbon/glass and carbon/basalt composites compared to all of the carbon composites.

ArySubagia et al. [64] investigated the effect of different stacking sequences of carbon and basalt weaved fabrics on the flexural properties of hybrid composite laminates which were manufactured by vacuum assisted resin transfer molding method. A positive hybridization effect was shown by the stacking sequences. The flexural properties of hybrid composites were strongly dependent on the sequence of fiber reinforcement. The interplay hybrid composite with carbon fiber at the compressive side showed higher flexural strength and modulus when compared to the time when basalt fabric was placed on a compressive side.

Hybrid epoxy composites with alternate stacking sequences of plain basalt and carbon fabrics were developed by Zhang et al. to improve the toughness properties of conventional carbon reinforced composites [65]. The toughness properties were studied by an open hole compression test. The results showed that the hybrid composites displayed a higher open hole compression strength while the plain carbon fiber composites showed less.

Wang et al. [66] studied the effect of fiber arrangement in 3D woven hybrid basalt/Kevlar 129 composites on their low-velocity impact properties. Aramid and basalt fibers were used to fabricate two epoxy structures. The first epoxy structure named interplay hybrid composite where different yarn types were placed in a different layer. The second, namely intraply hybrid composite where each layer was composed of two types of alternately arranged yarns. It is shown that the interply hybrid composite has higher ductile indices, lower peak load, and higher specific energy absorption at both warp and weft directions. The intraply hybrid composite had a layer-by-layer fracture mode for the interply hybrid composite.

In the paper [67] five different types of woven fabrics (Figure 13) with different volume percentages of nylon (0%, 25%, 33.3%, 50% and 100%) were used as reinforcement for the epoxy resin. The effect of nylon/basalt fiber content on the residual deflection totally absorbed energy, elastic energy, maximum force, maximum deflection, size and type of damage were studied at several low-velocity impact nominal energy levels (i.e. 16, 30 and 40 J). The results showed that the impact performance of these intraply hybrid laminates is greatly affected by nylon/basalt fiber content.

In a recent paper study [68], the authors performed a low-velocity impact and compression test after conducting impact tests at different nominal impact-energy levels (16, 30 and 40 J) on hybrid composite laminates reinforced by basalt-nylon intraply fabrics. Five different types of fabric were produced with a rapier loom: (homogeneous basalt fabric, a homogeneous nylon fabric and three hybrid basalt/nylon fabrics with different volume percentages of nylon (i.e. 25%, 33.3% and 50%)). For hybrid fabrics, the percentage of nylon or basalt was equal at the warp and weft directions. The results showed that at low impact energy, hybridization and variation in basalt/nylon fiber content cannot improve the impact performance of composite plates. Vice versa, the impact performance becomes more and more dependent on the content of nylon and basalt with increasing impact energy.

In recent years, both industrial and academic world are focusing their attention toward the development of sustainable composites that are reinforced with natural fibers.

Fiore V et al. [69] studied the natural fibers (i.e. animal, vegetable or mineral) that can be used as reinforcement. The basalt ones represent the most interesting of all properties. Basalt fibers are mineral fibers which offer better features in comparison to glass fibers. Composites made of basalt fibers within the polymer (both thermoplastic and thermoset), biodegradable, metallic and concrete matrices often always exhibit good properties. Basalt fibers within polymers (i.e. thermoplastic, thermoset and biodegradable), metallic and concrete matrices show promising properties. Hence, these fibers have the potential to be the next generation materials for structural application for infrastructure, automotive industry and consumer applications.

Igor Maria De Rosa et al. [70] studied the fibers extracted from Okra Bahmia Plant and were characterized by electron and optical microscopy and FTIR. Their thermal degradation behavior was fully observed through TGA and DTG curves. Mechanical properties of these fibers were examined by single fiber tensile tests and the results were analyzed through a two-parameter Weibull distribution. The fracture modes of fibers fractured in tension were also investigated. The results of the thermal and mechanical characteristics are comparable to those of other common lignocellulosicfibers. It confirms that these fibers show some potential as reinforcement in polymer matrix composites.

A. K. Bledzki et al. [71] studied that in the automotive industry, the glass fiber reinforced polymers are to be replaced by natural fiber reinforced polymer systems. So, higher requirements will be implemented to the physical fiber properties, fiber-matrix adhesion, and quality has to be assured. To improve the properties of epoxy resins (EP) and polypropylene (PP) composites, flax and hemp fibers were modified by mercerization. MAH-PP coupling agent was used for preparing the PP composites. The effects of different mercerization parameters such as the concentration of alkali (NaOH), temperature, and duration time along with tensile stress applied to the fibers of the structure. The properties of hemp fibers were studied and analyzed via the cellulose I–II lattice conversion. It is found that the mechanical properties of the fibers can be controlled at an abroad range by using appropriate mercerization parameters. Unidirectional EP composites were manufactured by the filament winding technique. A film-stacking technique was used in the PP matrix material combination. As an example, the influence of mercerization parameters on the properties of EP composites was studied with hemp yarn. Different macro-mechanical effects are shown in hemp and flax-PP model composites with mercerized, MAH-PP treated more MAH-PP-treated mercerized yarns. The composite's properties were examined by tensile and flexural tests.

R. Chandra et al. [78] Reviewed the composite damping mechanisms and methodology which is applicable to the optimization of the fiber-matrix adhesion and is essential for improving the physical and mechanical properties of natural fiber reinforced polymer composites. Hence, a physical or chemical modification of natural fibers or the use of coupling agent or that of a combination of both is possible to reach the required properties. [72–74] Because of their suitability for injection molding or extrusion processing, thermoplastic matrix materials are very important for greater design freedom. In automotive applications, Polypropylene (PP) is the most commonly used thermoplastic matrix material (likewise in hybrid fiber compounds). Epoxy resins (EP) are frequently used thermosets that are to be reinforced with natural fibers. The polar natural fiber and the nonpolar matrix material as PP have different and incompatible surface polarities, maleic-anhydride-polypropylene copolymer (MAHPP) and is commonly used for upgrading the interphase compatibility. [72-77].

