

EFFECTS OF NATURAL FIBRE SURFACE ON COMPOSITE PROPERTIES: A REVIEW

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Abstract: Processing of polymer composites by using green source of fibres as reinforcement has increased dramatically in recent years. Advantages of using natural fibre over man-made fibres include low density, low cost, recyclability and biodegradability. These benchmark properties make natural fibre a potential replacement for synthetic fibres in composite materials opening up further industrial possibilities. However, high level of moisture absorption by the fibre leads to poor wettability and insufficient adhesion within the matrix (interfacial adhesion) resulting degradation of composite properties. These properties hinder the potential of these fibres in providing successful reinforcement for polymer composites. In order to expand the use of natural fibres as successful reinforcement in polymer composites the fibre surface needs to be modified to enhance fibre-matrix adhesion. In this review paper, effects of natural fibre surface on composite properties are discussed. Several fibre surface modification methods are reported and their effects on composite properties are analysed. These properties constitute the prime area of research in developing green fibre polymer composite technologies.

Key words: Natural fibre, surface modification, composite properties.

1 INTRODUCTION

Increasing environmental awareness throughout the world has prompted design of materials that are compatible with the environment. Currently, synthetic fibres such as glass, carbon and aramid are being widely used in polymer composites because of their high stiffness and strength properties (Rout, Misra, Tripathy, Nayak, & Mohanty, 2001). However, these fibres have serious drawbacks in terms of biodegradability, initial processing cost, recyclability, energy consumption, machine abrasion, health hazards etc. (Bledzki & Gassan, 1999). Despite this, most significantly, adverse environmental impact alters attention from synthetic fibre to natural fibres. Introduction of biofibres such as natural fibres from annually renewable resources are gaining interest to be used as reinforcement in polymer composites to provide benefits to the environment with respect to the degradability and utilization of renewable materials (Rout et al., 2001).

Natural fibre such as flax, hemp, jute coir etc. based polymer composites form a new class of materials which have good potential to be used in polymer composites in many applications. The attractive features of these fibres are light weight, high specific modulus, non-toxicity, friendly processing and absorbed CO₂ during their growth (Abdelmouleh, Boufis, Belgacem, & Dufresne, 2007; Tserki, Zafeiropoulos, Simon, & Panayiotou, 2005). These benchmark properties open the wide area for natural fibres to be used in composite sector with consequences for the partial replacement of traditional synthetic fibres. However, these green sources of fibres are not problem free. Their structural compositions (such as cellulose, hemicelluloses, lignin, pectin and waxy substances) allow moisture absorption from the environment which leads to poor bonding with the matrix materials (Doan, Gao, & Mader, 2006). Certain chemical treatment on natural fibres is needed to enhance the performance as reinforcement in polymer composite materials. The chemical modification directly influences the fibres structures and changes their compositions. As a result, moisture absorption tendency by the fibre is reduced facilitating better bonding with the matrix materials. This provides better mechanical and thermal properties of fibre and composites (Abdelmouleh et al., 2007). For fabrication of composites, different orientation of fibres such as short-randomly oriented, long-unidirectional and woven fabrics were used and their composites mechanical and thermal properties have

been investigated by several researchers. Many academic and industrial research activities are ongoing to develop better fibre-matrix adhesion characteristics of the composites by using different chemical treatment, orientation of fibres and manufacturing methods.

The objective of this study is to review the reported works on various aspects of natural fibre and its composites and some of the basic issues in the arena of fibre matrix adhesion and the properties of composites.

2 NATURAL FIBRE COMPOSITE

In general, a composite is a material mixture created by synthetic/natural assembly of two or more physically and chemically distinct components, a selected filler or reinforcing agent (discontinuous phase) and a compatible matrix binder (continuous phase) in order to obtain specific characteristics and properties (Bledzki & Gassan, 1999). In natural fibre composites, natural fibres are used as reinforcement and binder material are polymeric. Different types of natural fibres, matrix and processing techniques are used for composite fabrication.

