

Oil Palm Fiber Biocomposite for Automotive Industries

2010-01-2030

Published
10/05/2010

Satya Panigrahi
Univ. of Saskatchewan

Copyright © 2010 SAE International

ABSTRACT

The properties of oil palm fiber were estimated and compared with oil seed flax and industrial hemp fibers. Biocomposite of oil palm fiber and linear low density polyethylene (LLDPE) was manufactured. The effect of fiber size, fiber content and fiber treatment on dimensional stability of the biocomposite was studied. The true density of oil palm fiber is found to be 1503 kg m^{-3} . The oil palm fibers obtained from field contained nearly one fourth impurities, and the equilibrium moisture contents (EMC) values of fibres nearly doubled with 25% increase in relative humidity. The dielectric constant of oil palm fiber was in the range of 7.76-8.31. The oil palm fiber resulted in thermograms with two endothermic peaks and three exothermic peaks with the first degradation temperature at 301.71°C . Alkali treatment reduced first degradation temperature to 297.1°C . The specific heat capacity of oil palm fiber varied from $1.083 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$ to $3.317 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$ in the temperature range of 20°C to 150°C . A sharp increase in composite thickness swelling upon immersion in water was observed in the initial days of immersion, which maintained constant thereafter. The thickness swelling increased with fiber size. In addition to thickness swelling, composites expanded linearly also during water absorption, however linear expansion was considerably less than thickness swelling. Higher fiber loading and alkali treatment caused more linear expansion. It was observed that maximum solid loss on water immersion was for small sized and also alkali treated fiber composites. Increase in thickness and decrease in linear dimension was observed after one sorption-desorption cycle. This irreversible change was also found proportional to fiber loading and alkali treatment.

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is a popular edible oil yielding crop grown in 42 countries worldwide on about 11

million ha. Annually it produces about 55 MT/ha of total dry matter in the form of fibrous biomass (Hasamudin and Soom, 2002). Among various parts of oil palm tree, empty fruit bunch (EFB) is preferable for fiber in terms of availability and cost. It was reported that the palm oil industry has to dispose about 1.1 ton of EFB per every ton of oil produced (Karina *et al.*, 2008) and EFB has potential to yield 73% fibers (Wirjosentono *et al.*, 2004). The only current use of this highly cellulosic material is as boiler fuel, in the preparation of fertilizers or as mulching material. When left on the field, these waste materials create great environmental problems.

Biocomposites are defined as the materials made from natural fiber and petroleum/ bio based polymers. Use of natural fiber as reinforcement in polymeric matrix in place of conventional inorganic glass fiber offers several advantages with regard to their less abrasiveness to processing equipment, environmental friendly nature, lower cost, greater deformability, biodegradability, renewable nature, non-toxicity, flexible usage, high specific strength, low energy cost, positive contribution to global carbon budget, combustibility, ease of recyclability, good thermal and insulating properties, good electrical resistance, good acoustic insulating properly, worldwide availability etc.

LLDPE is a popular thermoplastic material used mainly for packaging applications. The low processing temperature (less than 130°C) of LLDPE makes biocomposite manufacturing possible with natural fiber as a reinforcement materials (Panigrahi *et al.*, 2009).

The objective of this study was to characterize oil palm fiber in terms of physical, electrical, thermal and chemical properties and to study the dimensional stability of oil palm fiber-LLDPE composites upon immersion in water. The effect of fiber size, fiber content and fiber treatment on the

dimensional stability was studied. The properties of oil palm fibers were compared with Saskatchewan grown flax and hemp fibers.

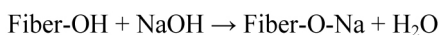
MATERIALS AND METHODS

RAW MATERIALS

The oil palm EFB's were obtained from a local palm oil mill at Pedavegi, Andhra Pradesh, India. The full fruit bunches (FFB) were steam treated at a pressure of 294 kPa for 1 h before stripping the fruits to yield EFB's, in a usual process in the palm oil milling sequence. The initial moisture content of EFB in the order of 65-70% (w.b) was brought down to 35-40% in an electrically heated forced convection cabinet drier. Fibers were extracted from dried EFB using a mechanical decorticator, where the EFB's were subjected to the action of rotating mechanical beaters. The extracted fibers were washed in distilled water to remove field impurities and dried in a hot air oven at 50°C for 48 h and stored in airtight containers for the experiments. Linear low density polyethylene in powder form was used in the experiments (procured from ExxonMobil Chemical Canada, Toronto, ON). The properties of LLDPE were: density-0.938 g/cm³, melt flow index-3.3 g/10 min and melting point-126.5°C.