The paper presents damping studies which involve macro-mechanical, micromechanical and viscoelastic (relaxation and creep) approaches. Models for interphase damping and damages in composites were observed. Some works related to improved damping models for thick laminates improves laminate damping and optimizes damping in fiber-reinforced composites/structures and these were all critically reviewed.

V. G. Geethamma et al. [79] learnt that the Coir fiber which is considered to be a poor reinforcing fiber in rubber because of its low strength and lack of physical characteristics which are generally essential for a reinforcing fiber. Interfacial adhesion between coir and natural rubber (NR) was improved by treatment of the coir fibers with alkali (sodium hydroxide and sodium carbonate) and NR solution, and by the incorporating the HRH/RH bonding systems. Composites containing 10 mm long coir fibers were vulcanized at 150° (Two according to their respective cure times). To measure the extent of fiber orientation, green strength measurements were carded out. The extent of fiber orientation in the composite was calculated from green strength measurements. It is observed that the extent of fiber orientation is highest in the natural rubber composite containing almost 40 phr coir fiber. But, the effect of high fiber orientation isn't reflected in the tensile strength of this composite. Likewise, no improvement in the anisotropy in tensile strength was observed for composites containing 60 phrfiber as expected from the anisotropy in green strength measurements. They also studied the variation of tensile strength. The tensile strength decreased sharply at 30 phr and showed only a slight increase even at a high fiber loading of 60 phr. This behavior is explained on the basis of the shear flow that occurs during compression molding and the poor interfacial adhesion.

M. Grujicic et al [80] studied the fiber-reinforced polymer matrix composite materials which show very complex deformation and failure behavior at ballistic/blast impact loading conditions. This complexity is normally attributed to a number of factors such as (a) hierarchical/multi-length scale architecture of the material's microstructure; (b) nonlinear, rate-dependent, pressure-sensitive mechanical response; and (c) the interplay of various intrinsic phenomena and processes such as fiber twisting, interfiber friction/sliding, etc. Material models which are used in the computational engineering analyses of ballistic/blast impact protective structures made by this type of materials, they do not generally include many of the aforementioned aspects of the material dynamic behavior. Discrepancies are also often observed between the computational predictions and their experimental counterparts.

To address this problem, the results of an extensive set of molecular-level computational analyses that shows the role of various microstructural/morphological defects on the Kevlar-fiber mechanical properties are used to upgrade one of the existing continuum-level material models for fiber-reinforced composites. The results showed that the response of the material is significantly affected as a result of the incorporation of microstructural effects, both under the quasi-static mechanical testing condition and dynamic ballistic-impact conditions.

This paper reviews the tensile properties of natural fiber reinforced polymer composites. Natural fibers have got the attention of researchers, engineers and scientists as an alternative reinforcement for fiber reinforced polymer (FRP) composites. They are used as a replacement for the conventional fibers like glass, aramid and carbon as they cost low, have good mechanical properties, possess high specific strength, non-abrasive, eco-friendly and biodegradable characteristics. The tensile properties of natural fiber reinforced polymers (both thermoplastics and thermosets) are mainly influenced by the interfacial adhesion between the matrix and the fiber. Many chemical modifications are used to improve the interfacial matrix–fiber bonding which results in the enhancement of tensile properties of the composites. Generally, the tensile strengths of the natural fiber reinforced polymer composites increase with the fiber content up to a maximum or optimum value, and then its value drops. But Young's modulus of the natural fiber reinforced polymer composites increases with increasing fiber loading.

Khoathane et al. [82] found that the tensile strength and Young's modulus of composites reinforced along with bleached hemp fibers increase the fiber loading. Mathematical modelling was also mentioned. It was discovered that the rule of mixture (ROM) predicted and experimental tensile strength of different natural fibers reinforced HDPE composites were very close to each other. Halpin–Tsai equation was found to be the most effective equation in predicting Young's modulus of composites which contain different types of natural fibers.

Bernd Lauke [83] studied the crack resistance of a particle reinforced polymers which were affected by the size distribution of particles. Particle debonding is a major dissipation mechanism that contributes and triggers other mechanisms such as matrix shear bands or plastic void growth. They assumed that the specific debonding energy at the particle/matrix interface as independent of particle size together with the debonding criterion which depends on the particle size leads to analytical expressions. This depends on the parameters of the particle size distribution function as well as the debonding probability function. But numerical results show nearly constant crack resistance by changing mean particle size. Using instead a debonding criterion with debonding stress do not depend on particle size which reveals that smaller particles increase fracture toughness. The increase is significant for composites with particle size distribution functions that show small standard deviations. If the debonding energy at the interface is proportional to the particle diameter then the crack resistance remains constant by changing particle size for both debonding criteria.

W. Liu et al. [84] said that natural fibers are currently being developed as a possible substitute for conventional reinforcement materials because they are ease of separation, carbon dioxide sequestration, low cost, low density, acceptable specific strength properties and biodegradability. Also, composites reinforced by natural fibers were also studied. An example is elephant grass-based bio-composites being investigated in Europe for automotive applications [85]. Traditionally natural fiber such as flax, jute, hemp, kenaf and sisal is used as reinforcement for bio-composites. But agricultural by-products such as corn stalk, rice stalk and grass are being studied as a potential resource for natural fibers as they are quite inexpensive and abundant [86].

