Influence of Chemical Treatment on Natural Fibers: A Review

G. Venkatakoteswara Rao, R. Vinayagamoorthy, K. Abinesh, M. Sudharsan, S. Ponmeganathan, and L. S. Deepak Kumar

Abstract Natural fiber composites are proven to be biodegradable nowadays and are applicable to several sectors. Many natural fibers are used as reinforcements in polymeric composites with and without pretreatments. Many studies have reported that the chemical pretreatment to natural fibers enhance the surface properties of the fibers and which in turn improves the strength of the composite. Though there are several treatment techniques, sodium hydroxide is majorly used as the chemical for treating the fiber. Apart from this, there are several other treatments namely benzoylation, peroxidation, silane treatment, etc. The present study gives a clear picture of various chemical pretreatments given to the natural fibers and their processing methodologies. These treatments are bond between reinforcement surface and also increases its strengthening mechanism.

Keywords Natural reinforcements · Compound treatments

1 Introduction

Natural fibres like hemp, sisal, flax, kenaf, and jute are extremely hydrophilic because of the presence of hydroxyl group teams (OH) of anhydroglucose repetition unit in polysaccharide structure. However, these fibres are coated with cellulose and waxy materials, thus hindering the hydroxyl group teams from reacting with chemical compound matrices. This will result in the formation of ineffective interfaces between the fibres and matrices, with resultant problems like debonding and voids in ensuing composites [1–5]. Chemical treatments provide a vital and effective means that to get rid of non-cellulosic elements in cellulose fibres and add practical teams to change higher bonding in chemical compound composites. Additionally, treatment will alter the crystalline structure of the polysaccharide as well as fibre tensile properties [6–12]. The main disadvantage of victimization fibres in chemical

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compound composites is that the incompatibility between natural fibre and chemical compound matrix because of the nearness of compound components (e.g., cellulose, lignin, hemicellulose, and wax substances). The natural fibers having various properties like biodegradable are comfortable to wear and not harmful for environment. Advantages of common fibers over counterfeit fibers embody tenuity, minimal effort, recyclability, and biodegradability [6, 13–17]. These benefits build characteristic fibers potential swap for glass fibers in composite materials. Mechanical properties of normal fibers, especially flax, hemp, jute, and sisal, are super band which should contend with glass fiber in specific quality and modulus. Table 1 records the mechanical properties of some common and fake fibers. Fiber reinforced composites are utilized as a replacement for plastics and hence they are used for several applications. They are made by reinforcing fibers inside the matrix element and are known to be fibre-strengthened composites. The pieces of normal fibers embody polyose, hemicelluloses, lignin, gelatin, waxes, and water solvent substances [6, 18–23].

2 Chemical Treatments

2.1 Alkaline Treatment

The treatment on regular filaments by sodium hydroxide (NaOH) is as a rule broadly used to alter fiber structure. Characteristic fiber assimilates dampness because of the nearness of hydroxyl bunches in the nebulous district of cellulose, hemicellulose, and lignin constituents. Amid soluble base treatment, alkalized gatherings (NaO–H) respond with these hydroxyl bunches (−OH) of the fiber and produce water particles (H–OH) which are therefore expelled from the fiber structure. At that point, the remaining alkalized gatherings (Na–O^-) respond with the fiber cell divider and produce fiber-cell-O–Na gatherings. Therefore, cellulose microfibrils are presented to the fiber surface. Thusly, treatment changes the introduction of the exceptionally stuffed crystalline cellulose request, shaping a formless region. Alkaline treatment additionally isolates the basic strands from their fiber packages by evacuating the covering materials, hence expanding the powerful surface zone of fiber for framework bond and improving the fiber scattering inside the composite. Treated fiber surfaces become rougher, which can additionally improve fiber-grid attachment by giving extra fiber locales to mechanical interlocking [1–6].

$$\text{Fiber} - \text{OH} + \text{NaOH} \rightarrow \text{fiber}-\text{O} - \text{Na} + \text{H}_2\text{O} \quad (1)$$

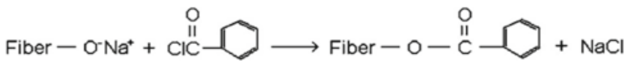
2.2 Acetylation Treatment

Strands are acetylated with and without a corrosive impetus to join the acetyl bunches onto the cellulose surface. By and large, acidic corrosive does not respond adequately with the filaments. Subsequently, it is important to go through an impetus to speed the acetylation procedure. Acidic anhydrides, pyridine, sulphuric corrosive, potassium and sodium acetic acid derivation, and so forth are generally utilized impetuses for acetylation process. Be that as it may, solid corrosive impetuses cause hydrolysis of cellulose which results in the harming of the fiber structure. For this, choice of impetus is an imperative factor for the acetyl treatment. The acetylation process is additionally affected by the response time. Longer response time permits acidic anhydride to get to fiber constituents. The reagent at that point responds with hemicellulose and lignin constituents and expels them from the fiber, bringing about the opening of cellulose surface to permit response with the lattice atoms [1–6].

