IOP Conf. Series: Materials Science and Engineering **191** (2017) 012003 doi:10.1088/1757-899X/191/1/012003

A study on flammability and moisture absorption behavior of sisal/coir fiber reinforced hybrid composites

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Abstract. Cellulosic fiber reinforced Polymer Matrix Composites (PMC's) are more frequently applied in construction industry and transportation, in which their flammability and water absorption behaviors are important. Fire resistance of cellulosic fiber reinforced composites is important parameter that often limits the application of composites in a given area. This work presents experimental results of a fire retardant behavior and moisture absorption behavior of different weight percentage (10, 20, 30, 40 and 50 wt. %) of sisal/coir fiber reinforced epoxy resin hybrid composites. Traditional cold pressing method was used to fabricate hybrid composites. Flammability behavior of the hybrid composite was studied by using vertical and horizontal burning rates as per standard UL-94. Addition of the cellulosic fiber increases the flammability since natural fiber supports fire. It proves as a bad flame retardant due to the generation of a surface layer during pyrolysis of the cellulosic fiber which exhibits poor fire retardant nature. This layer acts as supporter of fire, which spreads the heat from being transferred to the un-pyrolised material. The speed of flame is much faster in vertical burning position compared to horizontal burning position due to preheating of the specimen. Moisture absorption of sisal/coir fiber reinforced epoxy resin hybrid composites are studied according to ISO 62:1999 standard procedure. Absorption of moisture increases with increasing in the reinforcement weight percentage of cellulosic fiber in fabricated hybrid composite.

1. Introduction

Greater attention has been given to the cellulosic fiber reinforced Polymer Matrix Composite (PMC) materials in recent times due to persistent discussions on the climate changes and regulatory demands underlining the need for clean environment and utilization of renewable resources. This is mainly because the cellulosic fibers are de-composing in soil after use. Apart from decompose in nature, the cellulosic fibers involves number of advantages over petroleum based fibers such as high strength to weight ratio, abundantly available, low cost, easy process ability at relatively less energy requirement in tooling and assembly costs, higher strength and stiffness have made cellulosic fiber reinforced bio-composites widely acceptable in structural applications (1). Another distinct advantage is their ability to be engineered to obtain required properties in different directions by appropriate fiber placing in different layers of the laminated structure. Cellulosic fibers like sisal, hemp, coir, bamboo, banana, etc., have gained substantial important as reinforcements in PMC's. Among all cellulosic fibers sisal and coir fibers are most widely used cellulosic fibers and very easily cultivated. Sisal fiber is a hard fiber extracted from leaves of sisal plant. Coconuts are abundantly growing in coastal area of India. Coir fiber is one of the major wastes found in the southern coastal regions of India. Sisal and coir fibers are hydrophilic in nature and large amount of hydroxyl groups will give hydrophilic properties. This property will lead to a very poor interfacial bonding between fiber and hydrophobic matrix and very poor moisture absorption resistance. To enhance interfacial bonding between fiber and matrix fiber surface treatment must be carried out. Libo Yan et al. (2) studied the effect of sodium hydroxide treatment on microstructure and mechanical properties of natural fiber reinforced polymer composites. Noorunnisa Khanamet et al. (3) studied the effect of different types of surface modification of sisal fibers on the tensile and flexural properties of sisal fiber reinforced composites. Many authors have studied the effect of coir and sisal fiber based composites for physical and mechanical properties (4-5). These properties are based on the nature and morphology of the fiber, matrix properties and fiber-matrix interaction.