Indian grass which belongs to the Poaceae family is a native grass from the USA. It grows widely in North America. It is a perennial plant, growing during the summer months, and is generally used as livestock feed [87]. But little attention has been given to Indian grass fiber as a potential reinforcing fiber for bio-composites in research. Alkali treatment is a common method to clean and modify fiber surfaces to lower its surface tension and also enhance the interface adhesion between natural fibers and polymer matrices [88]. Researchers investigated the effects of alkali treatment on structure and properties of natural fibers [89–91]. But no studies on the effects of alkali solution treatment on the structure, morphology and properties of Indian grass fiber have been reported before.

Prashant Kumar Singh et al. [92] investigated the potential capabilities of three different thermoplastic materials. Acrylonitrile Butadiene Styrene (ABS), High-Density Polyethylene (HDPE) and Polyoxymethylene (POM) are used in plastic gearing applications. The gears are manufactured by injection molding process. Thermal and wear behavior of these gears are examined at different torque levels such as 0.8, 1.2, 1.6 and 2.0 Nm along with different rotational speeds at 600, 800, 1000 and 1200 rpm. A steady-state analysis of the gears is carried out at a torque of 1.4 Nm and a rotational speed of 900 rpm to measure the reduction in the gear tooth, durability and failure modes occurring in these gears. ABS gear fails due to excessive wear of the teeth. HDPE gear failure occurs due to the cracking at the root of gear teeth. ABS and HDPE gears complete 0.5 and 1.1 million cycles respectively before the failure happens. POM gear completes 2 million cycles without any hint of failure.

J. Spanoudakis et al. [93] examined the crack propagation at an epoxy resin reinforced with spherical glass particles. It has been followed by conducting a double-torsion test. The effect of strain rate, volume fraction and particle size upon the stability of propagation, Young's modulus, the critical stress intensity factor, K and the fracture energy have been studied. It is shown that the crack propagation behavior can be explained in terms of crack pinning. But it has been found that the propagation is also affected by blunting the particle-matrix interface breakdown. It was demonstrated and found that crack-front pinning is consistent with a critical crack opening displacement criterion.

Hu, X-z et al. [94] stated that interfacial bonding especially to carbon-fiber and aluminum-honeycomb sandwich composites, and their structural performance were investigated under bending and uniaxial compression in this review. The feasibility and effectiveness of short Kevlar-fiber interfacial toughening at the interface between the carbon-fiber face sheets and aluminum-honeycomb core were studied. It was observed that the adhesive joint, in-situ formed from resin and short Kevlar fibers at the interface became a composite. The protruding free fiber ends of the short Kevlar fibers which connect the bridge, face sheets and core have effectively increased the adhesion contact areas at both sides of the adhesive joint, leading to strong fiber-bridging if there is a case of interfacial cracking. The peak load and energy absorption of the sandwich composites were compared by predicting using the analytical models. With detailed fractography observations, toughening and strengthening mechanisms of the reinforced adhesive fillets were explained.

Performance and characteristics of honeycomb sandwich structures have been studied by many researchers. For instance, failure-mode maps of honeycomb-core sandwich structures under three-point bending, quasi-static indentation and low-velocity impact were built by Petras and Zhu [95 -96].

Carbon fiber composites and aluminum honeycombs have been used in aerospace industries. Their sandwich panels which include two carbon-fiber face sheets and an aluminum honeycomb core take full advantage of the complementary strength and light-weight properties. These laminar composite structures possess much-needed energy absorption capacity and also have favourable damping properties [97] along with high specific strength and stiffness. These structural properties, important to many structural applications, make carbon fiber and aluminum-honeycomb sandwich structures highly desirable. They can also be easily fabricated through laminating and also by offering unique and useful structure-property options to designers [98 - 100].

The interlaminar toughening method used by short Kevlar fibers was originally developed by laminar carbon fiber composites [101, 102] and can be adopted for carbon-fiberaluminum-honeycomb sandwich structures. Sun et al. [103, 104] have adopted the short-Kevlar-fiber interfacial toughening technique to toughen and reinforce the interface between the carbon-fiber face sheet and aluminum-foam core. Based on their three-point bending tests, up to 38% improvement in the peak load and about 80% improvement in the energy absorption were achieved from the short aramid-fiber interfacial reinforcement. Due to the similarities in the surface structures of aluminum foam and honeycomb, it is expected that the toughened interface can be equally effective for carbon-fiberaluminum-honeycomb sandwich structures.

A study on carbon-fiber face sheets and aluminum foam core sandwich structures [104] found that the short Kevlar fiber interfacial toughening increased the peak flexural load by 20 to 38%. The energy absorption increased by 64 to 68% where two layers of 12-g/m^2 kevlar tissues and different fiber lengths were used. When compared to an aluminum honeycomb, an aluminum foam core is much stiffer because of its interconnecting structures in the thickness direction and generally higher density. So, the compressive strength of aluminum foam is higher than that of aluminum honeycomb. The main reason why the peak flexural load of honeycomb core sandwich panels are not increased as much as that of foam core sandwich panels is due to the difference in compressive strength of sandwich cores. Even though the interfacial bonding was improved by the short Kevlar fibers, the weak honeycomb core was crushed at the contact point. This lead to a premature failure in the overall load-bearing capacity of the structure.

Yan Wang et al. [105] found and examined that the kevlar oligomer functionalized graphene (FGS) was prepared by simple grafting of amino-terminated Kevlar oligomer on graphene oxide(GO). It was followed by reducing with hydrazine hydrate. The incorporation of FGS shows more effect on the host polymers. High-level reinforcement of both PMMA and PI is observed with low content of FGS (<=0.2% wt). In this lower loading range, the tensile modulus and strength of composites increase almost linearly as a function of the adding amount of FGS. But no further improvement is observed as the content of FGS further increases (>0.2wt.%). The mechanism under the reinforcement effects the FGS loadings and it discusses the morphological characterizations of the composites. The thermal properties of the composites are also studied. The glass transition temperature and thermal stability of PMMA are also dramatically increased despite adding a small amount of FGS.