2.1 Natural Fibre

The most important types of reinforcing natural fibres are flax, hemp and jute due to their specific strength, modulus properties and availabilities. These fibres are plant based which are lignocellulosic in nature and composed of cellulose, hemicelluloses, lignin, pectin and waxy substances (Mohanty, Misra, & Hinrichsen, 2000). Proportions of structural composition of natural fibres are given in Tab. 01. Cellulose gives the strength, stiffness and structural stability of the fibre, and are the major framework components of the fibre (Leonard & Martin, 2002). According to the type of fibre, cellulose has its own cell geometry which is responsible for the determination of mechanical properties of plant fibres. Hemicelluloses occur mainly in the primary cell wall and have branched polymers carbon sugars with varied chemical structure. Lignin is amorphous and has an aromatic structure (Fakirov & Bhattacharya, 2007). Pectin structure is complex, their side chains are often cross-linked with the calcium ions and arabinose sugars. The lignin, hemicelluloses and pectin provides the adhesive to hold the cellulose framework structure of the fibre together. Natural fibres also composed of a small amount of organic (extractives) and inorganic (ash) components. Organic extractives are responsible for the colour, odour and decay resistance, and inorganic matters enhance abrasive nature of the fibre (Saheb & Jog, 1999).

TABLE 01: Structural composition and structural parameters of some natural fibres (Mohanty et al., 2000; Fakirov, 2007).

Fibres	Cellulose (wt%)	Lignin (wt%)	Hemicellulose (wt%)	Pectin (wt%)	Wax (wt%)	Micro-fibrillar/spiral angle (°)	Moisture Content (wt%)
Jute	61-71.5	12-13	13.6-20.4	0.2	0.5	8.0	12.6
Flax	71	2.2	18.6-20.6	2.3	1.7	10.0	10.0
Hemp	70.2-74.4	3.7-5.7	17.9-22.4	0.9	0.8	6.2	10.8

TABLE 02: Comparative properties of natural fibres with conventional manmade fibres (Mohanty et al., 2000; Dhakal et al., 2007).

Fibres	Density (g/cm ³)	Tensile Strength (MPa)	Young`s modulus (GPa)	Elongation at break (%)	Specific modulus (GPa/g/cc)
Jute	1.3-1.45	393-773	13-26.5	1.16-1.5	10-18.2
Flax	1.50	345-1100	27.6	2.7-3.2	18.4
Hemp	1.14	690	30-60	1.6	26-52
E-glass	2.5	2000-3500	70	2.5	28

The mechanical properties of natural fibres compared to synthetic fibre are presented in Tab. 02. Although natural fibres have relatively poor strength properties compare to synthetic fibres but specific modulus and elongation at break in a point are determining the potential of natural fibres as replacement or partial replacement forsynthetic fibres in fibre composites. Generally, fibres with high crystallinity and/or cellulose content, higher length-to-diameter (aspect) ratio and lower microfibrillar angle have been found to possess superior mechanical properties (Leonard & Ansell, 1999). From Tab. 01 & 02 it can be concluded that, hemp fibres have better properties over other fibres.

2.2 Matrix

Matrix is a binder material that holds the fibres in position and transfer the external load to the reinforcement. In natural fibre reinforced polymer composites, both thermoset and thermoplastic matrix are widely being used. The unsaturated polyesters, epoxy and phenolic resin are extensively utilized for the thermosets and polypropylenes, polyethylenes and elastomers are widely used for thermoplastic matrix (Joseph, 2001; Pickering, Li, Farrell, & Lay, 2007). Tab. 03 presents the comparison of thermoset and thermoplastic matrix.

