International Journal of Mechanical Engineering and Technology (IJMET)
Volume 8, Issue 12, December 2017, pp. 1113–1120, Article ID: IJMET_08_12_121
Available online at http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=8&IType=12
ISSN Print: 0976-6340 and ISSN Online: 0976-6359

SOME STUDIES ON MECHANICAL PROPERTIES OF NATURAL FIBRE POLYMER COMPOSITES WITH FIBRE SURFACE TREATMENTS

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ABSTRACT

Natural fibre reinforced polymer composites are being increasingly used for wide range of applications in automobile, industrial and domestic fields due to their high specific strength, lightweight, biodegradability, and environment friendliness. Their availability, low density and price as well as satisfactory mechanical properties, make them attractive alternative reinforcements to glass, carbon and other manmade fibers. It is reported that mechanical properties of natural fiber composites can be enhanced with surface treatment of fibers and also the cleaning of the surface and pretreatment of fibers lead to the improvement in thermal resistance of natural fibre composites. This paper reviews and investigates the various studies carried out on the effect of chemical treatments on mechanical properties and surface topographies of the different natural fibre composites.

Keywords: Fibre surface treatment, Polymer composite, Natural fibre composite

Cite this Article: Pankaj Giri, V. Charan Kumar, V. Jayakumar and G. Bharathiraja, Some Studies on Mechanical Properties of Natural Fibre Polymer Composites with Fibre Surface Treatments, International Journal of Mechanical Engineering and Technology 8(12), 2017, pp. 1113–1120
http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=8&IType=12

1. INTRODUCTION

Composite material is a material composed of two or more different materials, with the properties of the resultant material being superior to the properties of the individual materials that make up the composite. Composite materials are made to obtain unusual combinations of stiffness, strength, weight, high temperature performance, corrosion resistance, hardness, or conductivity. The composites are composed of two phases namely matrix and dispersed phase. The properties of composites are a function of the properties of both the constituent phases, their relative amounts, and the geometry of the dispersed phase. The reinforcing phase of the composites provides the strength and stiffness, to make them harder, stronger and stiffer than the matrix. The reinforcement is usually in the form of a fiber or a particulate.

Composites can be broadly classified into metal matrix composites (MMCs), ceramic matrix composites (CMCs) and polymer matrix composites (PMCs). This paper summarizes the various works carried out on the natural fiber reinforced polymer composites and their properties and the effect of chemical treatments of fibres on properties.

2. LITEARTURE REVIEW

2.1. Fibre Surface Treatments

Though many researchers have presented their work on fabrication and characteristic analysis of different natural fibre reinforced polymer composites, some of the key studies on nature fibre reinforced polymer composites involving various fibre surface treatments are presented in the following sections. Sakthivel [7] presented a review paper on the preparation of natural fibres using epoxy resin, harderner, natural fibre, sodium hydroxide, roller, bowl and stirrer through hand fabrication method. The flexural test, harness test, water absorption test, density test and impact test were performed to determine the applicability of fibre composites. The impact energy on scale of joule was 4 for coir, 5 for banana and 4 for sisal. The banana fibre got higher impact strength hence it is more favourable for usage in products. Based on the research by Satish Pujari et al [18] banana fibre has specific strength which is as equal to the composite of glass fibres 392- 677 MPa. Alkali treatments has increased its strength by removing its impurities as same as jute fibre. The interfacial characteristic of composites is investigated by microscopic examinations and their internal structure. The study by Ramesh [21] showed that the tensile properties in glass fibre reinforced composite got increased due to the increase in the interfacial strength. Hence the fibre surface treatment is appropriate step for increasing the properties.

The bond among the fibre and matrix is improved by using chemicals. Chemicals used for silane treatment are alkali treatment, peroxide treatment, permanganate treatment, isocyanate treatment, and maleic anhydride. Kayode Feyisetan Adekunle [1] reviewed the effect of surface treatment on natural fibres and reported hydrophilic nature of all cellulose fibre is a key disadvantage due to which there is a change of mechanical properties and other physical properties. Also climate, temperature, age and fabrication process influence its chemical composition. Since natural fibre are grown up in diverse climatic circumstances, hence the necessity to discover the appropriate process of fibre surface treatment cannot be overstressed. The Alkaline treatment decreases the impact strength of fibre composites as investigated by Senthilkumar and Ravi [3], in which they carried out the alkali treatment. In their study, sisal fiber was selected and was treated with diverse concentrations of sodium hydroxide solutions. A polymer matrix composite was made using untreated and treated sisal fiber as a reinforcement and epoxy as matrix material. The consequence of alkali (0%, 3%,6% & 9%NaOH solution) treatment and the mechanical properties (tensile strength, flexural strength and impact strength) were investigated. The outcome of the experiments was that 3% NaOH treated had maximum tensile strength of 55.02 MPa. The 6% NaOH treated fibre gave good flexural flexural strength up to 122.27 MPa .The maximum impact strength was attained when composites were untreated had a value of 490J/m. Hence it is established that the when the concentration of NaOH escalates above 3% the tensile strength decreases and flexural strength increases. For getting supreme impact strength, the fibres have to be untreated also for flexural strength and for tensile strength the composite needs to be treated.

