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Development of Epoxy/Banana Fibre Composites and their Physical Characterization

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A B S T R A C T

This paper presents an experimental study on the physical behaviour of the polymer composites prepared with epoxy as base matrix material and short banana fibre as reinforcement. The banana fibre was used in the form of short fibres. The fibre loading varies from 5 wt. % to 20 wt. %. Two different categories of composites are prepared. In the first category, Composites are prepared with raw banana fibre; in the second category, the composites are prepared with NaOH-treated banana fibre. The properties evaluated are density, void content and water absorption rate. From the investigation, it is concluded that the composites prepared with treated banana fibre deliver better properties than those prepared with raw banana fibres in terms of physical properties under investigation.

Keywords: Epoxy, banana fibre, surface modification, density, voids content, water absorption rate.

1. Introduction

Banana fibre is obtained from the pseudo-steam of banana plants mostly available in coastal areas. It is lingo-cellulose fibre and comes under the category of bast fibre which possesses good mechanical properties when compared to other natural fibres. Apart from various natural fibres, it has been seen that banana fibre has good specific strength properties comparable to synthetic fibre i.e. glass fibre. This is the main reason banana fibre in its long form was used as reinforcement in polymers and was investigated by many researchers in past. In this series, Joseph et al. [1] compared the mechanical properties of glass fibre-reinforced composites with banana fibre-reinforced composites. They performed a fibre pull-out test to evaluate the adhesion between the fibre and matrix body. In their analysis, they found that banana fibre shows better adhesion than glass fibre with a matrix material. S.M. Sapuan et al [2] studied the mechanical properties of woven banana fibre-reinforced epoxy composites. Idicula et al. [3] studied the thermophysical properties of banana fibre-reinforced polyester composites. Thermal conductivity, thermal diffusivity and specific heat are the major properties studied by them. Liu et al. [4] used banana fibre in high-density polyethene in their study and evaluated the morphological, water absorption and thermal stability of the fabricated samples.

Later Paul et al. [5] used banana fibre in the form of short length and incorporated it in polypropylene. Before that, they modified the surface of banana fibre with various chemical treatments to provide good adhesion between the fibre and matrix body. They used the solvatochromic technique to investigate the polarity parameters of the chemically modified banana fibre. After that, they observed that the polarity of the banana fibre decreased after the chemical treatment. The adhesion between the matrix and fibre was increased drastically as observed by the micrograph. The most effective treatment was alkali treatment as reported in their study.

Raghvendra et al. [6] used banana fibre with rubber and established natural rubber-based composites. They studied the mechanical properties of the fabricated composites. Venkateshwaran et al. [7] found that fibre length and its content were the most influential factor which determines the mechanical properties of the composites. In their study, they optimize the length of the fibre and produce a set of composites with varying content of fibres. Ramesh et al. [8] also fabricated banana fibre-reinforced polymer composites with thermoset polymer epoxy and experimentally determined its mechanical properties. Jorden et al. [9] improve the interfacial bonding between banana fibre and LDPE matrix with the help of chemical treatment. They used two different techniques for fibre treatment i.e. peroxide treatment and permanganate treatment. With two different techniques, they fabricated different sets of composites and evaluated the tensile and flexural strength. In their analysis, they found that peroxide treatment of fibre enhances both the properties of the composites whereas, permanganate treatment results in no effect on the properties of composites.

