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The Effect of Chemical Treatment on Mechanical and Thermal Properties of Abaca-Glass-Banana Hybrid Fibre Composites

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Abstract: In this study, Abaca-Glass-banana composites were fabricated by utilizing Bisphenol-A resin. To enhance fibermatrix bond alkalization (NaOH) and acetylation ($KMnO_4$)were performed on the fiber composites. Differential Scanning calorimeter (DSC) and thermo gravimetric examination (TGA) were utilized to explore the thermal stabilityand weight loss in the fiber compositedue to chemical constituent's after treatment. Mechanical properties, for example, flexural quality, flexural modulus, strain at break of untreated and treated fiber composites were examined. On consolidation results it was found that alkalized fiber composites shows better mechanicalproperties than untreated and acetylated composite. Thermal properties of the fibercomposites were likewise improved for the treated fiber. Comparative analysis shows that alkaline-treated fibers exhibited enhanced properties than the untreated fibers and acetalized fibers.

Keywords: Chemical Treatment; Abaca fiber; Glass fiber; Banana fiber; Alkalization; Acetylation; Mechanical properties; Thermal Properties; Automatic Tape laying machine.

Introduction:

Plastics are the most utilized materials in modern life and make a noteworthy, imperative commitment to for all intents and purposes. The most imperative advancements in plastic industry have happened subsequent to 1910. As the popularity of plastic is increasing, the environmentalists keep on raising concern in regards to the potential demolition that would be brought on by the expanding number of disposal of plastics. Natural fiber and fiber composites are identified as the best alternative for the plastic. Over the last thirty year, usage of composite materials has increased consistently, entering and overcoming new markets perseveringly.

Natural fibers for example jute, flax, hemp, coir, sisal, abaca, banana, etc. are frequently used as strengthening fibers in thermoset and thermoplastic matrix[19]. Fiber reinforced polymers are low cost, light weight and high specific modulus in contrast to the synthetic fibers and availability of renewable natural fibers, non-toxic, biodegradability are some of the remarkable features.

The fibers extracted from species Banana plant namely Banana fibers and abaca fibers are known for the strength, durability and resistant to sea water. An immaculate polymer does not have essential mechanical properties for application. Albeit, a large portion of the natural fibers cellulose goes about as a principle auxiliary segment, lignin, and hemicelluloses additionally assume an imperative part in deciding the attributes properties of the fiber. Along these lines, real confinement of utilizing this fiber as a part of high quality composite applications is poor bonding characteristics with the polymeric matrix and dimensional precariousness. This outcomes in poor mechanical properties of the composite materials[4]. The pure fibers are hydrophilic in nature while polymer matrix materials are hydrophobic. Subsequently, there is an innate incongruently between hydrophilic fiber and hydrophobic sap which brings about low mechanical properties.

The reinforcement by high quality fibers gives the polymer significantly improved mechanical properties and makes the fiber strengthened polymer composites (FRPCs)[2] suitable for an extensive number of different applications running from aviation to games hardware. While composites have demonstrated their value as weight-sparing materials, the present test is to make them financially savvy[3].

Chemical treatment, for example, Fatty acid derivate (oleoyl chloride), Isocyanate, Sodium chlorite, alkalization and acetylation responds with hydrophilic hydroxyl gatherings of common fiber and enhances hydrophobic attributes and encourages better holding with polymer matrix[18]. Few investigators utilized alkalization and acetylation treatments on normal fibers to enhance its composites mechanical and thermal properties. Effects on the mechanical and thermal properties of hybrid fiber composites with various chemical treatment are presented as a motivation to the theme of this paper.

Experimentation:

Abaca and Banana were obtained from Composite board Pvt. Ltd. Chennai, India. Synthetic woven roving Glass fabrics of E-Type at the density of 610gm/cm^2 were gathered from Idris Exporters, Chennai-India. Bisphenol resin was utilized as a curing catalyst. Abaca fiber is acquired from the pseudo-stem of the plant. It is incurred by banana plant family. The plant develops around 12 feet (4 m) tall and the fiber is separated from the trunk of the plant. The fibers are extracted from the base of the banana leaf. It is a bast fiber and is otherwise called Manila hemp. Cellulose, hemicellulose, lignin, pectin and ash are some of the major constituents of a fiber.

The matrix binding can be done by either by Thermoplastic or thermoset matrix[20]. Thermoset based reinforced matrix possess low viscosity and good wetting properties whereas thermoset polymers are brittle in nature. Thermoplastic based reinforced matrix are recyclable and good formability properties. Thermoplastic matrix based polymers should melted before processing[21]. The various factors that affect the structure of the fibrecomposites are plantfibre structure, moisture absorption of the fibre, Thermal stability of the fibre, length, loading and orientation and finally presence of voids[19].