M. Mukherjee et al. [106] investigated the thermomechanical behavior of fluorinated and oxy-fluorinated kevlarfiber-reinforced ethylene propylene (EP) composites. The composites have been prepared by using Brabender mixer and are cured by using compression molding technique. FTIR study was performed to understand the chemical reaction that occurred due to modification of composites. Thermal behavior and crystallinity have been studied by DSC, TGA, DMTA, and XRD. These studies show that thermal stability, storage modulus and, the crystallinity of the treated Kevlar fiber-reinforced (EP) increases when compared to the untreated derivative because of the surface-modified Kevlar fiber as it results in good adhesion between the fiber surface and EP matrix. Tensile strength increases if its a treated Kevlar fiber-reinforced EP when compared to the one which isn't treated. SEM study supports all the above results. AFM shows that the surface roughness increases because of the surface modification and it results in the incorporation of functional group-induced Kevlar fiber.

Joung-Man Park et al. [107] viewed the comparison of interfacial properties and micro failure mechanisms of oxygen-plasma treated poly (p-phenylene-2,6-benzobisoxazole (PBO, Zylon)) and poly (p-phenyleneterephthalamide (PPTA, Kevlar)) fibers/epoxy composites were studied by using a micromechanical technique and nondestructive acoustic emission (AE). The interfacial shear strength (IFSS) and work of adhesion, Wa, of PBO or Kevlar fiber/epoxy composites increase with oxygen-plasma treatment due to induced hydrogen and covalent bonding at their interface. Plasma-treated Kevlar fiber shows the maximum critical surface tension and polar term. The untreated PBO fiber shows the minimum values. The work of adhesion and the polar term were proportional to the IFSS directly for both PBO and Kevlar fibers. The microfibre fracture pattern of two plasma-treated fibers also appeared. When compared to slow cooling, the rapid cooling, case kink band and kicking in PBO fiber appears. The buckling of the Kevlar fiber was observed due to the compressive and residual stresses. Based on the propagation of microfibre failure towards the core region, the number of AE events for plasma-treated PBO and Kevlar fibers increases significantly when compared to the one which was not treated. The results of nondestructive AE were consistent with micro failure modes.

Sivalingam et al. [108] found that there has been a great demand for synthetization of different kinds of PANI/bio polymeric composite materials as it finds awide range of applications in in antistatic and electromagnetic interference shielding, sensors, electrodes and battery fields. The PANI compositestechnique was considered due to its application as a conducting polymer owing to its easy preparation and good environmental stability.They also found that it can be dopedeasily by protonic acids to attain high electrical conductivities. They also found that it was very difficult to produce PANI films because of its infusibility, poor mechanical properties, and poor solubility in all available solvents except doping with a proper dopant or changing the monomer.

Anish M. Varghese et al. [109] studied about the polymer composites made up of functionalized natural fibersto upgrade their applications in the near future. They found that natural fiber reinforced with polymer composites have been used for research of polymer science and technology because of the rising environmentaland economic reasons. Natural fibers are used as they offer better biodegradability, combustibility, nontoxicity, precise mechanicalproperties, no corrosion and also fatigue, less damage to while machining, lightweight, easily accessibility, nice surface finish, and so on. They were functionalized to upgrade the interfacial bonding with polymers and to successfully achieve high-performing composite materials. They observed that natural fibers functionalization enriches the characteristics of resultant composites like adhesiondegree, interfacial shear strength, wetting, mechanical performances, thermal stability, dynamic mechanical features, thermomechanical properties, reduction in waterabsorption and antibacterial properties.

TaneliVäisänena et al [110] studied different methods to enhance the characteristics of hemp fibers (Cannabis Sativa L by assessing different modification methods like alkali, enzymatic, steam, and wooddistillate treatments. They prepared composites at approximately 30 wt. % fiber contents to evaluate the suitability of these fibers as reinforcements for theepoxy resin.They found thatthe steam treated hemp fibers absorbed less water during 28 days at65% relative humidity (RH) and 20.0 °C. But the enzymatic treatment led to the lowest water absorptionvalues at 85% RH and 20.0 °C. When the hemp fibers were modified, the mechanical properties of epoxy-hemp composites wascompromised.But it led tosignificantly lower water absorption values.

SipingZhai et al. [111] reviewed the recent researcheffective thermal conductivity (ETC) on of polymer compositesmodels. They started by observing the classical theoretical models of ETC for polymer composites. Later, theoretical and simulation models were studied. They found that Polymer composites of highly effective thermal conductivity are widely used in industries for renewable energy systems and Electronic Systems. They used modelling methodstoolsto understand how the factors like particle and matrix properties and microscopic structuresinfluence the ETC of polymer composites. Then they concluded by giving an outlook regarding the ETC models of polymer composites.

C.Elanchezhiana et al [112] reviewed the possible Metal Matrix Composites of Grade 5 Titanium alloy (Ti-6Al-4V) with Kevlar and carbonfiber and their uses. They found that they can be used in marine industry for naval warships, for aerospace, fordefense sector and for the fabrication of various structures that need highstrength and impact bearing capacity.

When they are used, the cost is reduced significantly. Also, the performance of the vessels in terms of speed andmaneuverabilityimproves. They found through various results that the composites play a major role in importance and for improving better mechanical engineering development.

Syafiqah et al [113] reviewed that natural fiber based polymer composites have low applications in structural systems but have a great potential for reducing the product weight andreducing material. They examined the impact properties of hybrid composites that were produced having an aim to improve their structural characteristics and also the impact resistance. They also studied thepenetratingcharacteristics of hybrid composites when reinforced with natural and synthetic fibers and their suitability for modern structural applications.

