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Mechanical Characteristics and Novel Applications of Hybrid Polymer Composites- A Review

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Abstract

Hybrid polymer composites are fabricated by collecting two or more fibers or particulate fillers in individual polymer matrix. Hybrid composites can be combining from artificial fiber or natural fibers or both of them. Hybrid polymer composite material offers the designer to obtain the required characteristics in a controlled considerable extent by the choice of suitable fibers or fillers and polymer matrix. The mechanical characteristics of a hybrid composite mainly depend upon the fiber content, length of individual fibers, fiber orientation, and fiber to matrix bonding and configuration of both the fiber and filler. The investigation of the novel applications of hybrid composites has been of interest to the researchers for many years as evident from notices. This paper summarized a review on the mechanical characteristics and the potential application of hybrid polymer composites. Also, this paper concerned on different properties of natural fibers and its applications which were used to substitute artificial fibers.

1. Introduction

Hybrid polymeric composites are new and more developed composites as compared to the traditional fiber reinforced polymer composites. FRP composite contains on one reinforcing phase in the single matrix but hybrids can have more than one reinforcing phase and a single matrix phase or single reinforcing phase with multiple matrix phases or multiple reinforcing. The lightweight hybrid composite materials can introduce the high mechanical properties such as a high specific strength, stiffness and the relatively good energy absorbing characteristics. High performance composites are used in the processing of aircraft, wind turbine blades, automotive, Prosthetics, smart memory, ship structures and bridge construction. A hybrid composite consists of artificial fiber or natural fibers or mixed between them [1-2].

Natural fibers show superior mechanical properties such as stiffness; flexibility and modulus such as are sisal, Jute, hemp, coir, bamboo and other fibrous materials. The main advantages of natural fibers are of low cost, light weight, easy production and friendly to environment. The most common synthetic fibers are aramid, glass, polyethylene, and carbon. The lower stiffness and strength of polymer can be improved through the addition of stiffer and stronger fibers in polymer matrix composites. The particles are generally added to reduce the wear rate and improve the bonding strength of composites. The properties of the composites were improved with addition of filler materials [3-4].

This paper comprises a literature survey of the new and advanced researches. It presents the research works on the hybrid polymer composites and the effect of mechanical characteristics and process parameters on the performance of hybrid composites studied by different investigators. The review paper is carried out in the following areas.

2. Effect of hybridizing on Mechanical properties

Hybrid polymeric composites were prepared by using the Hand lay-up technique (HLU). Initially wood template was prepared at the up and down of the mold plate. Second reinforcement in the form of woven mats was cut as per the mold size and place at the surface of mold after Perspex sheet. Then resin in the liquid form was mixed thoroughly in suitable proportion with a hardener and poured on to the surface of mat already placed in the mold at room temperature. The resin was uniformly spread with the help of brush second layer of mat is then placed on the resin surface and a roller was moved a mild pressure on the polymer layer to remove any air trapped as well as the excess polymer present and the resin allowed to react chemically ("cure") to a hard matrix. Finally, the mould was then exit so that the resin will cure. This technique was repeated for each layer of polymer and reinforcements to produce the hybrid composite. The experimental setup of the HLU technique was reported in the previous paper [5].