The fiber–matrix interface is a dissemination or reaction zone, in which two stages are Chemical and/or mechanically consolidated. The interfacial attachment has a dominating influence to describe the mechanical properties of the composites[22]. In reinforcement process, a few issues happen along the interface because of the vicinity of hydrophilic & hydroxyl groups. This hydrophilic group hinders the reaction with the matrix. Pectin and Waxy substances cover the hydrophilic groups and act as an obstruction to interlock with the framework[23].

There are various strategies for mechanical consolidation of a fiber composite[24]. Choice of a techniques based on specific design, consequently, will rely on upon the materials and end-user or application. In order compare/identify the effect of the various chemical treatment over the abaca, banana, and hybrid composite, it is mandatory to maintain uniformity in all specimens. Keeping this in mind, In house automated tape laying machine is used for specimen preparation[23]. The fiber layup process is done automatically by placing multiple prepreg tows onto a mandrel by utilizing a numerically controlled machine. Articulating robotic arm is used to dispense the prepreg, clamp the prepeg at the mandrel head, cut and restart over 15 tows simultaneously. Tape layup is flexible, permitting softens up the procedure and easy direction changes, and it can be adjusted for both thermoset and thermoplastic materials. The head of the machine is incorporated with a spool of tape, a winder, winder manages, a compaction shoe, a position sensor and a tape cutter or slitter. Various courses are generally connected together as per the specimen and design is controlled by machine-control programming[25].

To improve the adequacy of interfacial holding, fiber surface should be modified with chemical treatment Compound medications uncover more receptive gatherings on the fiber surface and along these lines encourages productive coupling with the network. Accordingly, better mechanical properties of the composites can be accomplished[26] Chemical treatment will help in improving the interfacial bonding. The major issue of fiber composites begins from the hydrophilic way of the fiber and hydrophobic nature of the composite matrix. The inborn contradictorily between these two stages results debilitating bonding at the interface. Chemical treatment on reinforcing fiber can decrease its hydrophilic propensity and in this way enhance similarity with the lattice[27, 28].

There are various chemical treatment like alkaline, silane, Acetylation, Benzoylation, Peroxide, Maleated coupling agents and Permanganate treatments out of which alkaline and acetylation are performed on the abaca-glass-banana hybrid composite. Bisphenol-A is an organic compound used since 1957 for certain plastics and epoxy resins[29]. To improve the rate of reaction cobalt napthanate is used as an accelerator and methyl ethyl-ketone peroxide as catalyst are added to the matrix.

The alkaline treatment abaca-glass-banana fibre by NaOH is generally being utilized to change the cellulosic sub-atomic structure. NaOH react on the highly packed crystalline cellulose and create amorphous regions which gives more access to infiltrate chemicals. Water molecules are filled in the amorphous regions[2]. On reacting with the alkali, OH groups present among the atoms are separated and move out from the fibre structure. The cellulose molecular chains (cellulose + O + Na) will enhance the fibre resistance towards moisture absorption. It additionally takes out a specific bit of hemicelluloses, lignin, pectin, wax and oil covering materials[2].As an outcome, the fibre surface turns out to be perfect[6]. The resign, catalyst and accelerator are added to the alkaline treated fibre in an optimum ratio 1:0.02:0.02 respectively[9]. Further fibre is loaded to the automated tape laying machine.

Acetylation treatment is known as esterification technique for plasticizing fiber composites. CH_3CO responds with the hydrophilic hydroxyl bunches (OH) and remove the moisture. Thus, hydrophilic nature of the fiber is diminished and enhances dimensional stability of the composites[30]. Rough surface with less number of voids that give better mechanical interlocking with the network[1, 2, 24].Fiber are first soaked in CH_3COOH and subsequently treated with acidic anhydride for 1–3 h at elevated temperature[19]. Further fiber is loaded to the automated tape laying machine by adding the resign to the treated fibers.

Mechanical Testing:

Tensile Testing:

The manufactured fiber composites specimens are sliced utilizing a saw cutter for testing according to ASTM: D638 norms. The test is done at room temperature (303k) in Universal testing machine. The tensile stress is recorded as for increasing in strain. The tensile testing is carried until point of the failure on all the three different types of specimens based on their chemical treatment namely, Alkaline and Acetylation. The Stress and strain are plotted on the graphs.

