Chapter

Introduction of Natural Fiber Composite Using in Paperboard Industry

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Abstract

India is one of the largest countries having agriculture as the main profession for many people. A huge amount of natural fibers are present in the plants of agricultural land and forest. As these natural fibers have high potential due to their biodegradable nature, new ways must be found for the utilization of these natural fibers in industries. Nowadays, the paperboard producing ventures are confronted with two main problems, namely environmental pollution and insufficiency of raw materials. These ventures necessitate the spending of a lot of energy and money for diminishing the level of contamination in paperboard effluents. One method of diminishing the contamination in paperboard industries is the utilization of natural fiber composites. For the last two decades, there has been a lack of raw materials in paperboard industries. Consequently, it is important to find new resources. Presently, many researches focus on the development of natural fiber-reinforced composites for paperboard. The natural fiber composites could be used to solve the above two issues.

Keywords: chemically treated fibers, natural fiber composites, sawdust, properties, paperboard industry

1. Introduction

India is one of the biggest agricultural countries with agriculture as the main profession for many people. A large quantity and variety of natural fibers are available from the plants in agricultural land and forests. New ways have to be found for making use of these natural fibers in various industrial products. Presently, paperboard manufacturing industries face two major challenges, namely environmental pollution and deficiency of raw materials. These manufacturing industries have to put in more efforts and money for reducing the level of pollution in paperboard effluents. One way of reducing pollution in paper industries is the use of natural fiber composites. In the past two decades, worldwide raw material deficiency has been occurring in paperboard raw materials. Hence, it is necessary to go for alternative materials. Much interest is shown in the extensive research on using natural fiber reinforced composites in paperboard industry. The use of natural fiber composites is the solution for the above two problems.

In India, endeavors have been made to fill the gap between demand and supply of paperboard by utilizing different agricultural products and weeds. The natural fiber in reinforced polymer composite is considered as a substitute for synthetic fiber. The natural fibers have high specific modulus and moderate strength. They are completely combustible, affordable, lightweight, non-toxic as well as easy to recycle. The practical attributes necessary for paperboard are strength, anti-fungus, printability, processability, recyclability and biodegradability. The added advantage of using natural fiber composite in paperboard is that it reduces the global warming. The natural fiber composites solve the environmental effect to a great extent by zero emission of CO_2 to the atmosphere. The natural fibers can be produced at a relatively low cost and low specific weight compared to synthetic fibers.

1.1 Natural fibers

Natural fibers can be classified into three main categories: vegetable fibers, animal fibers and mineral fibers. Vegetable fibers are composed primarily of cellulose, hemicellulose and lignin, with the balance being made up of pectin, water soluble compounds, wax, inorganic and non-flammable substances which are generally referred to as ash. The structure, microfibrillar angle, cell dimensions, defects and the chemical composition of fibers are the most important variables that determine the overall properties of the fibers. Plant fibers will exhibit high ductility if the microfibrils have a spiral orientation to the fiber axis. The properties of plant fibers depend on the type and age of plant, type of soil, climate conditions, the extraction method used, the fiber structure, microfibrillar angle, fiber (cell) dimensions and chemical composition.

The contents of natural fibers are cellulose, hemicellulose, lignin, ash and moisture. The cellulose content has an important influence on the mechanical properties of fiber such as tensile strength, Young's modulus and strain-to-failure.

The physical properties of natural fibers like density and diameter are the most important properties to make the light weight composites. The mechanical performance of the fiber-reinforced composites is mainly the function of the fiber dispersion, fiber-matrix compatibility and aspect ratio of the reinforcement. The tensile properties such as tensile strength, modulus and strain-to-failure of natural fibers play an important role in deciding the properties of polymer composites.

1.2 Chemically treated fibers

Natural fibers are noted for their hydrophilic nature due to the high quantity of hydroxyl groups gathered in cellulose. One way of improving the interfacial bonding of the fibers with matrix is fiber surface modification. The cellulose of natural fiber contains hydrophilic nature, whereas lignin contains hydrophobic nature. Therefore, they are subject to modification. The hydroxyl groups may be required in the hydrogen bonding within the cellulose molecules, thereby reducing the activity towards the matrix.