Natural and artificial fibers can be used in many shapes in polymer composites, such as continuous and discontinuous, unidirectional fibers and randomly oriented fibers. By taking advantage of the properties of fibers reinforced composites, such as good specific properties and reduction in processing cost. The survey covering research work in the field of mechanical properties of hybrid fiber reinforced composites include: Mehta et al. [6] have investigated the properties of hybrid hemp/glass fiber reinforced polyester composites. The hybrid E-glass–hemp/unsaturated polyester resin (UPE) composite had an increment of 76% in tensile strength, and 34% in tensile modulus compared with that of untreated hemp based biocomposite. The impact strength of silane-treated fibers was 7% more than that of untreated fibers, while that of UPE–methyl ethyl ketone peroxide (MEKP) treated fibers was 21% more than that of untreated fibers. The interface modification and mechanical properties of newsprint, kraft pulp and hemp fiber reinforced polyolefin composite products was studied by Sain et al [7]. There are three different types hybrid laminates are processed by hand lay-up method by using glass, banana and hemp fibers as reinforcing material with epoxy resin. The mechanical properties such as tensile strength, flexural strength and impact strength were evaluated. It has been observed that the banana hemp-glass fibers reinforced hybrid epoxy composites exhibited superior properties and used as an alternate material for synthetic fiber reinforced composite materials [8]. Ramesh et al. [9] investigated the mechanical properties of sisal, jute and glass fiber reinforced polyester composites. The jute polyester composite material shows maximum tensile strength and can hold the strength up to 229.54 MPa. The maximum impact strength of the sisal fiber polyester composite has the value of 18.67 joules. Figure 1 shows an illustration of a composite material.

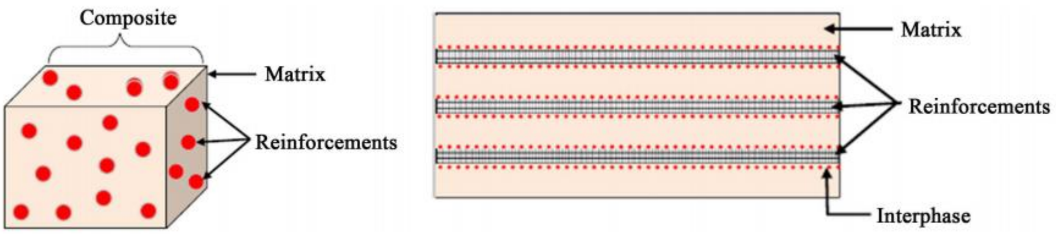

Figure 1 Composition of laminate and inter-phase which include resin as a matrix and fiber as reinforcement

Pujari et al. [10] studied the comparison and potentiality of jute & banana fiber composites emphasizes both mechanical and physical properties and their chemical composition. The employment and application of the cheaper goods in high performance appliance is possible with the help of this composite technology. The tensile and flexural properties of the hybrid composites made from polyester reinforced with glass and jute fibers were investigated. They observed that the maximum compressive strength and flexural modulus of this hybrid composite increases from (85 to 218 MPa) and (5790 to 11542 MPa), respectively, with the increase in the volume fraction of the glass fibers [11]. The mechanical behavior of banana/sisal reinforced polyester composites was discussed. Graphic illustration of different layering patterns of hybrid composites are shown in Figure 2. Tensile properties of the composites as a function of fiber concentration and fiber composition and layering patterns were determined. Maximum tensile strength was observed in composites having volume ratio of banana and sisal 3:1. It was found that the impact strength increased from 9 kJ/m^2 to 43 kJ/m^2 with the sisal fiber increased. The maximum values of flexural strength (65 MPa) and impact strength (43 MPa) in bilayer composites. Tensile strength was maximum value (58 MPa) in banana/sisal/banana composite [12]. Table 1 shows the physical and mechanical properties of some natural fibers and glass fibers in applications.

Akil et al. [14] emphasized the characteristics of kenaf fiber reinforced composites in terms of mechanical properties, thermal properties, as well as water absorption properties. It found that the use of kenaf fiber reinforced composite can help to generate jobs in both rural and urban areas; in addition to helping to reduce waste, and thus, contributing to a healthier environment.