Based on the investigation done by Easwara Prasad et al [4], the impact strength rises with increase in thickness. The untreated sisal polyester composite gave impact strength 3.581 Nm at its 30% fiber volume fraction. The composite which was treated shown impact strength of 1.962 N-m at its 30% fibre volume fraction. It was concluded that, 5 % NaOH treatment to 10 mm extended sisal fibers for 24 hours treatment time is not enough to improve the impact strength possessions of sisal-polyester composites. The chemical treatments enhance the attachment between the resins and matrix. The research done by William Jordan and Patrick Chester [5] shows that when the peroxide and permanganate treatment were done to the banana pseudo-stem fibers they found some inconclusive results; the peroxide treatment enhanced the tensile properties and permanganate treatment had an inconclusive effect. The untreated banana pseudo-stem fibers had higher tensile and stiffness but the post- fracture analysis showed improvement in interfacial bonding with treated fibres. Hence the permanganate treatment doesn't provide any improvement in mechanical properties unless it is alkali pre-treated prior to permanganate treatment.

2.2. Change in Surface Topography of Fibres

The change in the surface by removing impurities has greater impact on its properties. Fiore et al [2] studied the outcome of sodium bicarbonate treatment on raw sisal fibre. 10%w/w of sodium bicarbonate solution for various times (24, 120 and 250h) at room temperature and scanning electron microscope was used for finding out changes in the sisal fibres. Fibre pullout of single fibre was done and there tensile properties were tested. The conclusion from the test was that 120 hr was approximate period to treat sisal fibre to get increased interfacial adhesion and mechanical properties along with epoxy matrix. The improvement in mechanical properties due to treatment of alkalization is that there are alterations in surface topography of natural fibre composite as studied by Mwaikambo and Ansell [6] by treating various hemp, sisal, jute and kapok for composite.

The composite material degradation is the matter to study and analyze to choose appropriate natural fibre composite for future applications. The study conducted by Geetanjali [19] concluded that the amount to exposure of the composite material to NaOH shows increase in degradation. The glass fibre composites have wider application due their durability and strength to absorb the shock. The vibration characteristic is very important for the fibre to withstand the vibration by the external source a study by Rajesh et al [20] proves that treatment of fibre increases the internal adhesion between fibres and increases it free vibration characteristics due to increase in stiffness. The surface of the natural fibre was cleaned by caustic soda and was alkalized. Fibres were also treated with an acid catalyst to graft acetyl groups onto the cellulose structure, to reduce the hydrophilic tendency of the fibres and enhance weather resistance.

2.3. Improvement of Flexural Strength

Enhancement of tensile strength and flexural strength was shown by treatment of natural fibre composite with 7% NaOH as investigated by Benyahia et al [7]. In their work, they studied the alfa fibers with diverse concentrations of NaOH (1, 3, 5, 7%) for 24 hours, with 7% NaOH treatment there was improvement of tensile and flexure strength by 30% to 50%. Their SEM analyses revealed that NaOH treatment modified the fiber morphology and also Alfa fibers is cheaper in price than glass fiber reinforcements, so they have a very favorable scope in composites. The common problem encountered with natural fibre composite material are the poor adhesion, which is reported by Somashekar and Shanthakumar [9]; they concluded that sisal natural-fibre-reinforced epoxy composites could be certainly manufactured with enhanced mechanical properties and the tensile andf lexural properties can be enhanced by alkali treatments. The study also revealed that maximum strength and maximum toughness cannot be achieved simultaneously and optimum combinations of desired mechanical properties are possible only by proper fabrication of composites. The flexural strength could be improved by changing percentage of treatment of fibre, as per the study led by Mansour et al [12]. In their study, chemical treatment of fibers by sodium hydroxide was employed and they reported that when the alfa fibres were treated with NaOH at 1, 5 and 10% for a period of 0, 24, and 48h to 28° C. The enactment of composites treated with alkali was better compared to untreated. The fiber treated Alfa 10% NaOH with 24h, the flexural strength and flexural modulus was increased from 23 MPa – 57 MPa and from 1.16 - 3.04 GPa, the flexural properties of composites alkali treatment with 5% NaOH for 48 h were decreased because of reduction in lignin that binds the cellulose fibrils composed.

