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A review of coir fiber reinforced polyvinyl alcohol and other various adhesives based composites

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Abstract

This paper reviews the work done on the proposed combined polymer composite consisting of a poly-vinyl alcohol (PVA) and other various adhesive reinforced by coconut fibre (coir fibre). Reinforcement with natural fibres are popular due to its easy availability, easily extracted, enhance energy recovery, biodegradability, low density and low cost etc. Similarly growing concern about the environment, global warming, depleting petroleum reserves are the reasons to focus more on bio-degradable polymer composite. It also reviews the mechanical properties, methods of preparation, advantages of chemical treatment of the fibre, applications whereas the limitation and challenges of these composites materials. This review indicates that PVA and other various adhesives such as epoxy, ethylene vinyl alcohol (EVOH), and polyester etc. composites have potential for countless applications.

1.Introduction

1.1Composites

A composite or composite material is produced from combining two or more constituent materials together resulting different characteristics from the individual components. There are two categories of constituent that are matrix (binder) and reinforcement. Properties of composites are emphatically depending on the characteristics of their constituent materials, their dispersion and the interaction among them assists the requirements of composite for high quality to weight proportion, erosion resistance, lighter development materials and more of resistant structures have set tall accentuation on the utilize of modern and progressed materials that not as it diminished weight but to retains the stun & vibrations through custom fitted microstructures. Cutting edge and antiquated applications all makes utilize of the truth that composites can have improved quality, firmness and fracture, toughness while not showing an increment in weight. Composites are being utilized for pre-assembled, versatile and secluded buildings as well as for outside cladding boards. [1, 3]

1.2 Polymer matrix composite

Polymer matrix composites are the most common advanced composites. Generally, these composites consist of a polymer thermoplastic or thermosetting reinforced by fiber (natural carbon or boron). Thermosetting resins such as epoxy, polyester, polyurethane, silicon and phenolic are commonly used in composites requiring higher performance applications. These materials can be fashioned into a variety of shapes and sizes. Due to the low density of the constituents the polymer composites often show excellent specific properties. They provide great strength and stiffness along with resistance to corrosion. The reason for these being most common is their low cost, high strength and simple manufacturing principles. [1, 4]

1.3 Natural Fibers composites

Natural fibres are fibers that are produced by plants, animals and geological process. These fibres are used as a reinforcement constituent in composite materials. These fibers contain lingo cellulose in nature. Eco-friendly, lightweight, strong, renewable, cheap and biodegradable is the inherent feature of natural fibres. The natural fibers can be used to reinforce both thermosetting and thermoplastic matrices. They provide sufficient mechanical properties in particular stiffness and strength at acceptably low price levels. Recent advances in natural fiber development are genetic engineering. The natural fiber composites offer significant opportunities for improved materials from renewable resources with enhanced support for global sustainability. Natural fiber composites are attractive to industry because of their low density and ecological advantages over conventional composites [1, 2].

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1.4 Reinforcement by Coconut Fibre (Coir fibre)

Coir Fiber, one of the versatile products of the Coconut palm (Cocos Nucifera L.) is also known as the Tree of Life. The palm also known as coconut tree is truly a source of renewable raw materials for both Food and Non-Food products. This makes the coconut tree and the coconuts unique. Coir fiber is a lingo cellulosic fiber extracted from the coconut husk. The fiber can be extracted from either Green Coconut Husks or Mature Brown Coconut Husks. Both raw materials result in fiber types with slightly different characteristics. According to official website of international year for natural fibers 2009, approximately 746,000 tones of coconut fibers are produced annually worldwide, mainly in India, Sri-lanka, Thailand, Vietnam, Philippines and Brazil [6]. It has high specific strength and modulus, low density, reduced dermal and respiratory irritation, enhanced energy recovery, and low cost. Coconut fibre is getting popular in the composites industries because of its outstanding biodegradability and environmental friendliness that outperform the conventional glass, carbon, basalt, and aramid. [1,2, 18]