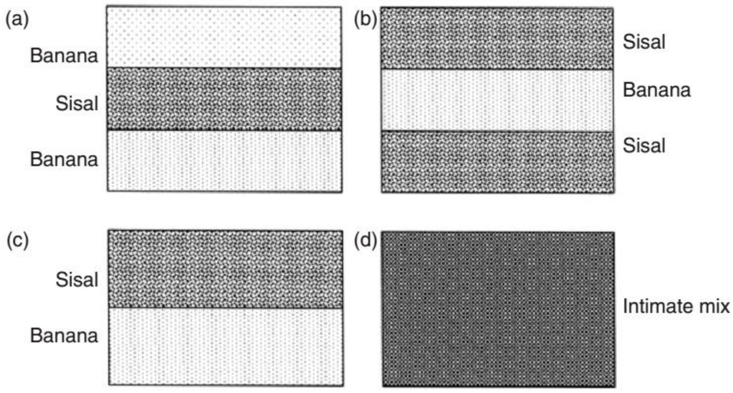

Figure 2: Schematic representation of different layering patterns of hybrid composites: (a) banana/sisal/ banana, (b) sisal/banana/sisal, (c) bilayer, and (d) intimate mix

Table 1 Physical and mechanical properties of some natural fibers and glass fibers [13].

Properties	**Fiber**							
	E-glass	**Hemp**	**Jute**	**Ramie**	**Coir**	**Sisal**	**Flax**	**Cotton**
Density (g/cm^3)	2.55	1.48	1.46	1.5	1.25	1.33	1.4	1.51
Tensile strength (MPa)	2400	5500	500	500	220	800	1400	400
E-modulus (GPa)	73	70	20	44	6	38	70	12
Specific (E/d)	29	47	12	29	5	29	30	8
Elongation (%)	3	1.6	1.8	2	18	3	1.6	7
Moisture (%)	-	8	12	16	10	11	7	19

The mechanical properties of kenaf fiber reinforced poly-l-lactic acid (PLLA) resin composites are investigated by Nishino et al. [15]. This study showed that the tensile strength and modulus were higher than those of the kenaf fiber and the PLLA resin composite. It was found that the maximum value of young's modulus (6.3 GPa) and the tensile strength (62 MPa) of the kenaf/PLLA composite at 70 vol.% fiber were comparable to those of traditional composite.

Zampaloni et al. [16] used kenaf fiber neutral polypropylene reinforced composites. They have concluded that fiber content of 30 % and 40 % by weight has been proven to provide adequate reinforcement and to increase the strength of the polypropylene composite. The kenaf fiber polypropylene composites have a higher Modulus/Cost and a higher specific modulus than sisal, coir, and even E-glass. The used of coir fibers, as reinforcements in polymer matrix and its influence on the mechanical properties of bio composites was discussed by Verma et al [17]. A banana fiber and silica powder reinforced composite material was developed by Singh [18]. It was found that the adding of fibers increases the modulus of elasticity and decreases the ultimate tensile strength of the epoxy. Pai and Jagtap [19] reported the surface morphology of some unique natural fibers and its effect on the mechanical properties of the composites. These fibers absorb the waves and dampen it much faster than their synthetic counterparts. The mechanical properties for natural areca fiber reinforced by epoxy composites were evaluated. It was found that the strength of areca fiber composites increases with the increasing in volume fraction of fiber in the composite and post composite curing time [20].

Hybrid polymer based composite were designed from glass, Kevlar and carbon woven fibers embedded within two different matrices: epoxy and polyester resins. It was found that the linear increase in tensile strength with an increase in volume fraction fabric for both polyester and epoxy based composites. In addition, the hybrid composites have shown up to more than 100% increase in modulus of polyester composites while glass fabric reinforced polyester composites showed high tensile properties [21], also the flexural strength and flexural modulus of carbon and glass fibers reinforced EH composites were investigated. The vacuum bagging technique was used for the fabrication of this composite. It was found that the hardness, flexural strength and flexural modulus were improved as the fiber reinforcement contents increased in the epoxy matrix material. The 60% carbon fiber/ composite shows 64.4% increase in the flexural modulus as compared to 60% glass fiber/ composite and 26.85% increase in the flexural modulus with that of 30% glass fiber and 30% carbon reinforced hybrid composite. These results indicate the good bonding between the fibers and matrix. [22]. Etcheverry and

