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A Review on Property Reforms for Fiber Matrix Composites through Various Surface Treatment of Fibers

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Abstract : The primary factor that defines the final performance of any composite material is the fiber-matrix interface. Hence, efficient amount of adhesion is needed for full-fledged performance of composite materials. When fibers are used without surface modification, they tend to produce composites with low strength. This in turn leads to weak adhesion and poor bonding between the fiber and matrix. Hence, there is a massive apprehension to alter the surface of fibers through various procedures, in order to overcome their intrinsic downsides and effectively employ these materials in countless applications. This paper deals with a review of prevailing research studies fixated on the surface treatment of fibers.

Keywords-natural and synthetic fibers, mechanical, thermal and wear properties.

1. Introduction

Presently, an argument to reduce ecological pollution has augmented the human morality, in relation with the exact removal of waste materials. Specifically, there is a resolution to employ natural left-over resources as renewable means for number of applications. Consequently, in recent ages there has been a growth in the development of materials meeting international implications counting economic feasibility, practice, price and biological imprint. The material could be extensively used in packing business, aerospace, sports, construction, and particularly in the locomotive industry. The fiber proposed to enhance the bond, after chemical treatment, does not only alter the surface but also help in refining the strength for improved adhesion of the fiber with the polymer matrix.

This may lessen the water absorption of composites with upgrading in their mechanical, thermal and friction resistance properties.

2. Literature Review

A series of research has been done to understand the surface treatment of fibers and its effect on the properties of composite materials. Basak et al. [1]investigated that bleaching treatment with hydrogen peroxide improves physical appearance of jute fibers, chopped into short fibers of thickness and length ranging from 0.1 to 0.5 mm. The fibers are water-logged in a 15wt% aqueous hydrogen peroxide solution for nearly 2hrs at 60°C, then dried overnight at 80°C. Bleaching treatment improved the physical appearance of the fiber without any significant change in its properties. Silane-coupling agent 3-Amino propyl triethoxy silane (APTES) treatment at 30°C and 75°C enhanced the fracture toughness. Solvent intake also increased up to 35%.Chen et al. [2] has studied three chemical treatments including the use of 5% sodium hydroxide and 5% hydrogen peroxide (5%NaOH-5%H_2O_2), 10% NaOH and 20% acetic acid (10%NaOH-20%CH_3COOH), and 18% NaOH and 1.6% carbamide (18%NaOH-1.6%$CO(NH_2)_2$) to modify the LS fiber bundles and their effect on the micro/nano structures, moisture absorption and mechanical properties of LS fiber bundles was investigated by using (SEM), (TEM), (PLM), (FTIR), X-ray diffraction analysis, moisture regain (MR) and tensile strength test. The results showed that the treatment with 10%NaOH-20%CH_3COOH could significantly improve the mechanical properties of LS fiber bundles, the increase of the tensile strength was 121.3%. However, the treatment with 5%NaOH-5%H_2O_2 could sharply decrease the mechanical properties of fiber bundles, the reduction of the tensile strength was 75.0%. Furthermore, the treatment with all the three above mentioned chemical combinations could reduce the moisture absorption of LS fiber bundles. The decrease in the moisture regain was found to be 29.0%, 16.9%, and 12.4%, respectively. Bio-composites made of poly-lactic acid (PLA) matrix reinforced with cellulose fibers (CF) were prepared using a twin-screw extruder and injection molding by Hirofumi et al. [3]. The CFs were coated with epoxy-based surface treatment agents. Accelerated degradation tests were carried out on these PLA/CF composites at high

temperatures (60 °C) or at constanttemperature and constant humidity (60 °C/70%RH).