Environmental awareness motivates the use of cellulosic fibers, but their composites shows worse in flammability behavior compared to glass, carbon, etc., fiber reinforced composites. The application of advanced PMC's is constantly growing, especially in automotive, structural applications and industrial sectors. Flammability is a censorious matter in numerous industrial applications especially in the region of transformation where small spaces make fires a noticeable hazard. M.W.Chai (6) et al. compared the fire retardant behavior of glass fiber and flax fiber reinforced epoxy resin composites. Flax fiber reinforced composites burst into flames earlier, releases higher amount of heat and their structure deforms notably during combustion. K.Ramanaiah (7) et al. studied fire retardant behavior of polyester resin and sansevieria fiber reinforced polyester resin composite. In results, sansevieria fiber reinforced composite catches fire earlier, release high amount of carbon dioxide and total smoke during combustion compared to un-reinforced polyester resin. Although in practice the commercial applications of natural fiber based plastics are constantly growing, there is still poor interpretation of certain aspects of their behavior, such as their fire retardant behavior. With the above background, the goal of present research work is to fabricate sisal/coir fiber reinforced epoxy resin bio-composite and conduct the burning rates test and evaluate the response of the composite to fire and water absorption behavior.

2. Experimental details

2.1. Used materials

Sisal and coir fibers were used in this study. These cellulosic fibers were collected from plants grown in Karnataka (India). Epoxy resin araldite (AW106) and corresponding hardener (HV 953) were used to fabricate hybrid composite sheets, which is a low temperature curing epoxy system. Epoxy resin and hardener at a ratio of 10:1 was mixed to prepare matrix material.

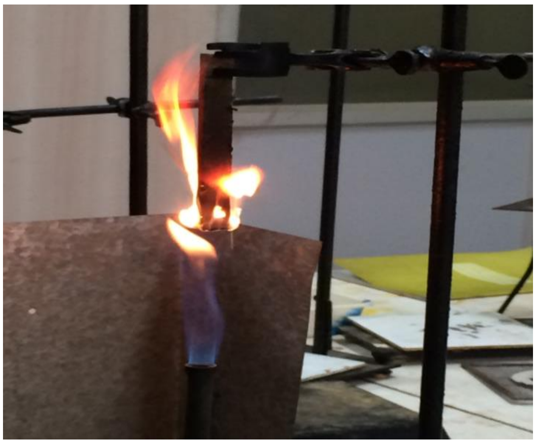
2.2. Hybrid composite preparation

A simple cold pressing method was used to prepare the hybrid composite sheets in metallic (cast iron) mold at high pressure. Were hydraulic pressing machine was used to fabricate hybrid composite sheet. Both female and male dies are coated with a thin layer of Poly Vinyl Alcohol (PVA) to ensure that the sheet will not adhere to the mold. Sisal and coir fibers were mixed and added in to matrix material in a boul. 10, 20, 30, 40, and 50 wt.% of sisal/coir (1:1) fibers are used to fabricate the hybrid composite sheet. A thoroughly-mixed mixture of sisal/coir fibers and matrix was discharged into the female die cavity. The male die was laid down on the female die and pressed to 410.4 kg/cm2 from hydraulic pressing machine for 3 hours. After drying, the hybrid composite sheet was cut to specimens to conduct vertical and horizontal burning rates and moisture absorption test according to UL standard (125*13.3*3 mm) and ASTM D-570 respectively.