F.A. Almansour et al [114]investigated the Mode II interlaminar fracture toughness by the influence of water absorption of flax and flax/basalt hybrid laminates. Four types of composite laminateswere fabricated by vacuum assisted resin infusion technique. They were neat vinyl ester (neat VE), flax fiber reinforced vinyl ester (FVE), flax fiberhybridized basalt unstitched (FBVEu) and flax hybridized basalt stitched (FBVEs). By using two data reduction methods,three-point-end-notched flexure (3ENF) tests were conducted to evaluate the critical Mode II strain energy release rate (GIIC) and the crack length (R-curve) at dry and wet conditions. The results found that the fracture energy of FBVEu composites, GIIC are in it.And GIIC prop were increased by 58% and 21% respectively when compared to that of FVE dry specimens.The results confirmed that basalt fiberhybridizationincreases the durability and water repellence behavior of natural fiber reinforced composites.

Wentao He et al [115] investigated the low-velocity impact response and post-impact flexural behavior of hybrid sandwich structures which consists of carbon fiber-reinforced polymer (CFRP) face sheets and aluminum alloy corrugated cores. They carried a range of impact energies and impact studies to determine the effects on the impact damage and residual flexural strength.Low-velocity impact tests were conducted to find the impact resistance of such structures with respect to impact load, absorbed energy and failure mode. Also, a procedure to numerically simulate the low-velocity impact tests and residual flexural strength tests of sandwich structures was created by the VUMAT subroutine in ABAQUS/Explicit. The studies revealed that the damage depends on the impact energy and its location. The residual flexural strength decreased even though the impact energy was lower than 10J.But there was a slight reduction with a further increase in the impact energy.

Yongxian Huang et al [116] reviewed the current development in the field of FSW of thermoplastic polymers, polymer matrix composites and multifunctional composites fabrication. They also studied dissimilar FSW of metal and polymer. Friction stir welding/processing (FSW/P) involved temperature, mechanics, metallurgy and interaction. It is a complex solid state joining and processing technology and has been widely applied to join aluminum and titanium alloy and also materials which are difficult to weld by fusion.

GanapathyKavitha et al [117]reviewed the positive impacton using marine microbes as PHB source with their applications in varied fields like aquaculture, medicine, antifouling and tissue engineering.PHB is biodegradable, ecofriendly and biocompatible thermoplastics. It varies in toughness and flexibility.They are used in ways similar to many non-biodegradable petrochemical plastics. There is a cause for concern due to the increasing significance of non-degradable plastic wastes. Owing to their costs, experts are in a quest for a substitute source like bacteria, microalgae, actinomycetes, cyanobacteria and plants. Hence PHB plays a vital role.

D. Savastru et al [118]presented the simulation results which wereobtained whenanalyzing an issue which concerns the fabrication of smart composite materials (SCM) by using fiber optic sensors. Also, Long Period Grating Fiber Sensors (LPGFS) was observed for obtaining necessary feedback at environment inputs such as mechanical stress, strain, temperature or pressure. There is a demand for SCM for their use in medical care, security, industry and aerospace applications.For performing the proposed analysis, thethermomechanical characteristics of composite polymer matrix that has a LPGFS embedded inside it, FEM technique is used. The polymer and optical fiber thermal and mechanical characteristics were taken into account. The analysis is performed in order to design and manufacture smart polymer composite materials using fiber optics sensors.

Pugila. D et al [119] found that natural fibers are currently being used by the automotive industry to make seats, dashboards, door panels, package trays, headliners, and trunk liners.

Thakur VK et al [120] evaluated the possibility of applying natural fibers as reinforcement for sheet molding compounding materials for use in the construction industry. The main goal was to preserve the environment by using natural fibers and reduce the use of synthetic ones. The benefits of natural fibers includeeco-friendly and are bio-renewablewhen compared to synthetic.

Koronis G et al [121] studied the mechanical properties of natural fibers which were determined by plant maturity, part of the plant harvested, harvesting season, rain, sun, harvesting region, and the conditions of the soil.

Cristaldi Gal et al [122] determined that natural fibers have excellent thermal and acoustic insulation criteria and they show several better properties over rock-wool or glass fiber owing to their cellular structure and low density.

Faruk O et al [123] observed that composites require optimal performance in terms of cost effectiveness, maintenance and durability. They also found that natural fiber-reinforced composites have various advantages and are critical for sustainability. One primary weakness of natural fibers is the variability in their characteristic properties. The challenges they faced in evaluating the properties of natural fiber-reinforced composites was whenestablishing their impact resistance.

D.B Dittenber et al [124] found that for the past twenty years, natural plant fibersare used as reinforcements in polymer composites to achieve sustainable green materials. They are widely used because they have ecological advantage,are renewable and biodegradable which reduce large amounts of embodied energy.

V. K Thakur et al [125] studied the different types of natural fibers, bastfibers (flax, hemp, jute and ramie) derived from plants. They are used in different applications such as automotive, marine and construction, because of their attractive properties in terms of weight and performance.

N. Venkateshwaran et al [126] found that there has been increase in fibers as reinforcement in composite materials. This interest is due to increasing prices of non-renewable oil products and better environmental regulations.

A.K Bledzki et al [127] analyzed some main challenges when using natural plant fibers. They are susceptibility to moisture absorption that leads to poor adhesion between fiber and matrix interface due to the presence of hydroxyl and polar groups in composites. The diffusion of water in the composites can cause swelling and plasticization which could affect the mechanical and thermal properties.

There is a demand to understand more the behavior of composite materials that are subjected to complex multi-axial loadingconditions which enables efficient deployment for load carryingapplications in aerospace, marine and other industries. The analysisof composites that are subjected to multiaxial loading hasbeen improved by initiatives such as the World Wide Failure Exercises. To replace costly and time consuming physical materials and structures,experiments with model-based virtualtesting, robust material and failure models has to be established and determinedby experimental data. There arevery less reliableexperimental data for multiaxial load cases due to the complexity ofmultiaxial testing and design of the test specimens. Also, aconsensus has not been reached in the composites communityon the appropriate definition and design of multiaxial testing methodologies for composites.[128–130]

Cruciform specimens are often chosen [131–136] to characterize the biaxial mechanical performance of composite laminates for biaxial tension, tension-compression and compression-compression loading. To successful test the cruciform specimens; it requires extensive and careful machining of the specimens to create a reduced gauge section thickness and a corner fillet to prevent premature failure outside the gauge section. Also, a sophisticated biaxial test machine with four independent actuators is often required.