Barbosa [23] improved the mechanical properties of glass fiber reinforced polypropylene by adhesion improvement and detected that the strength and toughness increase three times and the interfacial strength repeated in PP/GF composites prepared with polymerized fibers. The interfacial shear strength of PP/GF composites was improved (up to a factor of 2.1) with respect to the case of untreated fiber-PP composites. Particulate fillers consisting of ceramic or metal particles and fiber fillers made of glass are being used these days to dramatically improve the strength, hardness and wear resistance. The addition of alumina particulates in composites consisting of polyester resin reinforced with glass fiber were investigated by sahu [24]. The addition of Al_2O_3 improves the tensile, flexural and the inter-laminar shear strength of the glass-polyester composites. It was found that hardness increased from 62 HRF to 75 HRF with the increase in filler content from 0 wt.% to 15 wt.%. A maximum reduction of 1.7 gram/cc density with composites filled with 15 wt. % alumina with a maximum void percentage of 5.55.

Yamamoto et al. [25] observed that the shape of silica particle have significant effects on the mechanical properties such as fatigue resistance, tensile and fracture properties. It has been found that the epoxy resin filled with irregular crystalline silica-particles possessed the best combination of mechanical properties; also Adachi et al. [26] concluded the mechanical properties of EC were depended on volume fraction of particles, transition temperature and fragility. It was found that the fracture toughness K_{Ic} of the composites increased from 1.1 to 1.6 MPa. $m^{1/2}$ with transition temperature (Tg) increased from 340 to 410 K. The mechanical properties of Polypropylene (PP) have been improved by adding calcium carbonate filler [27]. It was found that the filler particle increases young's modulus of PP, yet causing the decrease of the strength and the toughness., Young's modulus increases up to 100% independently of the irradiation of the pure high-density polyethylene (HDPE), while for the polymer containing metallic fibers increases to approximately 200%. The resistance to impact increases by up to 600% due to the effect of the metallic fibers. The adding of the Titanium oxide (TiO_2) as reinforcement material varies from 10 wt. %. to 40 wt.%. The combined reinforcement effects yield the better mechanical properties with increased fiber length and particulate material. The highest impact strength of 138.3 J/cm^2 and 186.6 $J/\ cm^2$ at 40 wt.% fiber for fiber length of 3 cm and 5 cm lengths [28]. The effect of size and content of Al_2O_3 filler on impact strength and tensile strength on HDPE composites are investigated. It was observe that the tensile strength of the composites increase from 21 to 23 kJ/m^2 with the increase of particle size of Al_2O_3 filler from 0 to 30 vol.%. Also, the best mechanical properties at the HDPE composite filled with Al_2O_3 of 0.5 µm at content of 25 vol% [29]. Al-Khafaji [30] studied experimentally the mechanical behavior of polymer matrix composites and their hybrids which reinforced by carbon black particles with constant volume fraction (10) % and boron particles with different volume fractions (0, 2, 4, and 6) % which are bounded with polyester resin. It was found that the hardness increased with the increasing in the volume fractions of boron particle. The slightly decreasing of hardness at adding volume fraction (4%) of boron powder, it is attributed to existing of avoids which causes weakening of the chemical bond and interaction between the filler particles and matrix. The highest values of Young's Modulus and Charpy impact appears at volume fraction 4%. Genevive et al [31] used of snail shell powder at filler contents, 0 to 40 wt%. in polypropylene composites and this were manufactured by using an injection moulding machine. It was found that the snail shell powder improved the mechanical properties such as tensile modulus, flexural strength, and impact strength of polypropylene and these properties increased with increases in the snail shell filler content also, the all mechanical properties of the reinforcement by the periwinkle shell powder (PSP) of varying filler particle sizes (75µm, 125µm and 150µm) using injection moulding machine in polypropylene composites were improved by Nwanonenyi et al [32].