2.3 Processing Techniques

In principle, processing techniques for natural fibre composites are similar to those of the synthetic fibres. According to the length, orientation and type of the reinforcing fibre, randomly oriented (short), unidirectional (raw and carded) fibre and woven fabric are used as reinforcement to incorporate into the thermoset and thermoplastic resin. For thermoset composites the most basic fabrication method is hand layup, which is the manual mixing procedure between the fibre and resin. In this process, uniformity of the composite in terms of thickness, fibre to resin ratio and void content throughout the sample depends on the manual skill (Pickering et al., 2007). On the other hand, vacuum assisted resin transfer moulding have been widely used for composite fabrication. In this process thermoset resin is used to pull inwards under the vacuum pressure and mix with the fibre. Due to this, better chance of mixing between the fibre and resin can be achieved and more precise fibre spacing with uniformity in thickness of the final composite obtained. It facilitates the utilization of maximum fibre content with significantly lower percentage of void constituents compared to the hand lay-up process (Pickering et al., 2007). Another method, namely pultrusion, is used for both thermoset and thermoplastic matrix. Composite profile is produced by pulling the

reinforcement through a heated die and mixed with resin. For thermoplastic matrix compression molding (reinforcement mixed with resin and pressed with heated plate) and injection molding (fibre-resin are added as granulate to the machine and melted into fluid mass, then injected under high pressure into the form) are widely used for composite fabrication (Adekunle, Akesson, & Skrifvars, 2010). This process involves high temperature (over 200°C) and pressure (5 MPa) for complete reaction between fibre and matrix.

3 FACTOR EFFECTING COMPOSITE PROPERTES

Natural fibres have some problems that cause adverse affects on composite properties. As theses fibres consists of different chemical constituents in their structure and undergo different reactivity with the environment and matrix during processing. The following are the major issues which need to be addressed during fabrication of composite materials.

3.1 Plant Fibre Structure

Cellulose structure is composed of crystalline and amorphous regions. Fig. 01 presents the schematic view of secondary layer of fibre cell wall in which crystalline and amorphous regions are indicated. Strong intra-molecular hydrogen bonds with large molecules are formed by the crystallite cellulose. Compactness of crystalline region creates cellulose blocks that makes it difficult for chemical penetration to occur. However, dyes and resins are absorbed by amorphous region easily. In addition to this, plant fibres are highly polar and hydrophilic in character as hydroxyl groups are present in their structures. For distension of crystalline region, elimination of hydrophilic hydroxyl groups and removal of surface impurities (waxy substances), natural fibres need to be chemically modified. Chemical treatments such as mercerization, silane, acetylation, benzylation treatment etc. with or without heat are widely being applied to modify fibre chemistry (Abdelmouleh et al., 2007; Leonard & Martin, 2002; & Leonard & Ansell, 1999).

3.2 Thermal Stability of Fibres

The natural fibre starts degrading at about 240°C. Structural constituents of the fibre (cellulose, hemicelluloses, lignin etc) are sensitive to the different range of temperatures. It was reported that, lignin starts degrading at a temperature around 200°C and hemicelluloses and cellulosic constituents degrade at higher temperatures (Joseph, 2001). Thermal stability can be enhanced by removing certain proportion of hemicelluloses and lignin constituents

TABLE 03: Comparison of thermoplastic and thermoset matrix.

	Advantages	Disadvantages
Thermoset	<ul style="list-style-type: none"> Low resin viscosity Good fibre wetting Excellent thermal stability once polymerised Chemically resistant 	<ul style="list-style-type: none"> Brittle Non-recyclable via standard techniques Not post-formable
Thermoplastic	<ul style="list-style-type: none"> Recyclable Easy to repair by welding and solvent bonding Post formable Tough 	<ul style="list-style-type: none"> Poor melt flow Need to be heated above the melting point for processing purposes.

from the fibre by different chemical treatment. The degradation of natural fibre is an important issue in the development of natural fibre composites in both composite manufacturing (curing, extrusion or injection moulding) and materials in service (Sgriecia, Hawley, & Misra, 2008; Taj, Munawar, & Khan, 2007).