SiruiFuet al [137].Studied the combined effect of interfacial strength and fiber orientation on mechanicalperformanceof short Kevlar fiber reinforced olefin block copolymer.

J.G.Bakuckas et al. [138]examined the growth of damage in Titanium Matrix composites by using Acoustic Emission. Here, the TMC was studied by using various optical techniques like long focal length, highmagnificationmicroscope. The Acoustic Emission technique was used to locate the damage growth in between the matrices.

The main objective of the study was to develop a fire thermal model which is able to predict the evolution of the temperature gradient across a sandwich composite structure when exposed to fire. When analyzed under extreme conditions, itmakes it possible to put a material in non-ambient conditions. Theproperties of that material are often modified and new properties can then be studied. Thisoccurs when the material is subjected to a harsh environment of low or high temperature [139-140] generally put under a second stress such as an intense magnetic field, a light irradiation [141-142], amechanical stress [143-144] or a high pressure [145-146]. Due to these extreme conditions, the materialundergoes important physical and/or chemical modifications, often leading to the appearance ofmetastable states or phase transitions [147-148].

C.Y. Yue et al. studied the effects of heat treatment on the mechanical properties ofKevlar-29®Fibre. Here, the single-Kevlar® Fiber tensile test was used to evaluate and subjected to heat treatment at 100, 200 and 300^{o}C for a period of 2 to 8 hours. Kevlar-29®Fibre dimensions were thermally stable and did not vary with heat treatment but the Kevlar® Fiber tensile strengths and failurestrains decreased as the treatment temperature was increased [149].

A.S.Oryshchenko et al. tested the properties of Titanium alloys in ships. Here, Titanium ingot containing 5% Aluminum were used. They were melted using spongyTitanium with an ultimate Tensile Strength of 480 MPa. Also, Aluminum and Molybdenum equivalents were usedfor determining the permissible content of alloying elements to find various properties.The governingequation was given as,

$$[\text{Mo}]\text{eq} = [\%\text{Mo}] + [\%\text{v}]/1.4 + [\%\text{Nb}]/3.3 + [\%\text{W}]/2.0 + [\%\text{Cr}]/0.6 + [\%\text{Fe}]/0.6 \ [\text{Al}]\text{eq} = [\&\text{Al}] + [\%\text{Sn}]/3 + [\%\text{Zr}]/6 + [\%\text{O}]/0.1 + [\%\text{C}]/0.085$$

The above equation shows that Aluminum equivalent is the sum of equivalent concentrations of α-stabilizers andMolybdenum equivalents is the sum of equivalent concentrations of β-stabilizers [150].This yielded agoodresult for the implementation of Titanium alloys in marine applications.

OVERVIEW AND FUTURE SCOPE

Composite materials are widely used in automotive, aerospace, wind energy, electrical, sports, marine, domestic usages, constructions, medicine, chemical industries etc. They can be applied in structures solely subjected to compressive loads. They have good adaptability in fabricating thick composite shells, relatively high compressive strength, low weight, low density and corrosion resistance. Composite materials have good mechanical, electrical, chemical properties. Hence, they can be used in many industries. Parts of ships, automobiles and aerospace are manufactured by composite materials. They are also used to make furniture, window, door, mating, construction etc. For marine, sporting goods, chemical industry's better performance of the parts makes use of composite materials. We conclude that polymer composite materials have wide advantages & application in various industries. Lifestyle can be improved by it.

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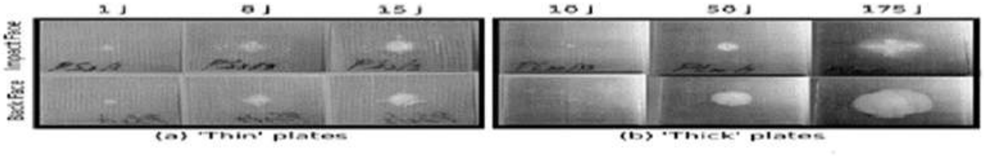
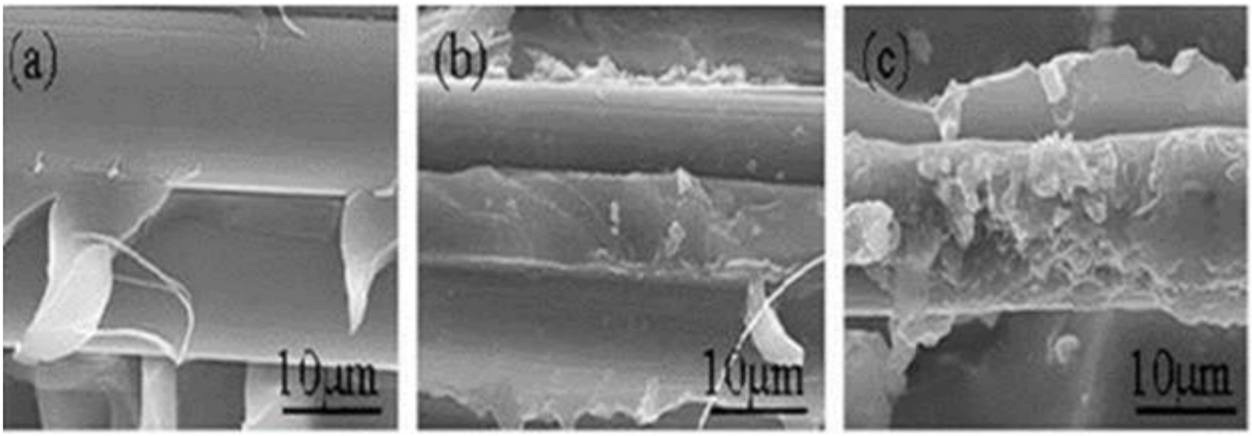
Image caption