Swain and Biswas [33] they used Al_2O_3 filled in jute fiber reinforced epoxy composites and carried out the physical and mechanical properties. It was observed that the addition of Al_2O_3 filler improved the properties of this composite. The hardness of the composites increased from 18 HV to 35 HV with the increase in fiber and filler loading. It was found that composite with 40 wt. % fiber and 15 wt. % filler exhibits maximum hardness value. Deshpande et al. [34] used bone and coconut shell powder fillers by varying ratios in E-glass fiber/jute fiber reinforced EC and studied its mechanical properties. It was concluded the mechanical properties of the composites were influenced by the powders filler content also, the composites filled with 15% shell powder displayed maximum value of flexural strength (1440 MPa), inter laminar shear strength (ILSS) (14.4 MPa) and hardness (71.58 BHN). The mechanical properties of the granite powder filled polycarbonate (PC) epoxy composites were investigated by Kareem [35]. It was found from this study that the EC reinforced with 20% granite confer better bending, tensile strength properties of this hybrid also; Gonçalves et al. [36] studied the mechanical properties and hardness characteristics of epoxy resin composite filler with granitic stone powders named 53-A and 12-A. The mechanical properties of all the composites increased as granite powder filler content increases. Higher tensile, flexural and impact strength of granite powder filler in vinylester composites than the pure vinylester resin exhibited by Baskaran et al. [37]. The impact strength of granite powder filled in vinyl ester composites increases gradually from (28 J/m to 40 J/m) up to 20 wt% granite powder content and then is found to decrease. The highest improvement of mechanical and thermal properties was recorded at 20 wt.% of granite powder filler.

Jagannathan et al. [38] studied the fatigue behavior of glass fiber reinforced EC filled by addition of rubber microparticles (9 wt.%) and silica nanoparticles (10 wt.%), under a standard helicopter rotor spectrum load. It was observed that the addition of 9 wt.% rubber microparticles and silica nanoparticles to the epoxy composite under the spectrum load improved the fatigue life three times, also Kinloch et al. [39] manufactured two types of GFRP composites, GFRP with neat epoxy matrix and GFRP with hybrid modified containing of rubber microparticles (9wt.%) and silica nanoparticles (10 wt.%). The results show the fatigue life of the GFRP-hybrid composite was exhibited 4-5 times higher than that of the GFRP-neat hybrid composites. The compression and fatigue strength of poly methyl methacrylate (PMMA) resin filler by addition of nano hydroxyapatite and ZrO_2 particles, where used in prosthesis denture applications were investigated by Salih et al. [40]. The fatigue strength value (90 MPa) of hybrid composite (PMMA-5% Kevlar fiber was higher than the fatigue strength (80 MPa) laminated composite specimen (PMMA fiber-3% Nano-H.A) and the pure PMMA resin (55 MPa). Sornakumar et al. [41] studied the effect of nano titanium dioxide fillers on the mechanical properties of glass fiber reinforced plastics. The mechanical properties of the glass fiber reinforced plastics enhanced by addition of nanofiller particles. The mechanical properties of the EC filled by nanoparticles were investigated by Lu et al. [42]. It was observed that the addition the nanoparticles enhanced the mechanical properties of this composites which contains an optimum values at nanoparticles with 1.3 and 2.6 wt %, also the flexural modulus and flexural strength of EC were increased from (2.9 to 3.8 GPa) and (120 to 210 MPa), respectively, by the adding the hybrid of nano particles in the EC. [43]. Mechanical and dynamic properties of unsaturated polyester-based composites and reinforced with three types of fabrics, E-glass, basalt, and carbon with various fiber configuration were investigated [44]. The results show that the reinforcement with an adding the basalt fabric and carbon fabric based unsaturated polyester composites as a fiber configuration $(2C/B/2C)_S$ enhanced the mechanical properties of the hybrid composite laminates among other various stacking sequences. Also, the changes of the dynamic response provide a proper indicator for predicting the current state of adhesive bonded joint.

