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Effect of Environmental Degradation on Mechanical Properties of Natural Fiber Reinforced Polymer Based Hybrid Composites: A Review

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Abstract:

Natural fiber reinforced composite materials have been widely used in the variety of engineering applications. Natural fiber composites may suffer when the material is exposed to adverse environmental condition for long period of time. A lot of research has been conducted and still ongoing for the possibility of the use of the combined form of natural fibers and synthetic fibers for the structural composite members under such type of conditions. The natural fiber reinforced composites have limited resistance towards the environmental effect. The idea of improving the strength is by adding the synthetic fibers along with the natural fibers in order to enhance the mechanical strength of the bulk material under the adverse conditions. Thus, the study of environmental conditions on the mechanical properties of hybrid composite is important. This review paper selectively represents all-round research carried by various researchers throughout the globe for the various natural and synthetic fiber reinforced composites subjected to different environmental conditions and their degradation of mechanical properties which is measured before and after the environmental exposer.

Keywords: *Natural Fiber, Hybrid composites, Environmental degradation, Mechanical properties.*

1. Introduction

In the course of life, composite materials are subjected to both mechanical loading and adverse environmental conditions. The natural fiber reinforced composite are reasonably lightweight, strong and free from health hazard, hence it is having the potential to be used as material for structural components used in ship building materials, automotive etc. Despite the advantages listed above, they suffer from some limitations such as poor moisture resistance especially low strength and moisture absorption compared to synthetic fiber such as glass fiber [1]. Natural fibers develop an option for most widely applied synthetic fiber in composites technology. The interest in natural fiber was increased because it is lighter and cheaper which provides better stiffness per unit weight than glass fiber [2]. Natural fiber source is renewable and it is considered green and environmental friendly. The fact that, it causes less impact on the environment and it can be recycled thermally.

Glass fibers have high impact strength, tensile strength and high chemical resistance. But these have relatively low fatigue resistance, low modulus and self-abrasiveness, and poor adhesion to matrix composites [3]. The traditional composite structures usually made of glass, carbon and aramid fibers are considered critical because of the growing environmental consciousness [4]. Advantages of natural fibers over traditional reinforcing fibers such as glass and carbon are: low density, low cost, ease of separation, acceptable specific properties, enhanced energy recovery, biodegradability and CO_2 sequestration.

2. Study of Mechanical Properties for Natural/Glass Fiber Reinforced Polymer

Natural fiber reinforced polymer matrix composites are very sensitive to the influence from environment agents such as moisture, temperature and water. The tensile strength of the linen fiber is directly proportional to the cross sectional area of the fiber and failure is due to the degradation of the individual layers [5]. The incorporation of natural fibers with glass fibers improves the tensile, flexural and impact strength of the materials and placing the glass fiber layers at the end of laminate possess good mechanical properties. The tensile properties of linen fiber hybrid composites are increased with increasing the content of linen fibers loading as compared to glass epoxy composites. The mechanical properties of natural fiber composites are somewhat lower, because of less brittle and typically less stiff [6]. Reinforcing glass fiber into the linen polypropylene composites enhanced flexural and tensile properties without any effect on flexural and tensile module. In addition to this, adding linen fiber with glass fiber improves water resistance and thermal properties of the hybrid composites [7].

The sisal/banana hybrid natural fiber composite specimens are prepared with different ratios by taking 0.4 volume fraction and tensile properties of these hybrid natural fiber composites are examined by using Rule of Hybrid

Mixture (RoHM) [8]. It was predicted the RoHM equation gives the tensile properties of the hybrid composites slightly higher than the experimental values. The tensile properties of vakka fiber composites increase with volume fraction of fiber and more than the sisal/banana fiber composites [9]. The flexural properties of vakka fiber composites are closer to the sisal fiber composites and more than that of the banana fiber composites [10]. The addition of sisal fiber in the composite increases the flexural strength, tensile strength and also impact strength. The overall tensile and flexural properties of natural fiber reinforced polymer hybrid composites are highly dependent on the moisture absorption, aspect ratio tendency, morphology and dimensional stability of the fibers used [11].