1.5 Polyvinyl alcohol (PVA) resins

As a water soluble synthetic polymer, polyvinyl alcohol (PVA) is colorless and odorless. Since 1930s, it is regarded to be a truly biodegradable synthetic polymer and has density of 1.19 g/cm3 and melting point of 180 °C. This polymer is non-toxic has properties such as high tensile strength and flexibility, good oxygen and aroma barrier properties, excellent emulsifying and adhesive properties, and high resistance to oil and grease. It has been used widely in papermaking, textiles, coatings, and as moisture barrier for dry food with inclusions. Modification of PVA with various fillers is common to enhance its film performance. The dispersion state of fillers in this polymer is critical in determining the final property of the polymer composites. [18]

1.6 Epoxy resins

The term epoxy has been broadly embraced for numerous employments far off fiber reinforced polymer composites. Epoxies are thermosetting polymer resins where the resin molecule contains one or more epoxide groups. Now days, epoxy adhesives are available in local hardware stores, and epoxy resins are widely used as the binder in counter tops or coatings for floors. The multitude of uses for epoxy continues to grow, and varieties of epoxies are constantly being developed to befitting the industries and products they are used in includes metal coatings, used in electronics, electrical components, high tension electrical insulators, paint brush manufacturing, fiber-reinforced plastic materials and structural adhesives etc

2. Literature Review

Bujang et al. [6] studied the dynamic characteristics of coir fibre reinforced composites. Composites of coconut fibre up to 15% were fabricated with polyester matrix and they were arranged in randomly oriented discontinues form. To determine the strength of the sample material, tensile tests were carried out similarly the dynamic characteristics of the composite material were obtained by experimental modal analysis. Thus the results show that the tensile modulus changes with the fibre content and the strength of coconut fibre reinforced composites tends to decrease with the increase of fibre which indicated ineffective stress transfer between the fibre and matrix. The stiffness factor also gives the same effect to the dynamic characteristic of composite where the natural frequency decreased with the increase of coconut fibre volume. However, the damping peak was found to be increased by the inclusion of the fibre. When higher fibre content of 10% was used, the damping peak showed the maximum value for almost all the frequency mode. Furthermore, by inclusion of coir fibres, the damping ratio was found to be increased giving an advantage to the structure in reducing high resonant amplitude.

Almeida et al. [7] studied the mechanical properties and structural characteristics of coir fibre reinforced polyester composites. The as-received coir fibre was characterized by scanning electron microscopy coupled with X-ray dispersion analysis. Composites prepared with two molding pressures and with amounts of coir fibre up to 80 wt. % were fabricated. Randomly oriented coir fiber-polyester composites are low- strength materials, but can be designed to have a set of flexural strengths that enable their use as non-structural building elements. Low modulus of elasticity, in comparison with that of the bare polyester allocates lack of an efficient reinforcement by coir fiber. Up to 50 wt. % of fibre, rigid composites were obtained. For amounts of fibre higher than this, the composites performed like more flexible agglomerates.

Asasutjarit et al. [8] investigated the effects of pre-treatment on properties of coir-based green composites. The composites were prepared using coir fiber treated with varying pre-treatment conditions. The process ability conditions and physical, mechanical and thermal characteristics of these composites were analyzed. Surface characterizations of the un-pretreated and pre-treated coir fiber were investigated from scanning electron microscopy (SEM) studies. It revealed that there is an improved adhesion between fiber and matrix in the case of pre-treated coir. SEM investigations confirm that the increase in properties is caused by improved fiber-matrix adhesion.

Waifielate el at [9] studied the mechanical properties of coconut fibre and verified the results obtained by finite element method using a commercial software ABAQUS. The experimental work was carried out on both inner and outer fibre specimen and results obtained were compared with simulation results such as plots of load vs. Extension and stress vs. strain at break were calculated. From this study inner coconut fibre has higher mechanical strength compared to the outer coconut fibre but on the other hand the outer coconut fibre has a higher elongation property which can make it to absorb or withstand higher stretching energy to the inner coconut fibre.