3.3 Fibre Length, Loading and Orientation

The properties of fibre reinforced polymer composites depend on the fibre length, percentage of fibre volume/loading, distribution and orientation into the matrix. When load is applied to the matrix, stress transfer occurs by shear at both the interface along the fibre length and at the ends of the fibre. The extent of load transmitted to the fibre is a function of critical fibre length (aspect ratio), direction and orientation of fibres relative to each other and the compatibility between fibre-matrix interfaces. Depending upon the orientation of fibre at the matrix, three types of fibre reinforcement can be obtained. Firstly, longitudinally aligned fibrous composites generally have higher tensile strength but lower compressive strength due to the fibre buckling. Secondly, in the transverse direction a fibre supports very low tensile stress, which is lower than the strength of the matrix. Finally, for the randomly oriented short fibre composites, prediction of mechanical property is far more difficult, because of the fibre dispersion, orientation and complexities for the load distribution along the fibre matrix interface. By controlling factors such as aspect ratio, the dispersion and orientation of fibres, considerable improvements in composites property can be accomplished (Fakirov, 2007; Leonard & Ansell, 1999; Joseph, 2001).

3.4 Presence of Voids

During the introduction of fibre into the matrix, air or other volatile substances may be trapped in the material. After curing microvoids may form in the composite along the individual fibres due to the fibre spacing and between the laminate and in the resin rich regions, which has the adverse effect on the mechanical properties of the composites. Curing and cooling rate of the resin can also responsible for void formation (Joseph, 2001). Higher void content (over 20% by volume) is responsible for the lower fatigue resistance, greater affinity to water diffusion and increase variation (scatter) in mechanical properties (Kenneth, 1992; Vaxman, Narkis, Siegmann, & Kenig, 2004). Composites at higher fibre content usually display more void formation (Vaxman et al., 2004).

3.5 Moisture Absorption of Fibres

The lignocellulosic fibres are hydrophilic and absorb moisture. There is a large amount of hydrogen bonds (hydroxyl groups -OH) presents between the macromolecules in the plant fibre cell wall. When moisture from the atmosphere comes in contact with the

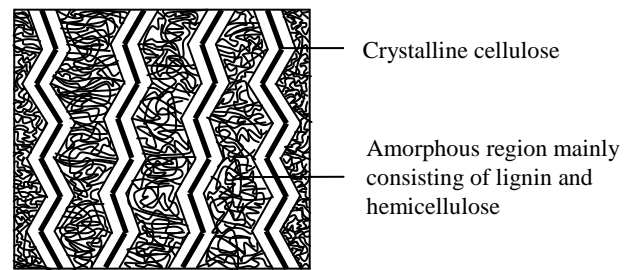


FIGURE 01: Schematic view of secondary layer of fibre cell wall (Bledzki & Gassan, 1999).

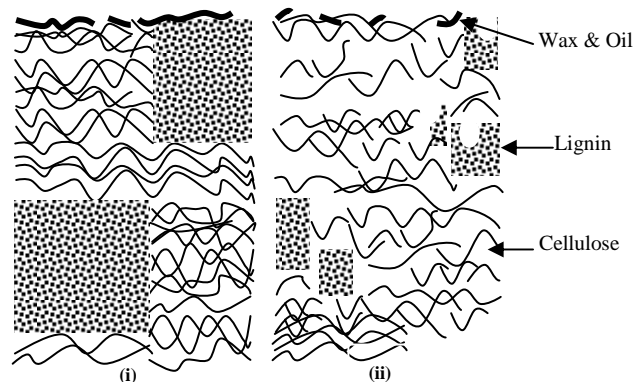


FIGURE 02: Typical structure of (i) untreated and (ii) alkali cellulose fibre (Leonard & Martin, 2002).

fibre, the hydrogen bond breaks and hydroxyl groups form new hydrogen bonds with water molecules. The cross-section of the fibre becomes the main access to the penetrating water. As a result, when hydrophilic fibre is reinforced with hydrophobic resin fibre swelling within the matrix occurs. This causes weak bonding between fibre and matrix, dimensional instability, matrix cracking and poor mechanical properties of the composites (Sarani & Poh, 2002).