3. Influence of process parameters on mechanical behavior

Venkateshwaran et al. [45] studied the water absorption behavior of banana/sisal reinforced hybrid composites. The moisture absorption becomes stabilize around 50 hrs for banana composite but, for jute composite water absorption rate becomes constant around 64 hrs. The trilayer composite of Banana/Jute/Banana has better tensile strength and modulus of 54.6 MPa and 13.69 GPa, respectively. The flexural modulus and impact strength increases as the length of fiber and weight percentage increased. The density, porosity and water absorption properties of sisal fiber and silica micro particles were studied by silva et al. [46]. It was observed that the low value of the volume fraction of fibers give good values of density, apparent porosity and water absorption. Nosbi et al. [47] studied the behaviors of kenaf fibers after long term immersion in water. Water absorption of the kenaf fiber immersed in the sea water exhibited highest absorption properties (pH 8.4) compared to the distilled water (pH 7). The impact energy and water absorption characteristics of the luffa fiber and Ground nut reinforced epoxy polymer hybrid composites were investigated [48]. It was found that the fiber volume fraction at 40% gives good absorption characteristics. Water absorption after 10 hrs increases at the rate of 1% - 5.5%. The maximum impact strength of the composites varies between 0.6 Joules to 1.3 Joules. The effect of water absorption on the mechanical properties of sisal and jute fiber composites were studied [49]. The jute fibers are give the best properties over all the immersion times analyzed and the sisal fibers were more strongly affected by moisture than jute fibers in epoxy matrix. The effect of water absorption and chemical resistance behavior of a graphite carbon fiber polymer composite was studied. It was found that, in water absorption test the material absorbs water below 1% but for graphite filled carbon fiber at volume fraction (10%) absorbs water more than 1% [50].

Suresha et al. [51] investigated the friction and wear behavior of G/E composites interfaced with graded fillers such as silicon carbide particles (Sic) and graphite. Addition of Graphite and Sic particulate fillers contributed in reducing friction and exhibited better wear resistant properties. G-E composite filled by silicon carbide gives higher resistance to slide wear compared to pure G-E composites. The friction and wear resistance of EC filled by low nanometer silicon nitride (Si_3N_4) particles were investigated by Shi et al. [52]. Strong interfacial adhesion between the nanoparticles and the epoxy matrix reduced improved resistance to thermal distortion of the composites. The flexural and impact strength increased as the nanoparticles filler increased of nano Si_3N_4/epoxy composites. The good mechanical and tribological properties at low filler content (less than 1 vol.%). Abdullah [53] studied the effect of the glass fiber and ceramic fillers ratios on the tribological behavior of glass-epoxy composite system under changing volume fractions in glass fiber, load and sliding distance. It was concluded that the wear resistance increase with the glass fiber volume fractions. The effect of ceramic whisker (7.5 wt.%) and solid filler (2.5 wt%) on the mechanical and dry sliding wear behavior of epoxy/glass composites was demonstrated [54]. It concluded that the whiskers and solid fillers have enhanced the wear resistance property of epoxy/glass composites. Patnaik1 et al. [55] demonstrated the influence of three different particulate fillers named by the fly ash, alumina and silicon carbide (Sic) on the erosion properties of glass polyester composites by Taguchi‘s. it is was observed that by the addition of hard particulate fillers such as flyash, Al_2O_3 and Sic enhances the erosion resistance of glass polyester composites. Li et al. [56] studied the tribological behaviors of pure polyetheretherketone (PEEK) and PEEK composites reinforced short glass fiber (30wt %). The friction coefficient and wear loss of the PEEK composite increased gradually and arrived to be a stable state as the increase of the sliding time. The PEEK composite reinforced with short glass fiber has an excellent wear resistance compared with the pure PEEK. The tensile strength and flexural strength of the PEEK composite were increased by 64% and 66%, respectively.