1. Impacted laminated plate GRP plates.[151]

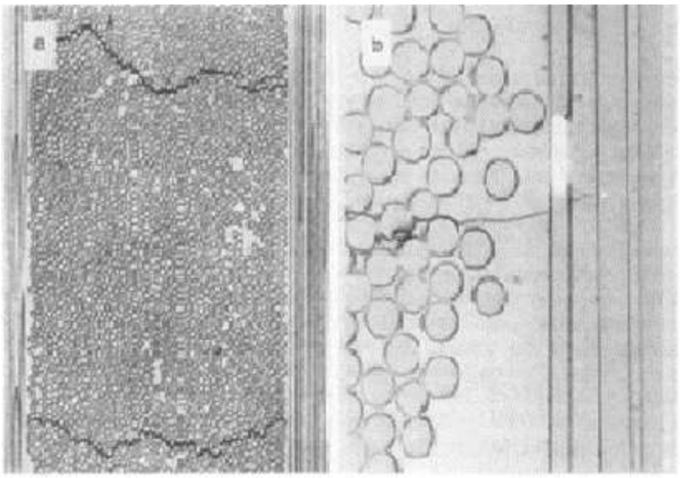


2. SEM images of split surface of Kevlar fiber composites of
   (a) DGEBA/MeHHPA/as-received fiber, [112]
   (b)DGEBA/MeHHPA/PA-functionalized fiber, [112]
   (c) DGEAC/DGEBF/DDM/ DETDA/PA-functionalized fiber.[112]

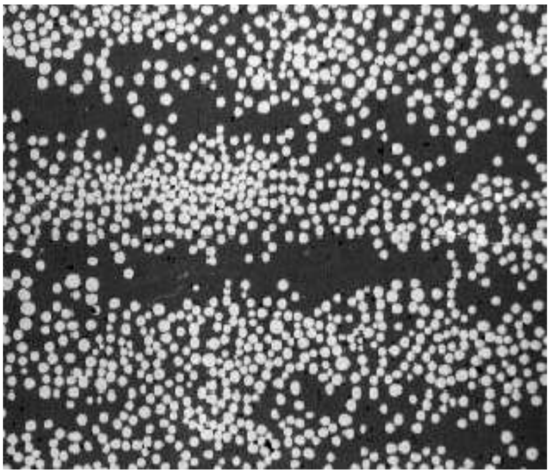


3. Microstructure of PAN carbon fibers (reproduced with permission from International Union of Crystallography(http://Journals.iucr.org/). [112]

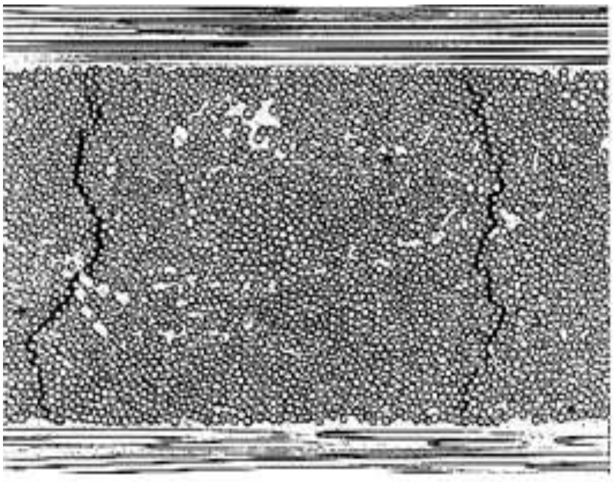
4. A crossplied FRP laminate, showing nonuniform fiber packing and microcracking (fromB. Harris, Engineering Composite Materials, The Institute of Metals, London, 1986).[153]



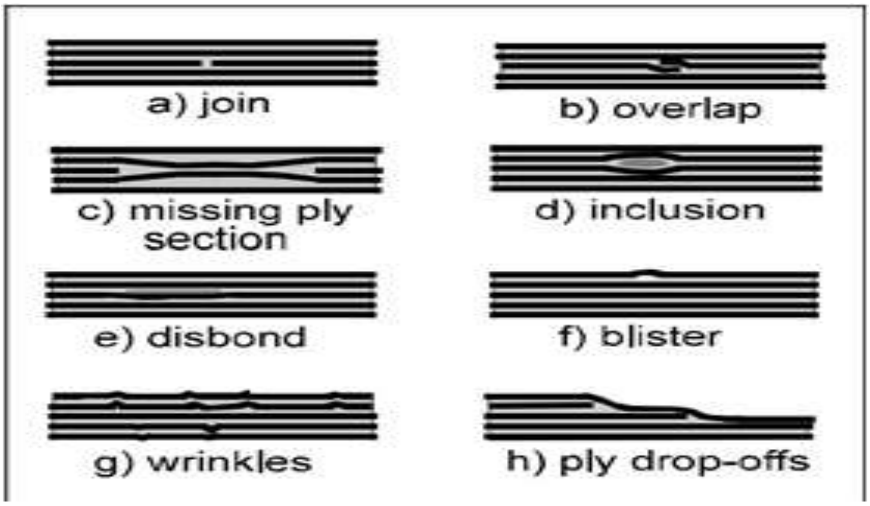
5. Real packing geometry: The cross section of a unidirectional SiC/CAS laminate of Vf = 0.4,The magnifications can be judged from the fibre diameter,15µm.[152]