BIOCOMPOSITE PREPARATION

Oil palm fiber is hydrophilic in nature. the hydrophilic character of palm fibers leads to low compatibility with hydrophobic polymer matrices and also to a poor dimensional stability as water uptake makes the fibers swell. Swelling of fibers can lead to micro-cracking of the composite resulting in the degradation of mechanical properties (Rana 2008). This problem can be overcome by treating fibers with NaOH to decrease the hydroxyl group from the fibers. Alkaline treatment is one of the most common treatments adopted to modify fiber before reinforcing any thermoplastic or thermoset polymer (Ray et al. 2000). In this treatment, removal of hydrogen bonding in the network structure is most important modification which increases the surface roughness. This treatment also removes certain amount of lignin, wax and oils covering the external surface of the fiber cell wall, depolymerize the native cellulose structure, and expose the short length crystallites (Mohanty et al. 2001). This treatment directly influences cellulosic structure of plant fibers, degree of polymerization, and removal of lignin and hemicellulosic compounds may lead to change in molecular orientation of the cellulose crystallites. The reaction of sodium hydroxide with natural fiber is given by the following equations (Agrawal et al. 2000):



Alkali treatment was conducted by immersing the palm fibers in 5% (w/w) NaOH solution for 1 h and washed with distilled water. The washed fibers were dried at 50±1°C for 48 h in a

hot air oven. Dried fiber was ground to 2 mm using the grinding mill (Thomas Wiley Laboratory Mill, Thomas Scientific, Swedesboro, NJ). The size reduction of palm fiber was done to ensure a homogeneous mixing of fiber and LLDPE resin.

The particle size distribution of ground fibers was determined following ASTM standard test sieves. The fibers were separated into three size fractions viz ASTM sieve size 20-40, 40-80 and 80-200. Mixing of LLDPE and palm fibers were done in a mechanical mixer, equipped with helical blades rotating at 40 rpm, for 10 minutes.

The biocomposite compounded mixture was fed to a designed rectangular compression mold of 200×200 mm size for 3 mm board thickness and molded in a compression molding machine equipped with water cooling facility. The processing parameters were: a) mold temperature: 150°C, residence time: 12 minutes compression pressure: 850 kpa pressure, curing time : 15 minutes. The specimen thickness was maintained as 3 mm. Pressure was maintained during the curing process to develop products with better dimension stability and mechanical properties.

DIMENSIONAL STABILITY

Test specimens of 77×26×3 mm size were conditioned at 50°C for 48 h and initial mass was noted using a precision balance of 0.01 mg accuracy. Exact sizes of individual specimen were measured using a digital micrometer of 0.01 mm accuracy. The specimens were fully immersed in distilled water filled in a container maintained at constant temperature of 30°C in a temperature controlled water bath. Specimens were taken out at regular interval of 24 h, wiped to remove surface moisture and measurements on thickness, length and breadth were recorded for a period of 192 h. The dimensional stability of composite specimens on water exposure was quantified in terms of change in dimensions. The gain in thickness expressed as a percentage of the initial specimen thickness is termed as thickness swelling (T_s). The linear expansion (L_e) was calculated using the following equation:

$$L_e = \left[\frac{\frac{L_t - L_0}{L_0} + \frac{B_t - B_0}{B_0}}{2} \right] \times 100 \quad (1)$$

where, L_t and B_t are the length and breadth of the specimen at time t , and L_0 and B_0 are the length and breadth of the specimen measured at the beginning of the experiment. After the experiment, the specimens were re-conditioned at the same temperature (50°C) and period (48h) at which specimens were conditioned and the difference in mass and dimensions were noted. The difference in mass between conditioned specimens at the beginning of experiment and re-

conditioned specimens after the experiment expressed as percentage of the initial mass is termed as solid loss on water absorption. Similarly, the difference in thickness and linear dimension between the specimens before and after experiment was termed as thickness swelling during sorption-de sorption cycle and linear contraction during sorption-de sorption cycle respectively. The experiment was repeated for five test specimens and the average values were reported.