Therefore the removal of moisture from fibres is an essential step before the preparation of composites. The moisture absorption of natural fibres can be reduced by different chemical treatment such as alkali, silane, acetylation, benzoylation and peroxide treatment on the fibre surface to remove hydrophilic hydroxyl bonds (Wang, Panigrahi, Tabil, & Crerar, 2007).

4 SURFACE MODIFICATION OF NATURAL FIBRES

The fibre-matrix interface is the diffusion or reaction zone, in which fibre and matrix phases are chemically and/or mechanically combined. Interfacial adhesion between fibre and matrix plays a predominant part in characterizing the mechanical properties of the composites. If there is a poor adhesion across the phase boundary, then relatively weak dispersion of force occurs and resulting poor mechanical properties of the composite (Wang et al., 2007). For reinforcement of natural fibre in composites, several problems occur along the interface due to the presence of hydrophilic hydroxyl groups on the fibre surface. This hydrophilic nature hinders effective reaction with the matrix. In addition to this, pectin and waxy substance covers the reactive functional groups of the fibre and act as a barrier to interlocking with the matrix. To optimize effective interfacial bonding between fibre and matrix, the fibre surface needs to be modified with different chemical treatment, reactive additives and coupling agents. Chemical treatments expose more reactive groups on the fibre surface and thus facilitate efficient coupling with the matrix. As a result, better mechanical and thermal properties of the composites can be achieved (Dash et al., 2000).

TABLE 04: Recent works on alkali treated fibre reinforced polymer composites.

Fibre composites	matrix	Applied treatment methods	Results on mechanical and thermal properties	References
Flax-Epoxy		Alkali treatment	30% increased in tensile strength and modulus with the removal of pectin.	(Xue et al., 2007)
Sisal-Polyester		0.5%, 1%, 2%, 4%, 10% NaOH treatment at room temperature	4% alkali treatment reported maximum tensile strength properties.	(Xue et al., 2007)
Hemp non-woven mat with Euphorbia resin		0.16% NaOH for 48hrs	Tensile strength was increased by 30% and doubled the shear strength properties was found compared to the untreated fibre composites.	(Leonard et al., 2007)
Jute-Vinylester		5% NaOH for 4, 6 and 8hrs	4h alkali treated composite accounted 20% and 19% increased in flexural strength and interlaminar shear strength properties.	(Dipa et al., 2001)
Sisal-Polycaprolactone		10% NaOH for 1, 3, 24 and 48hrs	Increased in elastic modulus with the increased with reaction time.	(Viviana et al., 2004)
Hemp fibre		8% NaOH treatment	Thermal stability was increased by 4%.	(Ouajai & Shanks, 2005)
Coir-Polyester		5% NaOH treatment for 72hrs	Flexural and impact strength was increased by 40% with respect to the untreated fibre composites.	(Prasad et al., 1983)

4.1 Physical Methods

Physical methods involve stretching, calendaring, thermo-treatments, hybrid yarn, cold plasma treatment, electric discharge method etc. on the fibre that do not make changes on the structural composition but modify the surface properties. These influence good mechanical bonding with the matrix and enhance composite properties (Abdelmouleh et al., 2007).

4.2 Chemical Methods

Most of the problems in natural fibre composite originate from the hydrophilic nature of the fibre and hydrophobic nature of the matrix. As a result, there is an inherent incompatibility between fibre and matrix. Chemical treatment on reinforcing fibre can reduce hydrophilic tendency and thus improve compatibility with the matrix. Several research activities have been conducted to improve fibre properties through different chemical treatments and their effects on composites properties. The following reviews the different treatment methods and their effects on the properties of fibres and composites.