2.4. Green Composites

The green composites are mainly fabricated by using trees and plants and there leaves. The green composite are biodegradable and has no negative effect on the environment. Mimi Azlina Abu Bakar et al [8] investigated the mechanical properties of kenaf fibre. The flexural strength, flexural modulus and impact strength was tested and fabricated with changing concentrations of weight: 5, 10, 15, 20 and 25 wt% by means of hot pressed method. The change in properties by alkaline treatment using 4% NaOH to the mechanical properties of the composite also found. The cracked surfaces by means of scanning electron microscope technique (SEM) were investigated to find the interfacial bonding among the epoxy resin matrix and the reinforcement. The flexural modulus was improved along with flexural strength by 79% and 24.7% and the impact strength by 14.7%. Rajasekaran and Gokul [10] studied mechanical properties of sugarcane fibre by treating it with NaOH and HCL with 4% and 3% composition and dry for 24 hour then the composite was fabricated. The treated fibres with NaOH solution showed higher tensile strength than other surface treatments. The results were promising and showed a great potential that agricultural waste has capability to substitute synthetic fibers. The breaking strength of treated sugarcane fibre was increased from 2.342 MPa to 20.014 MPa. Jai Inder Preet Singh et al [11] presented the mechanical properties of jute, sisal, banana, hemp and abaca fibers for polymer composite reinforcement at constant 40% fibre volume fraction after treatment of NaOH with natural fibres. The tensile and flexural strength increased due to alkali treatment. Jute fibre treated with NaOH based composite showed the tensile strength of 431 MPa and treated hemp fiber 96 MPa. The impact strength decreased with 5% alkali treatment for all types of natural fibers based composites. The research done by Joao Bessa et al [13] concluded that treatments with flax fabrics strongly affect the mechanical properties of the final composite materials, mainly breaking elongation and Young's modulus and the surface treatments can increase the elongation capacity of the flax fabrics reinforced thermoplastic polyolefin, without decrease of mechanical properties. This property of elongation is important for the automobile sector.

The natural fibre composite should withstand the heat from the external force. The investigation on outcome of alkali treatment on mechanical, morphological and thermal properties of date palm fibers done by Oushabi et al [4]; they investigated on the bond strength and fibre pullout energy with different percentages of NaOH: 0 wt%, 2 wt%, 5 wt% and 10 wt%. Treatments were done under mild conditions without heating for 1 h. Based on the investigation it was concluded that interfacial properties increased after alkali treatment, the non-cellulosic materials got removed which leaded to increase in tensile strength and thermal resistance of date palm fibres.The waxy layers and other impurities were also removed. The time of exposure of the natural fibre composite during treatment affects the mechanical properties as per the study done by Ridzuan et al [15] and they reported that soaked time during the alkaline treatment on fibres changes its tensile strength. Fibres treated by 10% of NaOH for 6 hr NaOH treatment produces the maximum tensile strength, though low elastic modulus. Fibres treated with 18hr and 24 hr got severe surface damage on the fibre. Mohit Sood and Gaurav Dwivedi [16] reviewed on fiber treatment and their effects on flexural properties and concluded that alkali treatments with 5%, 6% and 10% strength of NaOH solution the flexural properties were improved. When alkali treatment is mixed along with silane, the flexural properties are improved further. Along with coupling agents different mixtures of treatments could be applied on different fibres. For more improvement of flexural properties with fiber modification, matrix modification can also be completed.

Table 1 presents the summary of treatments on various natural fibre composites and their effects on mechanical properties.

Table 1 Summary of fibre surface treatments and their effect on mechanical properties