The flexural properties of vakka fiber composites are closer to the sisal fiber composites and more than that of the banana fiber composites. The addition of sisal fiber in the composite increases the flexural strength, tensile strength and also impact strength [12]. The mechanical behaviors of unidirectional linen and glass fiber reinforced hybrid composites with the aim of investigation on the hybrid effects of the composites made by synthetic and natural fibers [13]. The tensile properties of the linen/glass fiber reinforced hybrid composites were improved by increasing the glass fiber content. The incorporation of sisal–jute fiber with glass fiber can improve the properties and can be used as an alternate material for glass fiber reinforced composites [14]. The mechanical properties of the sisal fiber reinforced composites are lower than the jute fiber reinforced composites. The jute and glass fiber hybrid composite leads to the successful fabrication of jute fiber, glass and chopped fiber reinforced polyester composites with different fiber lengths is possible by simple hand lay-up technique and produce overall good mechanical properties [15].

3. Chemical treatment of natural fiber reinforced composite and its impact on mechanical properties

In recent years there has been a lot of interest in the use of natural fiber reinforced composites in more advanced applications. As a result, their mechanical properties needed to be increased, as well as service life modeling. The mechanical properties of natural fiber have been increased by treating it with 10% NaOH solution. Testing revealed that the alkaline treatment was successful in increasing tensile and flexural strength and interlaminar shear but decreased the flexural and tensile modulus by 10%. Addition of acrylic resin to the vinyl ester resin improves all mechanical properties except the flexural modulus which was decreased by 5%. In order to evaluate the long-term behavior, creep compliance master curves were generated using the time temperature superposition principle. Results suggest that fiber and matrix treatments delayed the creep response and slowed the process of creep in flax/vinyl ester composites [16].

4. Comparison between properties of various natural fibers [17, 18]

The Table 1 highlights the physical property of various natural fibers. The Table 2 represents the comparison of various properties between natural fiber and glass fiber. Table 3 highlights the study of the mechanical properties of different natural fiber reinforced composites exposed to different environmental conditions carried out by various researchers.

Table 1 Physical property of various natural fibers

Property	**Glass**	**Linen**	**Hemp**	**Jute**	**Ramie**	**Coir**	**Sisal**	**Cotton**
Density (kg/cm^3)	2550	1400	1480	1460	1500	1250	1330	1510
Tensile Strength (MPa)	2400	800-1500	550-900	400-800	500	220	600-700	400
Stiffness (kN/mm)	73	60-80	70	10-30	44	6	38	12
Elongation at break (%)	3	1.2-1.6	1.6	1.8	2	15-25	2-3	3-10
Moist absorption (%)	-	7	8	12	12-17	10	11	8-15

Table 2 Comparison of various properties between natural and glass fiber

Parameters	**Natural Fibers**	**Glass Fibers**
Density	Low	Twice that of natural fibers
Cost	Low	Low, but higher than NF

Renewability	Yes	No
Recyclability	Yes	No
Energy Consumption	Low	High
Distribution	Wide	Wide
CO_2 Neutral	Yes	No
Abrasion to machines	No	Yes
Health risk when inhaled	No	Yes
Disposal	Biodegradable	Not Biodegradable

Table 3 Comparative study of the mechanical properties of different natural fiber reinforced composites exposed to different environmental conditions