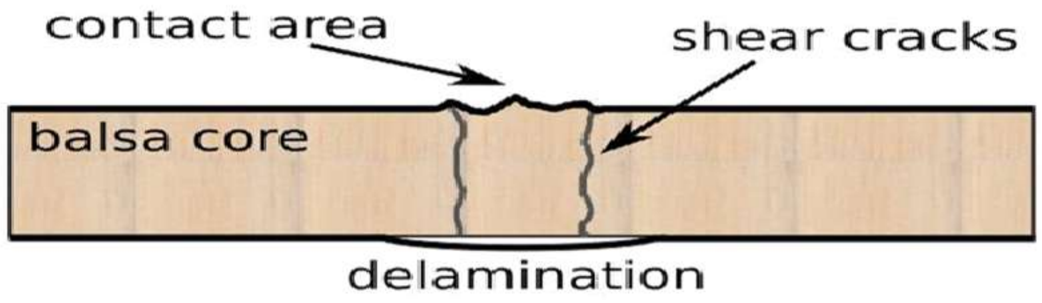
6. Photo micro graph of transverse ply cracking in a 0/90 GRP laminates.[152]

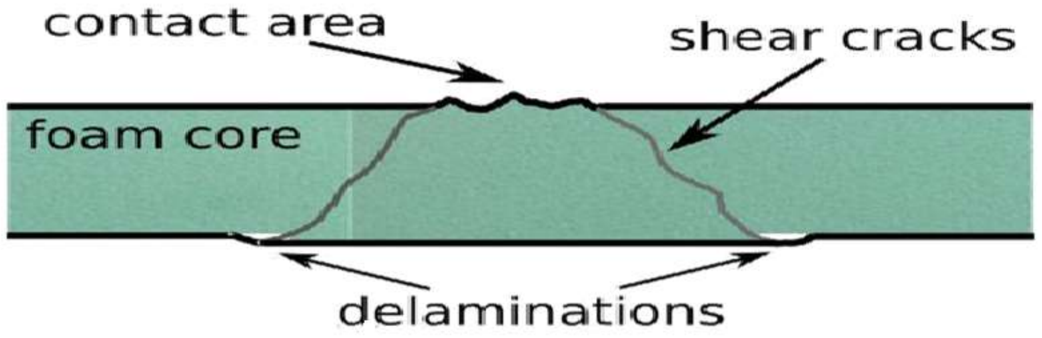


9. Some typical defects in composites laminates manufactured from prepreg sheets.[152]

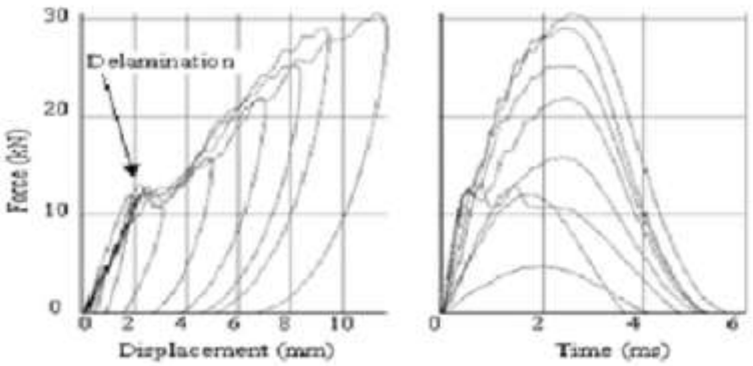


10.Balsa cross –linked PVC foam core shear failures.[151]

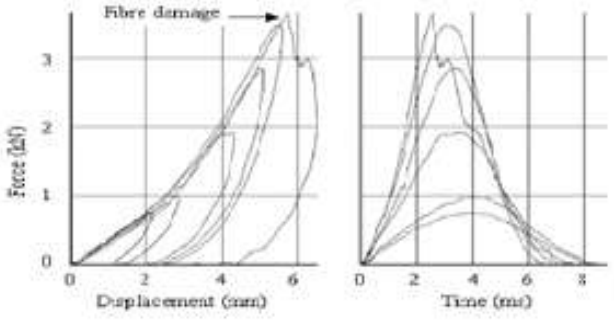




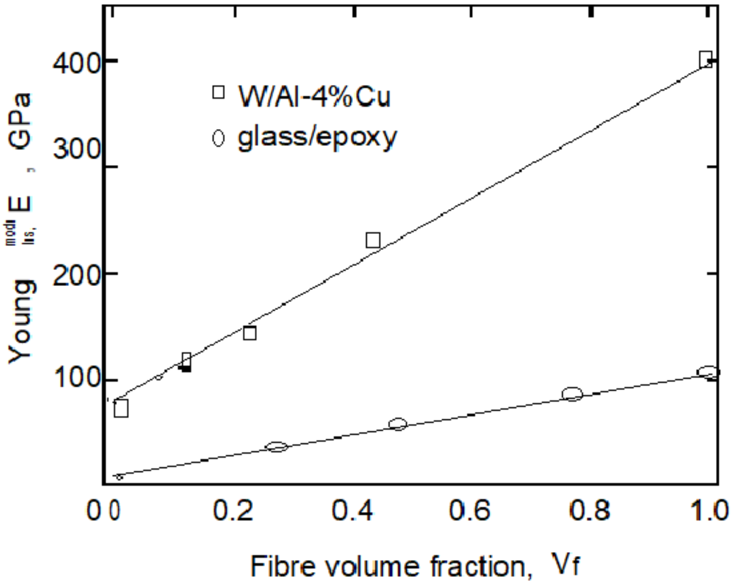
11.Typical response impact of thick laminates.[151]



12. Typical response impact of thin laminates.[151]



13.Confirmation of the rule-of-mixtures relationship for the young moduli, E_C ,Unidirectional composite consisting of tungsten wires in Al-4 % Cu alloy and glass rods in epoxy resin.[152]



14. Strength and density of various composite materials,M.F. Ashby, Materials

Selection in Mechanical Design, Pergamon Press, Oxford, 1992. [153]