$$\begin{aligned} &\text{Fiber} - \text{OH} + \text{CH}_3{-}\text{C}(=\text{O}){-}\text{O}{-}\text{C}(=\text{O}) \\ &- \text{CH}_{3x} \rightarrow \text{Fiber} - \text{OCOCH}_3 + \text{CH}_3\text{COOH} \end{aligned} \quad (2)$$

2.3 Benzoylation Treatment

Benzoyl treatment utilizes benzoyl chloride to diminish the hydrophilic idea of the fiber and improves interfacial grip, in this manner expanding the quality of the composite. Treatment likewise improves the warm security of the fiber. Amid this treatment, extractable materials, for example, lignin, waxes, and oil covering materials, are expelled from the fiber and more hydroxyl bunches (−OH) connected with cellulose are uncovered on the fiber surface. At that point, the filaments are treated with benzoyl chloride. Gracious gatherings of the fiber are additionally supplanted by the benzoyl gathering, and it connects to the cellulose spine. These outcomes in a progressively hydrophobic nature of the fiber and improves bond with the framework [1–6].



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2.4 Peroxide Treatment

Interface properties of fiber and lattice can be improved by peroxide treatment. The peroxide-incited uniting of polyethylene holds fast to the fiber surface. Moreover, peroxide starts free radicals that respond with the cellulose surface of the fiber too similarly as with the framework. Therefore, great fiber network attachment along the interface happens. This treatment additionally lessens the dampness ingestion limit of the fiber and improves warm soundness [1–6].

$$RO{-}OR \rightarrow 2RO \tag{4}$$

$$RO + PE - H \rightarrow ROH + PE \tag{5}$$

$$RO + Cellulose{-}H \rightarrow ROH + Cellulose \tag{6}$$

$$PE + Cellulose \rightarrow PE{-}Cellulose. \tag{7}$$

2.5 Silane Treatment

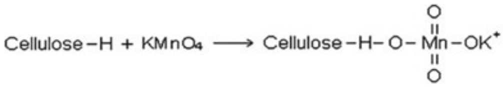
Silane is a multifunctional particle which is utilized as a coupling specialist to alter fiber surfaces. Silane particles structure a substance interface between the fiber surface and the framework through a siloxane connect. Silane experiences a few phases of hydrolysis, buildup, and bond development amid the treatment procedure of the fiber. Silane frames silanols within the sight of fiber dampness. This coreactivity gives subatomic progression over the interface of the composite. It likewise gives the hydrocarbon chain that limits the fiber swelling into the network. Amid the silane treatment, hydroxyl bunches on the fiber surface are secured by silane atoms. Because of this, hydroxyl bunches that presents in hemicellulose and lignin constituents cannot assimilate the air dampness. Accordingly, dampness retention limit of the treated strands is decreased [1–6].

$$CH_2CHSi\ (OC_2H_5)_3 \xrightarrow{H_2O} CH_2CHSi(OH)_3 + 3C_2H_5OH \tag{8}$$

$$CH_2CHSi(OH)_3 + Fiber{-}OH \rightarrow CH_2CHSi(OH)_2O - Fiber + H_2O. \tag{9}$$

2.6 Permanganate Treatment

Permanganate treatment on regular filaments is led by potassium permanganate ($KMnO_4$) in $CH3)_2CO$ arrangement. This treatment shapes profoundly responsive permanganate particles (Mn3+) which respond with the cellulose (hydroxyl gatherings) and structure cellulose manganate and starts to join copolymerization. This treatment upgrades compound interlocking at the interface and furnishes better fiber attachment with the grid. Treatment likewise responds with the OH bunches in lignin and expels them from the fiber, and therefore, the hydrophilic idea of the fiber is diminished. Higher convergences of $KMnO_4$ (over 1%) cause overabundance delignification from the fiber structure and corrupt its qualities.[1–6].



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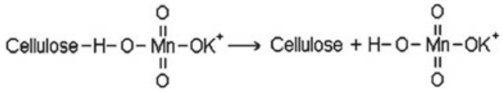

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3 Conclusion

Regular fibers are considered as potential trade for man-made fibers in composite materials. Albeit common fibers have points of interest of being ease and low thickness, they are not absolutely free of issues. A major issue of regular fibers is their solid polar character which makes inconsistency with most polymer lattices. Surface medications, in spite of the fact that negatively affecting financial aspects, are possibly ready to conquered the issue of contrariness. Synthetic medications can expand the interface attachment between the fiber and lattice and decline the water ingestion of fibers. Consequently, concoction medications can be considered in altering the properties of characteristic fibers. A few mixes are known to advance grip by artificially coupling the cement to the material, for example, sodium hydroxide, silane, acidic acid, and permanganate, peroxide, and so on. Fiber modification techniques examined in this paper have distinctive efficacy in causing grip between the lattice and the fiber. However, most compound medications have made different dimensions of progress in improving fiber quality, fiber fitness, and fiber–lattice bond in characteristic fiber-fortified composites.

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