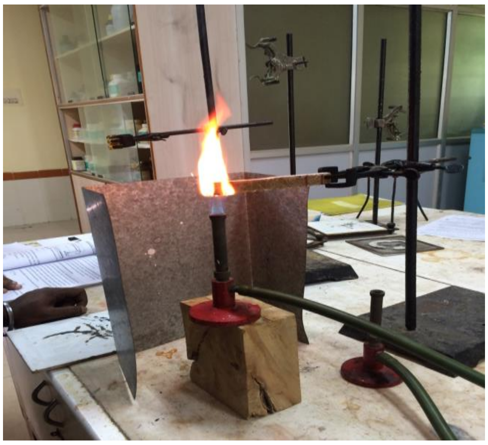
3. Results and discussion

3.1. Flammability behavior of hybrid composites

Fire retardant of sisal/coir fiber reinforced hybrid composite samples of size 125*13*3 mm was characterized for flammability behavior according to UL-94 standard for getting vertical and horizontal burning rates. For horizontal test, a 25mm Bunsen flame was applied to the leading edge of the sample. 6.35mm length of samples is introduced to Bunsen flame for 30 sec without altering place of Bunsen flame and sample. Then the sample is withdrawn from the flame. When the sample burns to the 25.4 mm mark before 30 seconds then the flame is removed. If the sample constantly burns after displacement of the flame, the time for the fire front to travel from the 25.4 mm to the 101.6 mm mark from the free end is noted to calculate the rate of burning. In vertical rate of burning test, a 19.05 mm Bunsen flame is applied to the bottom of the sample for 10 sec, replaced and then reapplied for a supplementary 10 seconds. The time of flaming and glowing is recorded as soon as the sample is replaced. The experimental setup for burning tests is as shown in figure 1.



(a) Vertical burning set-up



(b) Horizontal Burning set-up

Figure 1. Flammability burning setup of hybrid composites

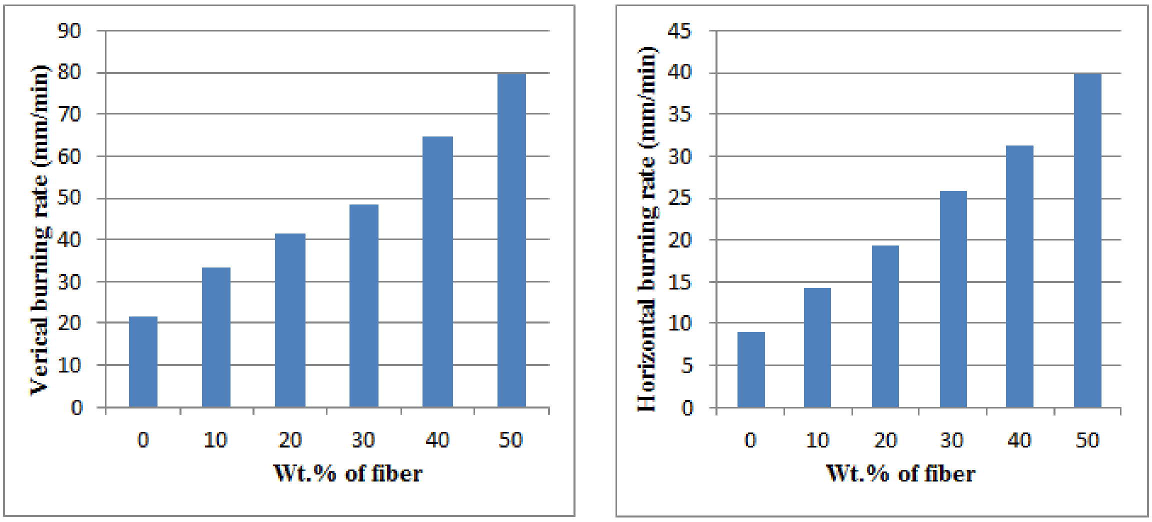


Figure 2. Burning rate of hybrid composites with different wt.% of sisal and coir fiber loading

The figure 2 represents the graphical representation of burning rate of vertical and horizontal burning for various wt. % of sisal/coir fiber reinforcement. The results indicate that addition of natural fiber increases the flammability. Hence natural fiber supports fire and is a bad flame retardant due to the generation of a surface layer during pyrolysis of the natural fiber composites which discloses poor fire retardancy. This layer behaves as supporter of fire, which spreads the heat to the un-pyrolised substance. In vertical burning test, the speed of flame is much faster than in horizontal position due to preheating of the specimen.

