DEVELOPMENT OF MODIFIED BAMBOO FIBER REINFORCED PLASTIC COMPOSITES AND STUDY OF THEIR PROPERTIES

by

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CERTIFICATE

This is to certify that the thesis entitled **"DEVELOPMENT OF MODIFIED BAMBOO FIBER REINFORCED PLASTIC COMPOSITES AND STUDY OF THEIR PROPERTIES"** being submitted by **Pradeep Kumar Kushwaha** to the Indian Institute of Technology, Delhi for the award of the degree of "**DOCTOR OF PHILOSOPHY**", is a record of the authentic research work carried out by him under my supervision and guidance. He has fulfilled all the requirements for submission of the thesis, which to the best of my knowledge has reached the required standard.

The results contained in this thesis are original and have not been submitted, in part or full, to any other university or institute for the award of any degree or diploma.

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ABSTRACT

The use of bio-fibers, as opposed to synthetic fibers, has been well recognized due to the positive environmental benefits with respect to ultimate disposability and raw material utilization. In addition, it has properties like low cost, light-weight, high specific strength and free from health hazard.

A major drawback associated with natural fibers for reinforcement purposes is their hydrophilicity. The presence of hydroxyl and other polar groups in the natural fibers would lead to poor wettability with the relatively hydrophobic polymers, resulting in weak interfacial bonding. Environmental performance of such composites is also poor due to delamination under humid conditions. Thus, in order to develop composites with better mechanical properties and environmental performance, it is necessary to impart hydrophobicity to bamboo fibers by reaction with suitable chemical reagents. Lignocellulosic fibers are amenable to chemical modification due to the presence of hydroxyl groups. Surface characteristics such as wetting, adhesion, surface tension, porosity can be improved by modification.

Bamboo mat reinforced epoxy and polyester composites were fabricated using hand lay up method using compression molding. The main thrust of the work reported in this thesis was to develop chemically modified bamboo fiber reinforced plastic composite and hybrid composite by reinforcing bamboo mat in polymer resins and to study its various mechanical properties (tensile, flexural and impact), water absorption, thermal degradation and electrical properties. SEM (scanning electron microscopy) has been carried out on tensile fractured surface to study the bonding between the fiber and matrix, surface morphology of fibers and the failure process in composites.

Chemicals used to modify the bamboo were sodium hydroxide, silane, acrylonitrile, methacrylamide, maleic anhydride, potassium permanganate, benzoyl chloride, benzyl chloride, dicumyl peroxide, benzoyl peroxide, hydrogen peroxide, acrylic acid, acetic acid and formic acid. Pre-impregnation and water treatment were also carried out. Hybrid composites with woven glass mat, woven glass strand mat, carbon nanotube and nano clay were also fabricated.

The mechanical properties of the composites reinforced with modified fibers have improved compared to the untreated fiber composite. Tensile strength of the modified (mercerized) BFRP composites has increased more than 55% in case of epoxy matrix and 69% in case of polyester matrix. SEM studies on the tensile fracture surface reveal an improved interfacial bonding between the matrix and the modified bamboo fiber. Mercerization also improves the water resistance property of the composites. Cyanoethylation increases the tensile strength by 45% and 31% for the epoxy and polyester composites respectively. With acrylonitrile treated BFRP composite the water uptake has been brought down to 13.96% for the polyester matrix composite. This is a sharp reduction in water uptake. An attempt has also been made to modify the bamboo fiber surface through the use of water. This is a very clean process as no chemical is involved. It was observed that upon hybridization with glass fiber the mechanical and water absorption properties improved in general. Addition of nanoclay in the matrix improved the elastic modulus of the bamboo composites. Due to reinforcement of CNTs in the epoxy matrix impact strength of the bamboo-epoxy composite has been increased by 84.5%.

The thermal degradation behavior of the chemically treated fiber composites vis-à-vis untreated fiber composite was investigated by thermogravimetry (TG). The treatments had a considerable effect on the thermal degradation behavior of the fibers, promoting an increase in the temperatures at which the thermal degradation took place. The degradation temperatures have increased and the weight losses have decreased. After 5% alkali treatment, degradation temperature has increased by 16.15 °C for epoxy composite and 21°C for polyester composite. Maleic anhydride treatment has increased the charred residue of the bamboo epoxy composite from 7.1% to 19.28%. Dicumyl peroxide treated bamboo polyester has the maximum residue of 8.57% among the polyester based composites at 650°C. Thermal stability of glass hybrids has also increased due to incorporation of glass fiber. Additions of nano clay and CNT have also lead to increased thermal stability of bamboo composites. The improvement in thermal stability will lead to better service performance of the composites at elevated temperature.

The dielectric properties of bamboo composites were carried out. For the chemically treated bamboo epoxy composites, the dielectric constant decreases more rapidly with increase in frequency compared to untreated fiber composite. In the case of chemically treated bamboo polyester composite, decrease in dielectric constant is less than that of untreated bamboo polyester composite. In hybrid composites, the dielectric constant decreases with the increase in glass fiber content. Maximum values of volume resistivity are obtained for peroxide treated bamboo epoxy and methacrylamide grafted bamboo polyester composites. The volume resistivity of glass fiber-reinforced composites is higher than that of bamboo fiber composite. Glass composites have the lowest dielectric dissipation factor (tan δ). tan δ of the chemically treated bamboo epoxy composites is higher than that of untreated composite.

The present work has established that chemically modified bamboo fiber reinforced plastic composites have superior properties in terms of enhanced mechanical properties, less water uptake and better thermal and dielectric properties as opposed to untreated BFRP composite.

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