4.2.1 Alkaline Treatment

Treatment on natural fibre by NaOH is widely used for both thermoset and thermoplastic composites. This treatment changes the orientation of highly packed crystalline cellulose order and forms amorphous region by swelling the fibre cell wall. This provides more access to penetration of chemicals. Alkali sensitive hydrogen bonds existing among the fibres break down and new reactive hydrogen bonds form between the cellulose molecular chains. Due to this, hydrophilic hydroxyl groups are partially removed and moisture resistance property is improved. It also takes out certain portion of hemicelluloses, lignin, pectin, wax and oil covering materials (Xue, Lope, & Satyanarayan, 2007; Leonard et al., 2007, Dipa, Sarkar, Rana, & Bose, 2001). As a result, the fibre surface become cleaner. In other words, fibre surface become more uniform due to the elimination of micro voids and thus stress transfer capacity between the ultimate cells improves. In addition to this it reduces fibre diameter and thereby increase aspect ratio, which results in better fibre matrix interfacial adhesion (Joseph, 2001). Composite properties such as mechanical and thermal behaviour can be improved significantly by this treatment. If the alkali concentration is higher than the optimum condition, excess delignification of fibre take place, which results in weakness or damage to the fibre (Wang et al., 2007; Xue et al., 2007). Fig. 02

presents the schematic view of cellulose fibre structure, before and after alkali treatment. Treated fibres have lower lignin content, partial removal of wax and oil cover materials and distension of crystalline cellulose order. Tab. 04 summarizes the recent results on the effect of alkali treatment on composites mechanical and thermal properties.

4.2.2 Silane Treatment

Silane is used as coupling agents to modify fibre surface. It undergoes several stages of hydrolysis, condensation and bond formation during the treatment process with the fibre. Silanols forms in the presence of moisture and hydrolysable alkoxy groups. It reacts with cellulose hydroxyl group of the fibre and improves fibre matrix adhesion to stabilize composite properties (Xue et al., 2007). The chemical composition of silane coupling agents (bifunctional siloxane molecules) allows forming a chemical link between the surface of the cellulose fibre and the resin through a siloxane bridge. This co-reactivity provides molecular continuity across the interface region of the composite. It also provides the hydrocarbon chains that restrains fibre swelling into the matrix (Wang et al., 2007; George, Sreekala, & Thomas, 2001). Natural fibres exhibit micropores on their surfaces and silane coupling agent act as a surface coating which penetrates into the pores and develop mechanically interlocked coating on their surface. Silane treated fibre reinforced composite provides better tensile strength properties than the alkaline treated fibre composites (Valadez-Gonzalez, Cervantes-Uc, Olayo, & Herrera-Franco, 1999). Seki (2009) investigated the effect of alkali (5% NaOH for 2hrs) and silane (1% oligomeric siloxane with 96% alcohol solution for 1 hr) treatment on the flexural properties of jute epoxy and jute polyester composites. For jute epoxy composites alkali over silane treatment resulted in about 12% and 7% higher strength and modulus properties compared to the alkali treatment alone. Similar treatment led to around 20% and 8% improvement for jute polyester composites. Sever, Sarikanat, Seki, Erkan, and Erdog (2010) applied different concentration of (0.1%, 0.3% and 0.5%) silane (γ -Methacryloxypropyltrimethoxysilane) treatment on jute fabrics polyester composites. Tensile, flexural and interlaminar shear strength properties were investigated and compared with untreated composites. The results for 0.3% silane treated composites showed around 40%, 30% and 55% improvement in tensile, flexural and interlaminar shear strength respectively.