Amuthakkannan et al. [57] studied the mechanical properties of woven basalt fiber and glass fiber with different fiber stacking sequences reinforced hybrid composites. The reinforcement of woven Basalt and Glass fibers hybrid composites significantly influencing on the mechanical properties of the composites and it found that the intermediate properties between basalt glass fibers reinforced composites. The tensile strength exhibited the stacking sequence of 8B/4G is the higher than other stacking of basalt and glass fiber composites. The effect of fiber loading on physical, mechanical and thermo-mechanical properties of the bidirectional and short carbon fiber reinforced epoxy composites were studied by Agarwal et al. [58]. It was demonstrated that increasing fiber loading leads to the mechanical properties of bidirectional carbon fiber improved as compared to short carbon fiber reinforced epoxy composites. Alavudeen et al. [59] studied the effect of weaving patterns and random orientation on the mechanical properties of banana/kenaf fiber-reinforced hybrid polyester composites. It was observed that mechanical strength increase in the plain woven hybrid composites compared than in randomly oriented composites and improved interfacial bonding of polyester composite. Abdellaoui et al. [60] investigated the effects of layers number and fiber directions on the mechanical behavior of epoxy resin composites. The mechanical behavior of laminated composites has enhanced by increasing the number of layers, also, the mechanical properties of laminated composite based on natural jute fibers and epoxy resin increased with increasing of number of layers. It was also observed that the use of different staking orientation reduces the anisotropic character of obtained lamented composites. The maximal Young’s modulus of laminated with 1, 3, 5 and 7 layers were found respectively at 5264, 5902, 6400 and 5562 MPa in case of 0° fiber direction and 0° cutting direction.

4. Novel application of hybrid polymer composite

There is a steady increase both in the number of applications being found for fiber reinforced plastics. Some of these systems are useful, however, only in highly specialized situations where limitations such as high cost and brittle fracture behavior are considered secondary to such qualities as low density, high rigidity and high strength and in fewer demanding applications where weight is not as critical.

4.1 Nanotechnology

The Composite materials have a wide range of applications in the field of Nanotechnology. The Nano composite is a resourceful conception having fillers on a nanometer scale isolated in the resin. Because of the diffusion of very small fillers, flame retardance and inflexibility of the resin improves significantly with the addition of only a tiny quantity of fillers. In medical application polymer nanofibers used for the cure of burns or wounds of a humanoid skin, Fig.3, and also to designed haemostatic procedures and devices with certain special and exclusive features [61].

4.2 Wind Power Generation

The wind-power engineering is a priority area of energy generation due to its resource-saving and ecologically safe. The power cost primary is determined substantially by basic power element blades. For example, the blades are shown in Fig.4 were fabricated from hybrid fibers (carbon, glass) [62].

Figure 3: Wounds of a humanoid skin [61]

Figure 4: Hybrid wind turbine system [62]

4.3 Hybrid Thermoplastic Application

Thermoplastic advanced composites have long held potential for mass-producing lightweight structural parts. The helmet shape is one that the Army has developed for its Future Force Warrior (FFW) initiative. These helmets, called PASGT helmets shown in Fig 5, are made using a composite comprising aramid fabric in a thermoset matrix. The construction must also be strong enough to withstand the daily wear of a soldier's activities and provide improved ballistic protection [63].

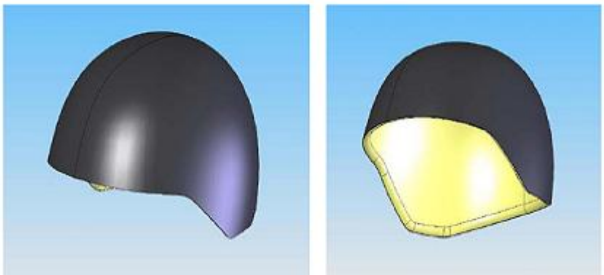

Figure 5: Hybrid helmets design [63]

4.4 Aerospace Applications

The use of fiber reinforced composites has become increasingly attractive alternative to the conventional metals for many aircraft components mainly due to their increased strength, durability, corrosion resistance, resistance to fatigue and damage tolerance characteristics. A modern civil aircraft designed as to encounter the several criteria of power and safety. As a result of forward-thinking technology that has gone beyond the design and application the glass and carbon reinforced hybrid composites are the best preferred materials, as shown in Fig. 6 [64].

4.5 Smart Memory

Hybrid Composites Growing requirement on the carrying into action of materials used in engineering practical applications postulate the development of this material then so called adaptive, multifunctional, smart, or intelligent materials. The physical properties of the matrix materials are either upgraded by the SMA elements.