Author	Fiber	Matrix (Polymer)	Treatment	Impact strength (J/m)/ (N/m)/ (kJ/m^2)	Flexural strength/ Modulus (MPa)/(GPa)	Tensile strength (MPa)	Key Inferences
Fiore et al [2]	Sisal	Epoxy	Sodium bicarbonate at 10% w/w for 924, 120 and 240h at room temperature	-	-	930 to 911.2	Tensile strength decreased; strength from T-120h and T-240h due to degradation by $NaHCO_3$
Senthil kumar and Ravi [3]	Sisal	Epoxy	Sodium hydroxide at concentration of (0%, 3%, 6%, and 9%)	490 (J/m)	122.27 MPa at 6% NaOH	55.02 at 3% NaOH	Tensile and flexural strength were enhanced for treated fibre and impact strength were improved for untreated fibre
Easwara Prasad et al [4]	Sisal	Polyester resin	Sodium hydroxide at 5%, cobalt napthanate as curing agent and methyl ethyle ketone peroxide as catalyst	Untreated fibre - 3.581 N/m and treated Fibre - 1.962 N/m (at 30% fibre volume fraction)	-	-	5% NaOH for 24hr treatment was not sufficient for improving impact strength
William Jordan and Patrick Chester [5]	Banana	Low density polythene composite	Dicumyl peroxide and potassium permanganate acetone	-	Untreated 21.99 ± 0.96 (at 20% fibre volume fraction) and treated 19.05 ± 0.40	Untreated 13.16 ± 0.40 (at 20% fibre volume fraction) and treated 12.92 ± 0.27	Peroxide treatment had little advantage whereas permanganate treatment has very less advantage
Benyahia et al [7]	Alfa	Isophthalic polyester	Sodium hyroxide at 7%	-	Treated - 33.12	Treated- 25.11	With NaOH at 7% there was increase in tensile and flexure strength
Mimi Azlina Abu Bakar et al [8]	Kenaf	Epoxy	Sodium Hydroxide at 4%	5.12 kJ/m^2	Treated 4.2 GPa (at 25% fibre volume)	-	Overall improvement of mechanical properties specially in flexural strength
Somashekar and Shanthakumar [9]	Sisal	Epoxy (Lapox-12)	Sodium hyroxide at 5% for 2hrs	Untreated 148.94 J/m (at 20% fibre volume)	Treated 62.677 MPa (at 20% fibre volume)	Treated 42.29 MPa (at 20% fibre	Flexural can be further improved and properties can be changed by careful design of composite

						volume)	
Rajasekran and Gokul [10]	Sugarcane	Polyester	4% Sodium hyroxide and 3% HCL	-	-	Untreated 9.671 Treated with NaoOH 45.502 and treated with HCL -23.829	NaOH treated fibre gives better results and sugarcane fibre is competetive to synthetic fibres
Jai InderPreet Singh et al [11]	Jute	Epoxy	5% w/w NaOH concentration	76 for treated jute fibre	87 MPa for non-treated jute	Treated jute fibre tensile 431 MPa	Impact strength decreases with NaOH treatment
Mansour Rokbi et al [12]	Alfa	Isophthalic polyester	NaOH at 1,5, 10% for 0, 24, 48 hr at 28°C	-	23 MPa to 57 MPa flexural Modulus for 24 hrs	-	When treatment was done for 48 hours the flexure properties decreases
Oushabi et al [14]	Palm	Polyurethane	NaOH (0, 2, 5, 10 wt%)	-	-	460 MPa	Alkalai treatment removes the dirt, impurities and improves thermal resistance
Ridzuan et al [15]	Napier Grass	-	10% NaOH for 6hr	-	-	94 to 96 MPa for 6,12,24 hrs	The alkaline treatment was found to improve tensile strength

3. RESULTS AND DISCUSSION

The natural fibre composites showed the great potential to replace the synthetic fibres and the previous researches on the fibres still have the area for improvement by changing the fabrication methods and composition of fibre and matrix. The alkaline treatment on the napier grass which is a green fibre got its tensile strength increased by 10% NaOH treatment for 6 hours. For the alfa fibre when the treatment is increased for the period more than 48 hours the flexural properties of the fibre decreased. The sisal fibre showed the highest 930 MPa to 911 MPa that has the greater potential to use in products which requires higher strength and even the flexural strength also got increased with treatment with sodium hydroxide. The jute fibre had favourable tensile strength of 431 MPa which is promising for the composite mixture. The sodium hydroxide treatment more than 48 hours decreased the flexural properties. The banana fibre with with peroxide treatment had little advantage and the potassium permanganate had none and is expected to improve by pretreatment. Overall put together the jute, sisal and kenaf fibre showed the favourable properties for the future applications and can be improved by futher treatment in future.

4. CONCLUSIONS

The various studies carried out on the effect of chemical treatments on mechanical properties and surface topographies of the different natural fibre composites have been reviewed and investigated. It is inferred that natural fibre composite is still a potential area of research that requires further improvement in mechanical properties for usage in industrial, domestic and automobile fields. Based on this study, the following observations have been made:

- It is noted that treatment of natural fibre composites are mostly done by sodium hydroxide which do not improve impact strength of natural fibres. Also additional investigations can be attempted to increase the mechanical properties of natural fibre composites so that to use them as alternate to synthetic fibres.
- The fabrication and treatment of natural fibre composite takes longer period of time which possibly can be reduced by further research to find alternative chemical for treatment.
- Research can be done further to find pretreatment methods to enhance the treatment from sodium hydroxide either by altering the composition of fibre to matrix ratio or by fabrication method.
- The surface cleaning by treatment improves the thermal resistance and which can be possibly improved by changing the composition of treatment chemical. Since improvement in thermal resistance can be major breakthrough for natural fibre composite to increase their applications.

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