The higher order structure changes and degradation characteristics of molded products were evaluated. In the accelerated degradation test at 60 °C, thermal and mechanical properties of PLA/CF composites showed no degradation, whereas at 60 °C and 70% RH, the melting point decreased by 25 °C and the storage modulus with increasing elapsed time decreased more than 50%. Thus, treatment aids in hindering degradation of PLA matrix and recovers adhesion between CF and PLA.Effect of alkali treatment on coir fibers was studied by Nam et al. [4]. The coir fibers with the length 100 mm and the diameter varying from 100 to 450 µm were selected carefully to be used in this study. First of all coir fibers were treated with 5% NaOH solution in a glass beaker for different soaking time (24 h, 48 h, 72 h and 96 h) at room temperature (RT). Next the fibers were taken out of the solution, then washed several times with fresh water and subsequently with distilled water. Finally, the coir fibers were air-dried for more than 2 days. The mechanical properties of alkali-treated coir fiber/PBS composites are significantly higher than those of untreated fibers. The best mechanical properties of alkali-treated coir fiber/PBS composite were achieved at fiber mass content of 25% in this study, which showed an increase of tensile strength by 54.5%, tensile modulus by 141.9%, flexural strength by 45.7% and flexural modulus by 97.4%. Surface properties of raw and chemically modified lingo-cellulosic fibers have been investigated by Gouveia et al. [5] using Inverse Gas Chromatography (IGC). The fibers chosen for the study were flax, hemp, kenaf, agave, agave hybrid, sisal and pineapple. The chemical treatments used were 4% NaOH and 2% zein treatment. The fibers were treated for 3 hours under ambient conditions with 4% NaOH solution, then washed and oven dried at 70°C. 2% zein solution was prepared by mixing the required weight of zein with an ethanol/water mixture in the ratio of 80/20. The fibers were immersed in this solution and were allowed to stand for 2 hours, then oven dried at 110°C. The surface energy and acid-basic character of fibers were seen to be influenced by the crystalline nature of fibers. Bast fibers exhibited higher surface dispersive energy than leaf fibers which was attributed to the intrinsic chemical composition of fibers. Both alkali and zein treatments were seen to decrease the dispersive surface energy. Coir fibers were surface treated and analyzed by Rahman and Khan [6]. The detergent washed fibers were aged with UV radiation to measure the effect of radiation oncoir properties.

Coir fibers were soaked in 5–50% NaOH for about 0.5 h at temperature ranging from 0 to 100°C in order to activate the OH groups of the cellulose and lignin in the fiber. The appropriate concentration of NaOH solution was 10–30%. The fibers were then washed many times in distilled water and finally dried. Highest tensile strength (156.3MPa) was achieved after the fiber was aged by 125 passes of UV radiation, which was 33% higher compared to the untreated fibers. Jute fiber reinforced epoxy composites were analyzed by Gopinath et al. [7]. The jute fiber treated with NaOH was mixed with different resins epoxy and polyester. The fiber resin weight ratio was taken as 18:82. The jute fibers were chemically treated with 5 and 10% NaOH solution. There was an increase in tensile strength for Jute-epoxy composites by 18.67% and jute-polyester composites by 16.67%. Increase in flexural strength for jute-epoxy was 15.6% and jute-polyester was 20%. Jute-polyester composite system is seen to have better impact energy than the jute epoxy composite for 10% NaOH treatment. Kurniawan et al. [8] evaluated the effects of atmospheric pressure glow discharge plasma polymerization on properties of basalt fiber/poly-lactic acid composites. Diameter of the BF was 8–12µm. Plasma polymerization was conducted on in house atmospheric pressure glow discharge plasma system, 3KV AC power supply and radio frequency source at 20KHz were used to generate the glow. Distance between electrodes was found to be 10mm. The precursor for plasma polymerization was acrylic acid monomer, with helium as the carrier gas. The basalt fiber was exposed to AGD plasma for 0.5min, 1.5min, 3min, 4.5min, and 6 min. Tensile strength was noted to increase by 45% whereas stiffness value enhanced by 18% at 4.5 minute exposure. Trend of initial strength and stiffness values declined followed by an increase beyond 1.5 min of plasma exposure, due to the plasma polymerization reaction on silane sized basalt fiber.Ranjan and Biswas [9]performed a study to determine the specific wear rate for jute epoxy composites with various fiber loading conditions and chemical treatments; alkali and benzoyl chloride treatment. Three body abrasive test was conducted and it was observed that the normal load, fiber loading and abrasive Size have great influence on specific wear rate. The parametric combination, i.e. sliding distance of 70 m, fiber loading of 30wt%, a normal load of 10 N, and abrasive size of 200 mm forms an optimum conditionfor minimum specific wear rate found at benzoyl treated composite.