Reference Papers	Compound material	Environmental Conditions	Results
M.A.A Ghani et al.(2012) [19]	Kenaf fiber, glass fiber, polyester resin	Test was conducted by immersing specimens into three different environmental conditions including sea water, distilled water and rain water at room temperature.	The mechanical properties of Kenaf fiber composites were deteriorated after moisture penetration. The mechanical properties of natural fibers were improved by hybridization of natural fibers with synthetic fibers.
Mohamad Zaki Abdullah et al. (2013) [20]	Kenaf fiber, PET Fiber, POM resin	The samples were exposed to moisture, water spray, and ultraviolet penetration in an accelerated weathering chamber for 672 hours.	The results of the investigation revealed that the hybrid composite had better retention of mechanical properties than that of the kenaf fiber composites and may be suitable for outdoor application in the automotive industry.
A.M. Amaro et al. (2013) [21]	Glass fiber, Epoxy resin	Test samples were immersed in hydrochloric acid (HCl) and sodium hydroxide (NaOH).	The corrosive environmental affects significantly the flexural strength and flexural modulus. The alkaline solution shows to be more aggressive than the acid solution, promoting the lowest flexural properties
Abdul Malek et al. (2011) [22]	Kenaf fiber, E glass fiber, epoxy resin	Water	Results show that the incorporation of E–glass fiber resulted in brittle failure. It also results in high strength, low ductile, and low toughness behavior
Z.N. Azwa et al. (2013) [23]	Kenaf Fiber, Epoxy resin	Treated and untreated Kenaf fiber and epoxy resin composites were exposed to high temperatures up to 600°C.	Untreated fibers have shown lower decomposition temperature and lesser residues. The samples physically experience shrinkage at 250 °C with kenaf fiber/epoxy composites

			demonstrates fine cracks.
Venkata S. Chevali et al. (2010) [24]	Nylon 6/6 (NY66), polypropylene (PP)	The fiber-reinforced thermoplastic composites were exposed to ultraviolet irradiation and moisture absorption.	All materials showed surface cracking with increasing UV exposure. Creep compliance of UV-exposed PP LFT increased, whereas the creep compliance of NY66 40 LFT moderately decreased with increases in UV exposure.
Nabila Belloul et al. (2015) [25]	Glass Fiber, Polyester resin	This work treats the behavior of a glass fiber/unsaturated polyester (UP) composite with structural defects subjected to the attack of two corrosive solutions: H_2SO_4 and NaOH.	The obtained results showed that, in the acidic solution, the glass fiber and the fiber/matrix interface absorption share is more significant than the alkaline solution. While the Fourier transforms infrared analysis (FT-IR) of the UP resin revealed the presence of chemical degradation phenomenon.

6. Applications:

Due to the environmental awareness among all over the world, the attention was drawn towards the use of natural fiber as reinforcing element in polymer matrix. Composites made of the same reinforcing material as natural fiber system may not give good results as it undergoes different loading conditions during the life span [26]. In order to solve this problem, hybrid composites are the best solution for such applications. A hybrid composite is a combination of two or more different types of fiber in which one type of fiber balance the deficiency of another fiber [27]. Among various natural plant fibers, linen fiber has a great potential to be used as reinforcement in polymer composites. Composites made of natural fibers offer the opportunity for various applications in fields such as civil structures, consumer goods, low cost housing and for many other common applications where the cost of reinforcements at present restricts the use of conventional reinforced plastics such as polymer [28].

In the past decade, natural fiber composites have been developed, in which several natural fibers such as ramie, hemp, jute, sisal, bamboo; banana, oil palm fibers, etc. are used as reinforcements in place of glass fibers and coir can be used as a potential reinforcing material for making low load bearing thermoplastic composites [29]. Hybrid fiber composites with coir and other fibers rather than glass may open up new applications. The natural fiber reinforced composite have high stress to weight ratio, high corrosion, impact resistance, non-conductive, avoid electrical hazards, low maintenance requirements, reduced cost, easy installation due to light weight and fire retardant [30]. These composites are used in under roof applications in aerospace industries, door panels, automobile industry, construction material for buildings, sporting goods industry and marine application [31]. The hybrid natural fiber composite materials are used in a number of consumable goods. The natural fibers are of interest for low-cost engineering applications and can compete with artificial glass fibers and these composites were used as a source of energy to make shelters, clothes, construction of weapons [32]. The lightweight natural fiber composites improve fuel efficiency and reduce emissions in the use phase of the component, especially in automobile applications.

7. Conclusion:

The mechanical and physical properties of natural fibers vary from fiber to fiber. Natural fiber reinforced composites are used in many engineering applications, because of its superior properties such as specific strength, low weight, low cost, fairly good mechanical properties, non-abrasive, eco-friendly and bio-degradable characteristics. Incorporation of natural fibers with glass fiber can improve the properties and used as an alternate material for glass fiber reinforced polymer composites.

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