The interest towards using natural fiber as reinforcement in composites has increased dramatically and it represents one of the most important uses in paperboard industry. Cellulosic fibers are hygroscopic in nature; moisture absorption can result in the swelling of the fibers which may extend to micro-cracking of the composite and degradation of mechanical properties. This problem can be overcome by treating these fibers with suitable chemicals to decrease the hydroxyl groups which may be required in the hydrogen bonding within the cellulose molecules. The mechanical and chemical bondings at the fiber surface are mainly dependent on the surface morphology and chemical composition of the fibers. Therefore, the microscopic analysis of fiber surface topology and morphology is of extreme importance in fibrous composites. Hence, in the present research, an attempt has been made for heat, alkalization, silane, acetylation, acrylation, permanganate and benzoylation treatments of fiber to modify the physical properties, morphology, crystallinity and thermal stability of *Passiflora foetida* Fiber (PFF). The reinforcing efficiency of natural fiber depends upon the cellulose and its crystallinity.

To identify the influence of treatment on the fibers, chemical composition, the Fourier Transform Infrared (FTIR) spectra is utilized. The crystalline structure of cellulose in PFF is detected by wide angle X-Ray Diffraction (XRD) spectra. Thermal degradation of fibers is analyzed by Thermogravimetric Analysis/Differential Thermogravimetric analysis (TGA/DTG).

1.3 Sawdust (SW) filler

There are at present million sawmills working in urban region of India. A large quantity of SW is generated in sawmill industry. Fundamentally, this natural SW is utilized as a fuel source as well as a source for furniture item, namely plywood. The3'R concepts, namely "Reduce, Recycle and Reuse" can be applied to filler. SW represents an imperative renewable source of filler as a part of biopolymer composites.

SW is important in light of the fact that it is reused of ease, low weight and high stiffness. It diminishes shrinkage of composite in the wake of embellishment. Hence, the SW is tried as a filler material in a newly identified PFF with polymer composite and the resulting modified properties of filler are analyzed. The treated SW filler is randomly dispersed in the matrix such a way to obtain a homogeneous and isotropic macroscopic behavior of composite.

1.4 Fiber paperboard properties

Leu et al. [1], Stepanov et al. [2], Gonzalez et al. [3] and Adu and Jolly [4] have pointed out that the paperboard materials are classified into three types based on the source materials used for preparation as shown in **Figure 1**.

Increasing global consumption, modernization and luxury of the paperboard make a need to cut 7.2 billion trees for paper production for packing purpose. Of late, the raw material required for paperboard is 10 million tons per annum and this may be increased to 20 million tons per annum from 2020. Madras Consultancy Group (MCG) has reported that 21% of the world's packaging market is done in India. The non-food material packing by paperboard has increased to 6.3% and this may also be increased to 2.4% per annum for next 5 years. Due to the shortage of raw materials, the paperboard industries are looking for the non-wood plant wastes. This may attract the researchers to investigate the alternate raw materials for paperboard products.

The pulp has been used as a raw material for paperboard industries. During the sulfur emission, the processing of paper may cause air and land pollution. The carbon-positive, water-positive, zero-solid waste disposal, Elemental Chlorine Free (ECF) technology and ozone technologies are being used to reduce toxins in

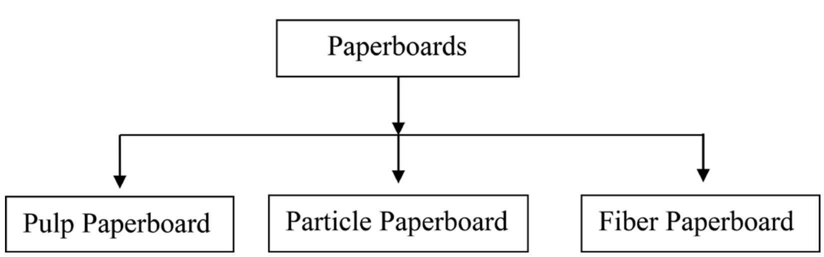

Figure 1.
Types of paperboard materials.

the effluent discharged from paper industries. These technologies help in producing brighter and stronger paper products. By using these above technologies, the pollutants can be kept within the limits as per the Biochemical Oxygen on Demand (BOD) and Chemical Oxygen on Demand (COD) national standards.