3.2. Water absorption of hybrid composites
Water absorption property of sisal/coir-epoxy resin hybrid composites was evaluated according to ISO 62:1999 standard procedure. Fabricated hybrid composite specimens were dried in oven at 500C and cooled to room temperature. After weighing the dried specimen to an accuracy of 0.1mg, they were immersed in distilled water in a plastic tub at room temperature. Once in 24 hours, the specimens were taken out from plastic tub, all the water from the surface was removed with clean cloth and the specimens were weighed. Same procedure was repeated for 28 days. The percentage of water absorption of sisal and coir fiber reinforced hybrid composites increases with increasing the fiber content (4). The percentage of water absorption was plotted against the time (days) as shown in Fig 3 which shows that the water absorption becomes stable after 25 days. Fig 4 shows the variation in the amount of moisture absorption with increase in fiber content. This shows that the moisture absorption increases with the increase in fiber content, thus composite sample shrinks, expands and de-bonding between fibers and matrix. As the composite sample shrinks and expands, de-bonding between fibers and matrix creating a voids which act as a reservoir for the water, so increasing its overall saturation level. Indication of this model is suggested by drying out the samples and gauging the post-test weight. With recognition that, moisture plays an important role influencing the mechanical behavior, the long term durability of PMC's. Water diffuses through the matrix and reaches the inter phase region and the reinforcement. Dissolution of polymer matrix, de-bonding of fiber matrix inter phase and degradation of fibers during aging in water, may all lead to the reduction in mechanical properties of the PMC's. Shrinkage and swelling of fibers may also happen, causing the decoupling at interphase, which leads to the de-bonding of the fibers. It is seen that the samples are immersing in water leads to rapid de-bonding, delamination and loss of structural integrity. Thus, the strength of PMC's is affected by immersion in water. The figure also shows that the moisture content increases with the increase in the soaking duration. Higher water absorption rates can be attributed to the hydrophilic property of cellulosic fiber due to the hydroxyl group (-OH) on the cellulosic molecules. Hydrogen bond forms between water molecules and hydroxyl group (8).

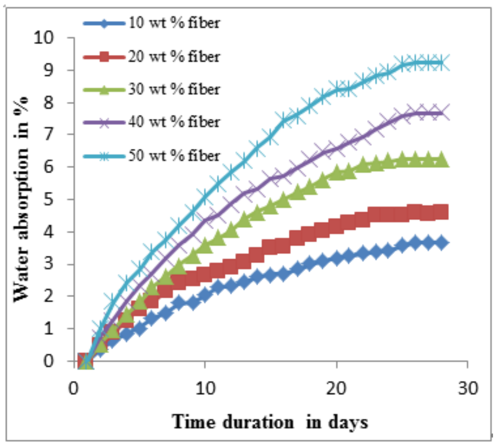


Figure 3. Wt.% of moisture absorption of different sisal/coir content of hybrid composites

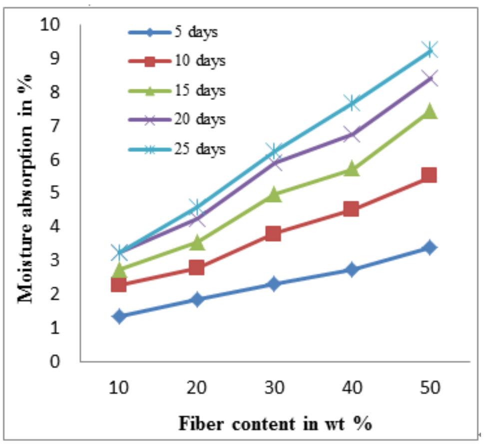


Figure 4. Variation in the amount of moisture absorption with increase in fiber content.

4. Conclusions

Experiments were conducted to establish the fire retardant behavior and moisture absorption behavior of different wt. % of sisal and coir fiber reinforced hybrid bio-composites. The experimental results lead to the following conclusions.

- Increasing the weight percentages of fibers in composites increases flammability and discloses poor fire retardant.
- Among all fabricated hybrid composites, 50 wt. % fibers reinforced hybrid composites burst into flames earlier, liberates more quantity of heat, and deforms in shape notably during combustion.
- Moisture absorption (%) behavior reveals that the absorption of water content of hybrid composites increases with increase in the wt.% of fiber content and also increases with the increase in the soaking duration.0
- Sisal/coir fiber reinforced polymer matrix composites can used in many applications like domestic (window panels, tables, etc.,), automobiles (car dash-boards), etc., but they are not suitable where the fire response is serious consideration.

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