Gupta and Srivastava [10] investigated hybrid composite of sisal and jute to determine the specific wear rate for the composite after treatment with 5% NaOH solution for 30 min. It was seen that on increasing the load and sliding speed, there was in coefficient of friction values. Alkali treated fiber composite showed 400% lesser specific wear rate than neat epoxy resin. Tensile strength after alkali silane treatment was found to be 401.368Mpa. The effects of surface treatment of a basalt fiber by low-temperature atmospheric oxygen plasma on the inter-laminar fracture behavior of basalt/epoxy woven composites were investigated by Kim et al. [11]. There was noticeable improvement in the interfacial adhesion of fiber matrix system and wettability. The fracture toughness value improved by 16%. Zin et al. [12]investigated the mechanical and chemical

properties of banana fiber after treatment with NaOH (4 to 8% w/v conc.) for 2 to 4 hours of immersion. It was recorded that beyond 6% conc., the mechanical properties deteriorate hugely. Tensile strength of about 371MPa was observed during 6% NaOH concentration treatment for 2 hours, which was 75% higher. Inter-laminar shear strength increased from 1.12MPa to 3.96MPa. Seki et al. [13] studied the modification of the jute fiber surface through oxygen plasma treatment of 40 KHz frequency source to improve its mechanical properties. Inter-laminar shear strength increased by 32% (at 30W power) and 47% (at 60W power). Flexural strength increased from 31.4MPa to 39.7MPa (at 30W) and 45.6MPa (at 60W), that is by 45%. 60W power range for 15 minutes has been found most suitable for oxygen plasma treatment in order to improve the mechanical properties.Effect of fiber surface treatment on the properties of bagasse fiber–reinforced unsaturated polyester composites has been investigated by Vilay et al. [14]. Bagasse fibers were soaked in 1% concentration of NaOH solution for 3 h at room temperature. For Acrylic Acid (AA) treatment, Bagasse fibers were immersed in NaOH solution for 30 min, and then soaked in 1% of acrylic acid (AA) solution at room temperature for 1 h. There was an increase in average tensile strength from 96.24 ± 29.95MPa to 156.88 ± 45.46MPa and 229.01 ± 35.56MPa for both the treatments respectively. Ramakrishna and Sundararajan [15] studied the effect of fresh water, calcium hydroxide and sodium hydroxide of pH 7.5, 14 and 13 respectively on natural fibers; coir, sisal and jute fibers. All fibers lost their entire initial tensile strength once exposed in the three mediums, except, sisal which managed to show60–70% of its initialtensile strength in fresh water.

Effect of fiber surface treatment on the fiber–matrix bond strength of natural fiber reinforced composites has been studied by Gonzalez et al. [16]. The fibers were treated with a NaOH aqueous solution (2% w/v) for an hour at 25°C. For the silane treatment of the fiber, 1% silane and 0.5% dicumyl peroxide dissolved for their hydrolysis in a mixture of methanol–water (90/10 w/w) were used. The pH of the solution was adjusted to 3.5 with acetic acid and stirred continuously during 10 min. NaOH treatment provided no effective improvement to the fiber surface. Silanizationenhanced the tensile strength of the composite material from 21MPa to 27MPa. The relationship between the surface chemistry of cellulosic fibers treated with an atmospheric cold plasma generated by dielectric-barrier discharge has been studied by Wielen et al. [17]. Plasma treatment intensities of 1.0 and 5.0 kW/m^{2}min were applied to test sheets at temperature (23.5°C) and atmospheric pressure. Wet tensile index increased from 0.53N/mg to 0.57N/mg (low treatment) and to 0.63N/mg for high treatment intensity. Wet stiffness index improved from 45.5N/mg to 48.N/mg for low and to 67.5N/mg for high treatment intensities.Zhang et al. [18] investigated the influence of relative humidity (RH) in composite fabrication on the interfacial shear strength and flexural properties of flax/ unsaturated polyester composites. At 60% RH, flexural strength was low, after 70% RH, flexural strength started decreasing rapidly. At 90% RH, flexural strength reduced by 35% and flexural modulus by 39%. A reduction in the mechanical properties of the final composites has been noticed at high relative humidity.A study on the effect of surface treatment on sisal fibers was carried out by Srisuvan et al. [19]. Alkalized woven sisal fibers (A-sisal Fibers) were prepared by soaking the fibers in 2wt% NaOH aqueous solution for 2 h at room temperature. Silanized woven sisal fibers (S-sisal) were soaked in 2wt% A-187 aqueous solution with a pH of 3.5 for 2 h at room temperature. All composites showed lower flexural strength than neat epoxy resin and the blend. Nonetheless, the composite containing silanized sisal fiber showed an improvement of flexural strength compared to the composites prepared using alkalized sisal fiber.

3. Inference

The main expected effect of the research performed is to study the rapid development and use of lower cost advanced materials through productive surface treatment and selection of novel materials; Awareness and knowledge of the different surface modification techniques and their suitable combination. The use of natural fiber reinforced composites as an alternative from environmental point of view with significant improvements in fields of research and industrial productivity in order to set a base or foundation for future study or scope in the field concerned for the betterment of society and human race as a whole marks the basis of this review study.

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