FIBER MORPHOLOGY

Oil palm fiber morphology was studied by images captured by scanning electron microscope (JSM 840A scanning electron microscope, Japan). The fiber samples surface was vacuum coated with a thin layer of gold to provide electrical conductivity. The layer of gold coating was thin and did not affect the resolution significantly. Accelerator voltage was set to 20 kV and the working distance was 15 mm. Images were acquired digitally using Gellar Microanalytical dPICT software.

FIBER CHEMICAL COMPOSITION

The oil palm fiber, oil seed flax fiber and industrial hemp fiber chemical composition were analyzed using Ankom model A 200 fiber analyzer and residual oil content were analyzed using Ankom model XT 15 extractor.

DENSITY MEASUREMENT

The true density of a material is the mass per unit true volume (excluding the pores). Material mass was measured by a weighing balance of 0.01 mg accuracy and the true volume of a sample was measured using a nitrogen gas-operated multi-pycnometer (Quantachrome Corporation, Boynton Beach, FL, USA)

FIBER IMPURITY CONTENT

In order to determine the impurity content, unwashed oil palm fibers were conditioned at 50°C for 24 hours and approximately 5 g samples were weighed to an accuracy of 0.01 mg and designated as raw sample weight. The sample was washed with distilled water till such time the surface impurities are washed off. Then the surface moisture blotted with tissue paper and kept in oven at 50°C for 24 hours and the weight recorded as clean sample weight. The difference between raw sample weight and clean sample weight expressed as percentage of raw sample weight is termed as the impurity content of fibers. Data reported is average of three replications.

EQUILIBRIUM MOISTURE CONTENT(EMC)

The Equilibrium moisture content (EMC) of oil palm fiber at a temperature of 30°C and humidity levels of 25%, 50% and 75% was estimated. The samples were conditioned at 50°C

for 72 hours in a hot air oven and placed in a temperature and humidity controlled environment chamber (Angelantoni climatic systems, Italy-model UY 150) and weight was monitored periodically till equilibrium. The moisture content at equilibrium expressed as a percentage of initial weight was termed as EMC.

DIELECTRIC CONSTANT

Dielectric constant was calculated from the capacitance values. The capacitance was measured using LCR Q bridge (Model 6018, scientific mestechnik pvt. Ltd., Indore, India). The specimen was placed between copper electrodes and shielded both sides using acrylic insulators of thickness 10 mm and clamped tightly. The measurement was done at a frequency of 1 kHz with parallel equivalent circuit. The fiber samples were placed in a cavity and compressed uniformly to 3 mm thickness while taking measurement.

The dielectric constant or static permittivity D_k of a material is defined as the ratio of the capacitance of a condenser containing the material to that of the same condenser under vacuum. The capacitance of a condenser measures the extent to which it is able to store charges. Dielectric constant D_k can be calculated from the capacitance using following equation.

$$D_k = \frac{Ct}{E_0 A} \quad (2)$$

where,

C- capacitance of the specimen

t- thickness of the specimen

E_0 - permittivity of free space (8.85×10^{-12} F/m)

A- area of specimen under electrode.

FIBER THERMAL DEGRADATION BEHAVIOR

The thermal degradation behaviour of oil palm fiber was studied in comparison with flax and hemp fibers in a differential scanning calorimeter (DSC)-TA instruments-Q 2000. The fiber specimens were dried at 70°C for 24 hours and approximately 6-10 mg samples were hermetically sealed in aluminium pans before being scanned. The instrument was operated in a standard mode with heating scheme of 20°C-500°C for oil palm fiber and 20°C-400°C for flax and hemp fibers. The specimen was heated at the rate of 20°C/min in a nitrogen environment purged at 50 ml/min. The thermograms were analyzed for any changes in the thermal behavior between fibers and also on alkali treatment on oil palm fiber.