Morsyleide F. Rosa et al. [10] studied the effect of fiber treatments on the mechanical properties of starch/EVOH/coir bio-composites where the influence of fiber treatments by washing, mercerization and bleaching and all the treatments removed surface impurities on fibers, producing modifications on the surface and improving thermal stability of both fibers and fiber-reinforced composites. Results were supported by SEM analyses. Composites from treated coir fibers had better TS than those made from the untreated fibers, and improved values for TS and E, compared to blends without fibers. The composites made with mercerized fibers showed a considerable 33% improvement in tensile strength and a 75% improvement in tensile modulus over that of the neat starch/EVOH blend. Results indicate a better wettability of treated coir fibers with matrix and corroborated the role of treated coir fiber as not afiller, but as a reinforcing agent. This research indicated that starch/EVOH blends reinforced with treated coconut fibers have superior characteristics when compared to pure starch/EVOH blends.

Biswas and Kindo et al. [11] Studied the processing and characterization of natural fiber reinforced polymer composites and observed that impact velocity, erodent size and fiber loading were the significant factors in a declining sequence affecting the erosion wear rate.

Cervalho et al. [12] studied the effect of chemical modification in on the effect of coconut fibre composites lignocellulose fibres from green coconut fruit were treated with alkaline solution (NaOH 10% w/v) and then bleached with sodium chlorite and acetic acid. Alkali treated bleached fibres were mixes with high impact strength polystyrene (HPIS) and placed in injector chamber to obtain the specimen for tensile test. Specimens were tested in tensile mode and fracture surfaces of composites were analyzed by scanning electron microscope and x-ray diffraction. The experimental results showed that the addition of 30% alkali-treated and bleached fibres reinforced in HPIS matrix provided the considerable change in mechanical properties in comparison of pure HPIS.

Biswas and Kindo et al. [13] studied the mechanical behavior of coir fiber reinforced polymer matrix composites and observed that that the mechanical properties of the composites such as micro-hardness, tensile strength, flexural strength, impact strength etc. of the composites are also greatly influenced by the fibre lengths.

Jonjankiat et al. [14] investigated the properties of eco-friendly bio-composites prepared from poly (vinyl alcohol) (PVA) and cellulose microfibers (CMF). It was observed that interactions of -OH groups of PVA with CMF molecular chains lead to increase in the melting point and crystalline of bio-composites. It was observed that the addition of CMF filler increased the shear strength of samples from 1.55 to 2.41 Mpa.

Shehamayee das et al. [15] Bleach treated coir fibre and then cast them with epoxy resin using handmade mould. XRD patterns confirmed that degree of crystalline decreases by the treatment of coir fibre with H2O2. SEM image shows roughness of surface structure of composites which confirms that the adhesion is increased after treatment. FTIR spectra confirm that water content of composites decreases due to intermolecular hydrogen bonding. The 3 point bending test (INSTRON) shows that the strength of bleached fibres increases with the comparison of raw fibre.

The increase in the mechanical and thermal properties of sago pith waste as a bio-filler (SPW) on poly (vinyl alcohol) (PVA) was studied by Yee et al. [16]. The composite was prepared in a twin-screw extruder using one step extrusion and these composite had improved tensile modulus, whereas the tensile strength reduced because the SPW had increased the rigidity f the PVA. The molecular force interactions between SPW/PVA at high loading of PVA are great that they could overtake the PVA itself so these outcomes indicates that the interactions between PVA and SPW are reactive to induce synergistic effects. Similarly, the formation of hydrogen bond between the components of the composite was confined by an FT-IR analysis shows the addition of the PVA has reduced the water absorption of the composites.