4.2.3 Acetylation Treatment

Acetylation treatment on natural fibre is generally known as esterification method for plasticizing of cellulose fibres. Fibres are acetylated with and without an acid catalyst to graft acetyl groups onto the cellulose structure. It reacts with the hydrophilic hydroxyl groups and swells the fibre cell wall. As a result, the hydrophilic nature of the fibre decreases leading to improvement in dimensional stability of the composites (Sreekala, Kumaran, Joseph, & Jacob, 2000). In general, acetic acid and acetic anhydride individually do not react sufficiently with cellulosic fibres. For this, to accelerate the reaction, fibres are initially soaked in acetic acid and consequently treated with acetic anhydride between the time periods of 1 to 3 hours with higher temperature. Moreover, this treatment provides rough surface topography with less number of void contents that give better mechanical interlocking with the matrix (Tserki et al., 2005, Xue et al., 2007). Rowell, Young, and Rowell (2000) investigated acetic anhydride treatment on several types of cellulosic fibres to analyse the effects of equilibrium moisture content and reported that, this treatment improved moisture resistance properties. This was due to the removal of hemicellulose and lignin constituents from the treated fibre. Mishra et al. (2003) used acetic anhydride treatment on alkali pre-treated (5% and 10% NaOH solution for 1h at 300C) dewaxed sisal fibre with glacial acetic acid and sulphuric acid, and reported, improved fibre matrix adhesion characteristics of the composites. Bledzki, Mamun, Lucka-Gabor, and Gutowski (2008) studied different concentration of acetylation treatment on flax fibres and reported 50% higher thermal properties. Moreover, 18% acetylated flax fibre polypropylene composites showed around 25% increase in tensile and flexural properties compared to the untreated fibre composites.

4.2.4 Benzoylation Treatment

Benzoylation treatment uses benzoyl chloride to decrease the hydrophilicity of the fibre and improve fibre matrix adhesion, thereby increasing the strength of the composite. It also enhances thermal stability of the fibre (Manikandan, Thomas, & Groeninckx, 2001; Xue et al., 2007). During benzoylation treatment alkali pre-treatment is used to activate the hydroxyl groups of the fibre. Then the fibre is soaked in benzoyl chloride solution for 15mins. Afterwards ethanol solution is used for 1h to remove benzoyl chloride that adhered to the fibre surface followed by washing with water and oven dried. Joseph et al. (1996) implied benzoyl chloride treatment on alkali pre-treated sisal fibre and reported higher thermal stability compared to the untreated fibre composites. Similar treatment was carried out on flax fibre reinforced low density polyethylene composites by Wang et al. (2007) and reported 6% and 33% improvement on tensile strength and moisture resistance properties.

4.2.5 Peroxide Treatment

Interface properties of fibre and matrix can be improved by peroxide treatment. The peroxide-induced grafting of polyethylene adheres onto the fibre surface and the peroxide initiated free radicals react with the hydroxyl group of the fibre and matrix. As a result, good fibre matrix adhesion occurs. This treatment also reduced moisture absorption tendency by the fibre and improves thermal stability (Wang et al., 2007; Kalaprasad et al., 2004). Sapiha, Allard, and Zang, (1990) reported that, treatment with benzoyl peroxide or dicumyl peroxide of the cellulosic fibre led to higher mechanical properties of composites. The mechanism of peroxide treatment involves alkali pre-treatment on the fibres then coated with benzoyl peroxide or dicumyl peroxide (around 6% concentration) in the acetone solution for 30 mins. Complete decomposition of peroxide can be achieved by heating the solution

at higher temperature (Xue et al., 2007, Kalaprasad et al., 2004). Joseph, Thomas, and Pavithran (1996) investigated optimum concentration of benzoyl peroxide (6%) and dicumyl peroxide (4%) treatment on short sisal fibre-reinforced polyethylene composites and reported improved tensile strength.

5 CONCLUSIONS

Natural fibres are gaining interest as reinforcement for polymer composites due to their potential mechanical properties, processing advantages, environmental and economic benefits. The performance of natural fibre-reinforced composite can be affected by many factors. Surface treatment is essential to reduce hydrophilicity of natural fibres, therefore increase their adhesion with hydrophobic matrix. Chemical surface treatments include alkalization, silane, acetylation, belozoylation and peroxide treatment. These treatments modify the structural constituents and surface morphology of the natural fibre. Significant improvements in mechanical properties and thermal stability have resulted from these surface treatments. As a result, introduction of natural fibres from renewable resources for structural composites can offer acceptable properties and provides benefits to the environment by replacing synthetic fibres according to the applications.

6 ACKNOWLEDGEMENTS

The authors gratefully acknowledges to Dr. Mainul Islam for providing helpful suggestions regarding this study.

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