Flexural Testing:

Flexural test determines the maximum stress induced in the outer most fiber. The specimen are sized according to ASTM: D790. Cross head speed is maintained at 2 mm/min. The experiments are done five times on each specimen and average result of the flexural stress at the point of failure is reported below.

Thermal Testing:

The thermal testing determine the heat transfer rate through hybrid composite specimen. Thermal analysis was performed using differential Scanning calorimeter and Thermo gravity analyzer. The hybrid composite specimens weighing 8 mg were utilized for testing. Testing is done three times on each specimen and average results are analyzed. Both test were performed in Nitrogen environment where the gas is purged at 15ml/min and heated at the rate of 15^0C/min up to 500^0C.

Result and Discussion:

Tensile properties of untreated and treated fiber reinforced composites are shown in figure 1.The modulus for all the NaOH treated fiber composites were increased in contrast with the untreated fiber composites. At higher concentration such as 5%, 10% and 15% NaOH treated composites showed 17%, 20% and 25% improvement in strength and 15%, 20% and 26% change in modulus properties. This was perhaps because of the evacuation of hemicelluloses, lignin and cellulosic constituents from the fiber after soluble base treatment. Accordingly fibers turned out to be more hydrophobic and expanded bond at the interface between the fibers. Acetylated composites indicated the steady change on tensile properties with the concentration of the acetylene. In all cases acetylated composites demonstrated better tensile property in contrast with the untreated composites[31]. This Strength diminished with the increase in concentration of the acetic acid. The reason for lowering the property is due to reaction between acid and resin, which reduces the strength of the fiber. On consolidating results we infer that tensile properties of acetylated composite fibersare better than untreated composite but not higher alkali treated composite.

The Load versus Displacement for distinct of composites along with the untreated composite is shown below in figure 2. The flexural property of alkali treated composite is high. The graph increments linearly with displacement to the most extreme flexural strength and after that, it gets diminished.

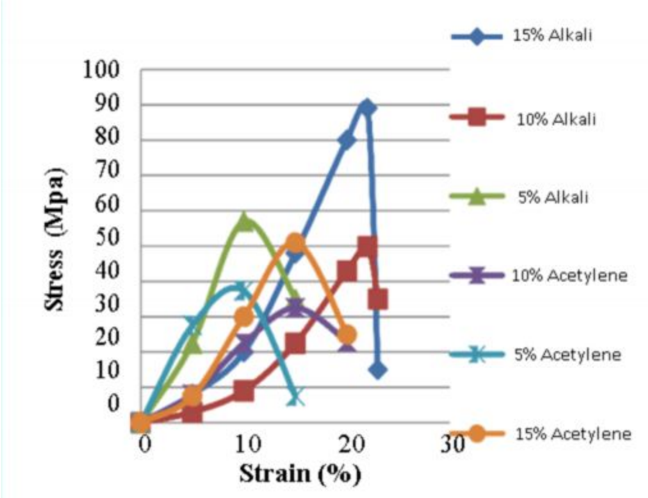

Figure 1. Stress-Strain graph for Tensile loading

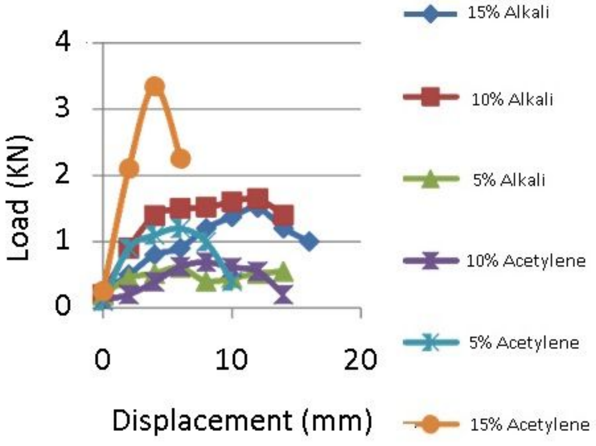

Figure 2. Flexural strength variation

Differential Scanning Calorimeter investigation induces to recognize the compound action happening in the fiber as heat was applied[14]. Figure 3,4 explains Heat flow rate of the untreated, Alkaline and Acetylation regarded hybrid fiber composite. Both untreated and treated fibers displayed endothermic nature between the temperature of 60-100°C and an exothermic peak between 300-350°C. Evaporation of moisture from the fibers is the main reason for the endothermic nature[8, 32]. The temperature range between 100-220°C demonstrates no exothermic or endothermic changes mirrored that the fibers were thermally stable. Natural fiber lignin debases at the temperature around 200°C while alternate constituents, for example, hemicelluloses and α-cellulose debases at higher temperature[18]. Similarly deterioration of lignin, hemicelluloses and α-cellulose of the fiber leads to exothermic reaction. For Untreated fiber the exothermic peak is observed at 240-370^0C where degradation of α-cellulose, hemicellulos and lignin takes place. For the acetylated composite decay between 320^0C - 370^0C. From this examination, it can be found that the treated fiber composite's is all the more thermally stable contrasted with the untreated fiber since the untreated hemp filaments have lower decay temperature.