Manufacturing industries have to take more efforts and spend much money for reducing the level of pollution in paperboard effluents. For reducing pollution in paper industries, natural fiber composites are used in the present study. The following properties are suitable for paperboard. Paperboard should have higher ductility, modulus, impact strength, durability, fungal and water absorption resistance. It should possess elasto-visco-plastic properties, namely rheological behaviors such as delayed strain recovery, stress relaxation and creep resistance.

Basically, the natural fibers are in the form of small hollow structure. Brindha et al. [5] and Sharma et al. [6] have found that natural fibers with cellulose of 34% and above and less than 30% of lignin are suitable for paperboard production. Runkel's ratio, slenderness ratio and flexibility coefficient are significantly derived indices to determine the suitability of composite material for paperboard making. In composite materials, Runkel's ratio less than 1, slenderness ratio more than 33 and flexibility ratio between 60 and 70 of fibrous materials are good for paperboard making because fibers are more flexible and they would collapse easily and form a paperboard with large bonded area. As per ISO standard 536, the minimum thickness of 0.25 mm and grammage above 224 g/m^2 are required for paperboard.

1.5 Determination of the density of PFFs

To calculate the volume fraction of fibers in composite, it is necessary to determine the density of PFFs. The fiber density is found using pycnometer as per ASTM D 578-89. The fibers are mixed with methyl benzene (known as toluene) immersion liquid. Initially, the fibers are impregnated in methyl benzene for 2 hours to remove the micro bubbles. Then the fibers are dried for 2 days in air tight non-hygroscopic desiccator containing calcium chloride. The density of the toluene (ρ_T) is 0.8669 g/cm^3 at 20°C. Then the fibers are cut into 10 mm and placed in the pycnometer. The density of PFFs is calculated by the expression.

$$\rho_{PFFs} = \left(\frac{m_2 - m_1}{(m_3 - m_1)(m_4 - m_2)}\right) \times \rho_T$$

where m_1 is the mass of the unfilled pycnometer (kg), m_2 is the mass of the pycnometer loaded with cleaved fibers (kg), m_3 is the mass of the pycnometer loaded with methylbenzene (kg) and m_4 is the mass of the pycnometer loaded with hacked fibers and methylbenzene solution (kg). The density of natural fiber is found.

1.6 Properties of polyester

Based on the reports obtained from the supplier's datasheet, the properties of the polyester resin are as listed in **Table 1**.

The density of the composite is low due to the addition of lower density PFFs.

1.7 Determination of the density of SW

The density of SW is determined by Maharani et al. [7]. It is estimated by the addition of SW into a volumetric cylinder of 100 cm^3 (V_o). Itis calculated by the expression.

$$\text{SW density} = (W_a - W_b)/V_o$$

Properties	Values
Density	1.1 g/cm^3
Tensile strength	16–18 MPa
Tensile modulus	0.25–0.4GPa
Flexural strength	30 MPa
Flexural modulus	1.1–1.4 GPa

Table 1.
Properties of polyester resin.

Where w_a is the weight of empty volumetric cylinder while w_b is the combined weight of SW and volumetric cylinder. The density of SW is 1.17 g/cm^3.

1.8 Procedure for v_f to w_f

To achieve the desired volume of fiber and matrix in the composite, the weight of fiber and matrix is to be calculated as follows:

1. To find the density of composite, $\rho_c = \rho_f V_f + \rho_m V_m$

2. To calculate the volume of composite from pattern size

$$V_c = \text{Length} \times \text{width} \times \text{thickness}.$$

3. To find the mass of composite, $m_c = \rho_c \times V_c$

4. To calculate the weight percentage of fiber, $\%w_f = \frac{\rho_f}{\rho_c} \times V_f$

5. To find the weight of the fiber to be added in the mold, $w_f = \%w_f \times m_c$

The present book deals with the mechanical properties, chemical compositions, crystallinity and thermal stability of the newly developed composites. Finally, the results are analyzed to ensure the suitability of natural fiber as an optional fiber-material for paperboard industry.

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