Samia S. Mir et al. [17] characterized brown single coir fibre for manufacturing polymer composites reinforced with characterized fibres. Adhesion between the fibres and polymer is one of factors affecting the strength of manufactured composites. In order to increase the adhesion, the coir fibre was chemically treated separately in single stage (with $Cr_2(SO_4)_3{\bullet}12(H_2O)$) and double stages (with $CrSO_4$ and $NaHCO_3$).Both the raw and treated fibres were characterized by tensile testing, Fourier transform infrared (FTIR) spectroscopic analysis, scanning electron microscopic analysis. Mechanical properties of characterized fibre in this analysis were found to be better than the raw fibre and that of the double treated even better. Scanning electron micrographs showed rougher surface in case of the raw coir fibre. The surface was found clean and smooth in case of the treated coir fibre.

Ing Kong et al. [18] PVA integrated with the NaOH modified coconut fibre to form treated composites was studied and the results showed improved properties of hardness and young's modulus with the increment of fibre volume fraction. The samples were prepared by hot pressing. High content of alkali modified fibre is essential in composites fabrication in order to produce composites with high modulus, high hardness, high degradation temperature, and low moisture sensitivity. Moisture absorption and desorption test verified that the moisture uptake and release ability of composites could reduced by increasing the treated fibre content. The composites material that possesses these properties can be used in the biodegradable food packaging applications and other applications.

Obiukwu Osita, et al. [19] investigated the mechanical properties that the young's modulus and the hardness of the composite were improved with the increment of fibre volume fraction and showed best at 10%. PVA was integrated with the epoxy and palm kernel fibre volume to form composites and the result showed fibre volume on mechanical properties is greatly dependent. The samples were prepared in ASTM D368 type 1 mould. It was observed that the effects of reinforcing PVA matrix with the palm kernel fibers caused the composite to be more flexible and easily deform due to high strain values and reduction of high resonant amplitude. Increase in fibre volume showed improvement on the young's modulus and the hardness of the composites. 10% fibre volume showed best tensile result whereas 12% fibre volume lowered the young's modulus and the hardness of the composite. The microstructure observation showed that fibre has a uniform bond between the epoxy and PVA.

Chizoba obele et al. [20] studied the mechanical properties of coir fiber reinforced epoxy composites for helmet shell. The samples were prepared by using hand lay-up hand techniques and mould was made from existing helmet shell. The treatment of coir fibre with alkaline solution removes wax, lignin, oils and other fiber constituents that may reduce adhesion between fibre and matrix resulting weak boundary layer. 30% wt coir filler gave the highest impact strength, maximum stress that the composite can withstand. Above 50 wt% of coir fibre there is decrease in tensile strength that was due to poor circulation of the epoxy matrix around each other. The tensile modulus of coir/ epoxy increases with an increase in filler loading.

3.Application and limitation of coir fibers

According to the studies done by the researches, coir fiber has tremendous application such as cording, packaging, furniture's, bedding, flooring and so on. Similarly, major limitation of using coir fibres as reinforcements in hydrophobic thermoplastics such as polyolefin's and thermo-set matrices is because coir fibre contains strongly polarized hydroxyl groups and adhesion between polarized hydroxyl group and non-polar hydrophobic matrix results poor interfacial adhesion, and poor wetting of fiber-matrix creates difficulties in mixing them.

4.Conclusions

The present review focuses with a target to investigate the capability of the coir fibre reinforced PVA and other various adhesive composites and to study the mechanical properties of these composites. This review displays the utilization of coir fiber as reinforcement and yield further information for research in this area. As the fibre volume affect on the mechanical properties of the composites due to dispersion of fibre and interfacial adhesion between fibre–matrix. Chemical treatment of coir fiber can reduce the limitation of coir fiber and provide better interfacial adhesion and good wetting between fiber and matrix. The source of coir fibre is influential in mechanical properties of these bio-composites and treated fibers have been used in wide variety of applications.

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