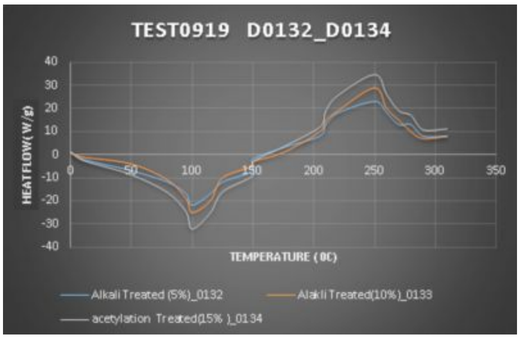

Figure 3. DSC analysis of Alkali treated fiber

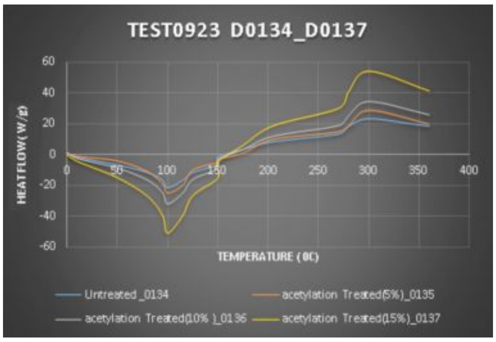

Figure 4. DSC analysis of acetylation treated fiber

TGA experimental testing was performed to check weight reduction on fibers at various temperatures. Figure 4, 5 demonstrates three phases of weight reduction process with respect to temperatures.From the graph, it clearly understood that weight reduction begins from60°C-100°C was because of the moisture evaporation. The second stage of weight loss temperature around 100°C - 220°C to deterioration of hemicelluloses and lignin. The third stage weight loss takes place around 300-350^0C due to the α-cellulose evaporation. It was clearly understood from the graph that Untreated composite degrades completely at 200^0C. From the graph we conclude thatdegradation temperatures of lignin, hemicelluloses and α-cellulosic constituents for acetylated filaments were higher than the untreated and alkalized fiber composite. Therefore, it can be reasoned that acetylated filaments were more thermally stable than the untreated and alkalized fiber composites.

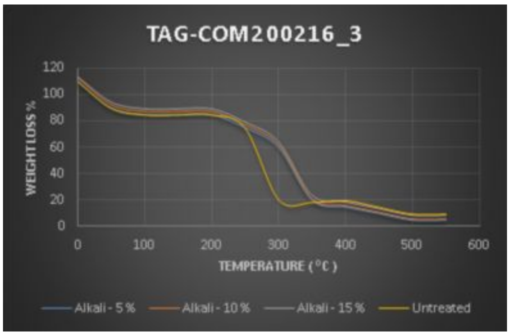

Figure 4. TGA analysis of Alkali treated fiber

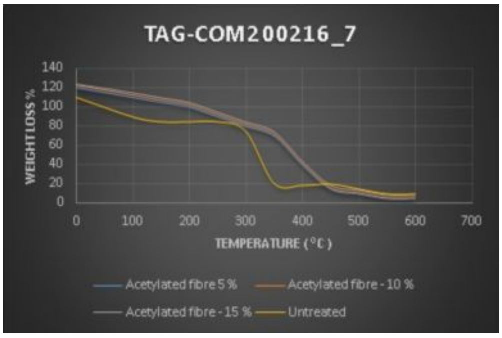

Figure 5. TGA analysis of acetylation treated fiber

Conclusion:

1. The treated fibers shows better Mechanical, Thermal properties than untreated fiber composites.
2. It was clearly understood from the experimental results that Alkali treatment enhances the fiber composite's mechanical properties than acetylene treatment.
3. DSCanalysis proves that untreated fiber loses their thermal stability at 200^0C, Alkali treated fibers decay at 300^0C and Acetylene treated fibers decay the 340^0C.
4. TAG analysis proves that weight reduction in alkali and untreated fibers are much higher than acetylene

treated fiber composites.

5. In order to enhance thermal stability of the fiber composite acetylene treatment is performed.

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