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Technical Report

Degradation of compressive properties of pultruded kenaf fiber reinforced composites after immersion in various solutions

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ABSTRACT

In this paper, water absorption behavior of pultruded kenaf fiber reinforced unsaturated polyester composites was investigated. Residual compressive properties of the composites after immersion were also reported. Composites were prepared using pultrusion method with minimum kenaf fiber content of 70% w/w. Water absorption tests were performed at room temperature under three different solutions, i.e. distilled water, sea water and acidic solution. The diffusion coefficient of water absorption and maximum moisture content were calculated by measuring the water uptake of specimen at regular time interval. Diffusion coefficient and the highest moisture content values were recorded for composite immersed in distilled water followed by acidic solution and sea water. The water absorption of kenaf fiber reinforced unsaturated polyester composites was found to follow a Fickian's behavior where it reach equilibrium. The compressive properties were found to decrease with the increase in the percentage of water uptake. The decay in compression properties is attributed to the plasticization of the fiber–matrix interface and swelling of the kenaf fiber.

1. Introduction

Natural fibers form an alternative for most widely applied synthetic fiber in composites technology and manufacturing. The interest in natural fiber was known because it is cheap and lighter in weight which provides better stiffness per weight than glass. Furthermore, natural fiber source is renewable where it considered being green and environmentally friendly. By their fairly good mechanical properties the usage of natural fiber are retained in all sort composite preparations. Unlike natural fiber, synthetic fibers like glass have been used as reinforcement in composite manufacturing via various fabrication methods. Similarly, if natural fiber reinforced composites (NFRC) were to offer an alternative fiber to the composite industry, it has to accommodate all the processing avenues of it counterpart, glass fiber.

There exist many natural fibers which have been explores such as sisal, jute, flax, hemp, etc. One of the popular natural fibers is kenaf fiber. These kenaf is an annual plant due to its rapid growth and it is an inexpensive and a renewable source plant. Kenaf fiber is obtained from the bast of stems of plants genus *Hibiscus*, family of *Malvaceae*, species of *H. cannibinus* and requires less water to grow because it has growing cycle of 150–180 days with average yield of 1700 kg/ha [1].

Similarly, various composite manufacturing techniques available such as, RTM, compression moulding etc. However, some of these techniques require fiber in the continuous form which is not readily available form of natural fiber. In the case of engineering composites, filament winding and pultrusion methods are most popular. Pultrusion is a unique processing technique for composite manufacturing. Pultruded composite is always associated with high strength, stiffness which particularly due to high fiber content, i.e. 70%. So, pultrusion is among a few composite processing techniques that could process composite with up to 70% fiber content in unidirectional fiber configuration. It is a continuous molding process to manufacture a composite by using continuous fiber and liquid resin. The impregnation is accomplished by guiding the reinforcement over and under rods located below the resin surface [2]. The fiber is dipped into impregnated resin bath and emerges via shape guidance before being heated in the die. Finally the composite is left to cool off before being pulled and cut into the required length.

As we know, our surrounding area is full of moisture and air. All types of polymer composites will absorb moisture to a certain extent when immersed in water or exposed to humid environment [3]. In fiber reinforced polymer (FRP), not only polymer matrix that absorb moisture but also the fiber especially the natural fiber. This particularly due to the hydrophilic nature of the natural fiber that is more sensitive towards water absorption than synthetic fiber which causing instability in the properties of the composites [4]. There are three different mechanisms that conduct the moisture

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penetration into composites materials namely: (1) diffusion of water molecules into the micro gaps between polymer chains, which is the main mechanism, (2) capillary transport into the gaps and flaws at the interfaces between fibers and polymer, due to incomplete wettability and impregnation, and (3) transport by micro cracks in the matrix, formed during the compounding process [4]. It has been demonstrated that the water absorption affect the performance of natural fiber reinforced composites [3,4].

In this study, kenaf fiber reinforced polyester composites were immersed in three different solutions; distilled water, seawater and acidic solution at room temperature. The water absorption behaviors of the composites under these three different solutions were evaluated. Composite samples in the form of compression test specimen were used. Compression properties before and after immersion were analyzed and discussed.

2. Experimental

2.1. Materials

Kenaf fiber was obtained from herbaceous annual plant extracted from stem provided by Malaysian Tobacco Board (LTN), Malaysia. The polyester resin used for the study was purchased from Revertex (Malaysia) Company.