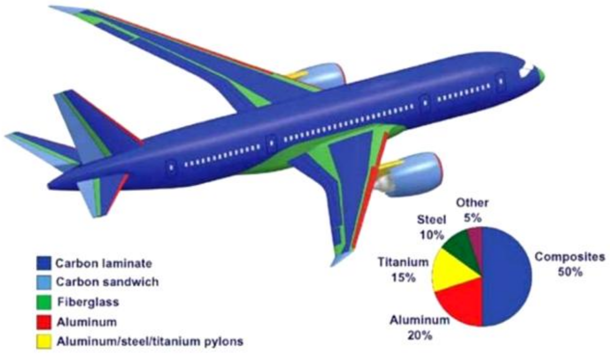

Figure 6 : A modern aircraft (Boeing: 777) [64]

4.6 Chemical Industry

The composite materials are one of the most popular materials used in chemical industry due to its various advantages of being light in weight, have better resistance against fire and show resistance to chemicals. Composite grips the wide use in chemical industry are used in the manufacturing of structural supports, storage tanks, exhaust stacks and blowers, columns, pumps, reactors etc. for acidic and alkaline environments.

4.7 Orthopedic Aids

Prosthetics and Orthotics help people who acquire disability or were born with physical defects, by fitting them with artificial supports. Prosthesis is an artificial substitute for a missing part of the body, Fig.7. The artificial parts that are most commonly thought of as prostheses are those that replace lost arms and legs, but bone, artery, heart valve replacements, artificial eyes, teeth are also termed prostheses [65].

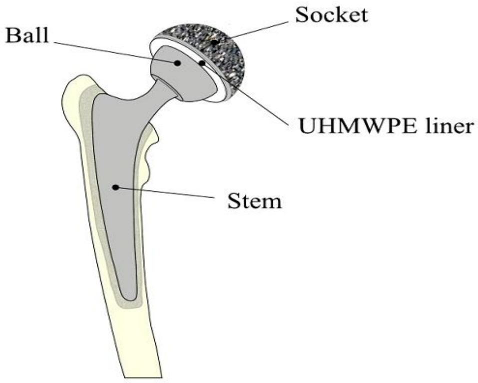

Figure 7: Typical hip prostheses [65]

4.8 Automobile/Transportation Sector

In spite of the potential benefits and many advantages of lighter weight and high durability resulting from corrosion resistance, advanced composites are not used widely in automotive applications. There must be some step's should be taken on a global level to make advanced composites material attractive for some wide-spread use in trucks, cars etc., Fig. 8 [66].

Figure 8: M-Van step Assist: 1 st commercial launch for TPO nano-composite application [66]

4.9 Bridges Construction

From the previous decade, largely in several countries, the research and development of totally hybrid FRP structures in civil engineering has developed. All the structural elements have been made with hybrid fiber reinforcement plastics (GFRP & CFRP). The all HFRP solution was chosen for this bridge due to its heavily corrosive atmosphere. The bridges' pultruded composite components deliver critical mechanical properties at a much lower weight than steel. West Mill Bridge has a span the length of 10 meters and the width of 6.8 m. Total weight of the construction is 37 t. It has load carrying capacity for vehicles up to 46 t with an axle load of 13.5t, Fig. 9. Each of the four main supporting beams are constructed of four profiles reinforced by glass and carbon fibers and glued together. [67].

Figure 9: West Mill Bridge [67]

Conclusions

In the present review, the fabrication, the mechanical properties, process parameter and the modern applications of hybrid polymeric composites has been reported. Successful manufacturing of HPC is available by hand-layup technique (HLU). The mechanical properties of the HPC are enhanced linearly with the volume fraction of high strength fibers up to certain maximum value beyond which a negative hybrid effect has been observed because of formation of agglomerates. The application of hybrid polymer composites as an alternative composite material, especially in building construction, transportations sector, aerospace and wind power applications is highly reasonable with lightweight, high strength and low cost.

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