2.2. Preparations of composites

Unidirectional Kenaf fiber reinforced unsaturated polyester composites were prepared using pultrusion technique. The kenaf fiber is stored in a creel stand, and was then guided into preheating chamber. Kenaf yarn was then pulled through resin bath and followed by the heated die where the kenaf fiber fully impregnated with polymer resin before going into cooling die. The processing parameters are given in Table 1.

2.3. Material characterization

2.3.1. Water absorption tests

Moisture uptake was determined by measuring the weight periodically by soaking the specimen in water. Compressive specimens were used and prepared in accordance to ASTM D5229. The specimens for compression test were cut into 25.4 mm length and 12.7 mm diameter cylinder. Prior to absorption experiments, the samples were dried until the weight stabilized. The specimens were then immersed in distilled water, sea water and acidic solution at room temperature and the weight change was monitored as a function of time. Typically the weight of the specimen was monitored at the intervals of 24, 48, 72, 96, and 120 until 6240 h (260 days).

2.4. Mechanical properties

2.4.1. Compression test

Compression test were conducted at room temperature in accordance to ASTM D695 [5] test method with a diameter of 12.7 mm and 25.4 mm in length. The crosshead speed was set at 5 mm/min.

Table 1
Parameter of the pultrusion.

Parameter	Pulling speed (mm/min)	Temperature (°C)
Kenaf fiber pultruded composites	195–210	135

3. Results and discussion

3.1. Water absorption

Water absorption behavior of the composite is one of the main concerns in composites structural applications especially for natural fiber reinforced composites. For a given composite system, the water absorption characteristic depends on the content of the fiber, fiber orientation, temperature, area of the exposed surface, permeability of fibers, void content and hydrophilicity of the individual components [3,6–9]. Fig. 1 shows percentage of weight gain as a function of square root of time for pultruded kenaf fiber reinforced polyester composites immersed in distilled water, seawater and acidic solution at room temperature. The percentage of weight gain was calculated by

$$M\ (\%) = \left[\frac{M_1 - M_0}{M_0}\right] \times 100 \qquad (1)$$

where M (%) is the moisture content in percentage; M_1 (g) is the weight of the wet sample at a given time and M_0 (g) is the initial weight of the sample. From Fig. 1, it is clear that the moisture content increases with immersion time. This finding has been reported previously concerning the natural fiber reinforced composites [7,8] although the natural fiber and manufacturing method to prepare the composite are not similar. However, the increase in weight is not consistent with respect to the immersion time. At the beginning of the curve (up to 17 days of immersion), the weight increased sharply demonstrating the rapid moisture penetration into the composite materials. This trend is true for all solutions considered in this study. These phenomena can be attributed to the penetrability of water and capillary action, where it becomes active as the water penetrating into the interface through the voids induced by swelling of the kenaf fibers. Rate of water absorption slows down after 20 days of immersion, before reaching saturation state after 260 days of immersion. It is interesting to note that after 104 days of immersion ($\sqrt{50}$ h), the recorded weight gain of specimen immersed in acidic solution is almost similar to the one immersed in distilled water. Analysis of the solution reveals that the pH of acidic solution was almost neutral (approximately pH 7) after 260 days of immersion in comparison with the initial pH of 3 at the beginning of the test. In the saturated state (260 days of immersion), weight gain of the KFRPC in seawater is the lowest. One possible explanation is that the present of ionic salt in seawater block the diffusion path after a long term exposure thus slows down the absorption process. In general, the water absorption behavior of KFRPC in all three solutions can be considered as Fickian process where it shows an increasing trend at first and followed by saturated trend in the

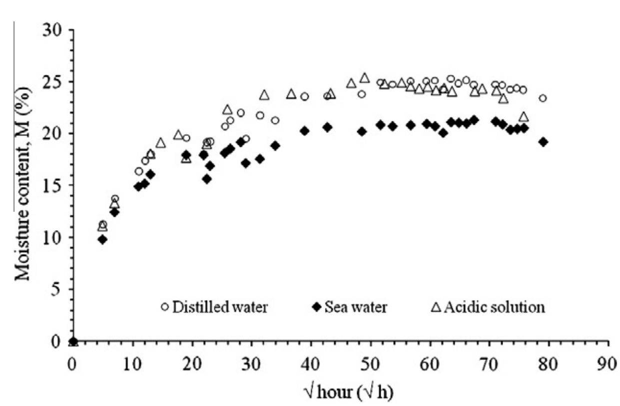

Fig. 1. Water absorption content curves in distilled water, sea water and acidic solution for compression specimens.