Muktha and Gowda [10] focused their work on the water absorption and fire resistance behaviour of banana fibre-reinforced polyester composites. Komal et al. [11] studied the effect of surface modification of banana fibre on the mechanical properties of polypropylene-based composites. They also investigated the thermal properties of the composites prepared with untreated and treated fibres. In their analysis, they found significant improvement in the different mechanical and thermal properties of the composite material prepared with the NaOH-treated banana fibres. Pham et al. [12] study the effect of processing parameters of the acrylonitrile butadiene styrene-reinforced banana fibre composites. Mohan and Kanny [13] studied the mechanical characteristics of unmodified and nano-clay-treated banana fibre-reinforced epoxy composite cylinders. They compared the properties of nano clayinfused banana fibre-reinforced composites with alkaline (NaOH) treated and untreated banana fibre-reinforced epoxy composites. Eze et al. [14] studied the effect of various surface treatments on the banana fibre on the mechanical properties of polyester-based composites. From the analysis, they concluded that acetic acid and sodium sulphite are good surface treatment reagents but less effective than 3-aminopropyltriethoxysilane (APTES) silane solution for the improvement of the tensile properties of banana pseudo-stem fibre-reinforced polyester composites for different industrial applications. Balaji et al. [15] studied the mechanical and thermal properties of epoxy composites reinforced with short banana fibres. From the experimentation, they reported that the various mechanical properties like tensile strength, flexural strength and impact strength increase with fibre loading and show maximum strength values at 15 wt. % of the fibre and decrease thereafter. Subramanya et al. [16] prepared samples using alkali-treated and untreated banana fibres. The effects of alkali-treated fibres were studied. In their study, banana fibre-reinforced epoxy composites are developed and their mechanical properties such as tensile strength, impact strength and fracture toughness are evaluated and found remarkable improvement in those properties. Nguyen et al. [17] studied the mechanical and thermal behaviour of epoxy composites reinforced with banana fibre. In very recent work, Aseer et al. [18] studied the water absorption rate and the tensile properties of polyester/banana fibre composites. Dilipkumar et al. [19] created epoxy/banana fibre composites and examined how fibre content and length impacted the mechanical and acoustic properties of the samples. They modified the fibre reinforcement composition using two different weight fractions—5% and 10%—and three fibre lengths: 10 mm, 20 mm, and 30 mm. The tensile test results indicated that the composite with a 20 mm fibre length and 10% fibre content exhibited the greatest load-bearing capacity and resistance to tensile loading. In the three-point bending test, the composite with 5% fibre content and a 30 mm fibre length showed the highest flexural load-bearing capacity.

2. Material considered

Epoxy is taken as the matrix material in the present investigation. It is used with its corresponding hardener. Epoxy resin composites are cost-effective and are superior in properties. Banana fibre, a well-known natural fibre in the form of short fibre is used as a reinforcement. The main aim of the work is to develop an isotropic material. Sodium hydroxide is used to treat the surface of the banana fibre. In the present work, 2 moles of NaOH are used for the fabrication of the composite body.

3. Composite Fabrication

Epoxy/banana fibre composites are prepared using the hand lay-up method. Before fabricating the composites, the banana fibres are treated with 2 moles of aqueous solution of NaOH. Two categories of composites are fabricated. In the first category, raw banana fibres of approximately 4 mm length are used. For the preparation of the second sets of composites, surface-modified banana fibres of the same size are used. The method used for fabricating the composites for both sets of the samples are same. In each category, four combinations of samples are prepared where the fibre loading varies from 5 wt. % to 20 wt. %.

4. Experimental Results

The experimental density (ρce) of composites under study is determined by using the Archimedes principle using distilled water as a medium (ASTM D 792-91). The theoretical density (ρct) of composite materials in terms of weight fractions of different constituents can easily be obtained using a rule of the mixture model. Water absorption tests were carried out according to ASTM D 570 standard..

5. Results and Discussion

The densities of the neat epoxy and the composites prepared are measured with the help of a well-known water immersion technique based on Archimedes' principle using equation 3.1. The density of neat epoxy is measured to be 1.142 g/cm3. The densities of the epoxy-based composites for two different categories of composites are presented in Figure 4.1. The figure reflects the theoretical density along with the measured density. The theoretical density is obtained from the rule of the mixture model using equation 3.2. From the figure, it is clear that the density decreases linearly with fibre loading. The decrement is mainly due to the less intrinsic density of banana fibre. As the fibre loading increases, the content of the epoxy within the composite decreases and hence the overall density of the composite decreases. Also, the density obtained from the rule of the mixture model is on the higher side as compared to the measured density for each category of the composites. It is because while calculating the density using the rule of the mixture model, we are not taking into account the presence of voids which were there in the actual composites. The density of air voids is less as compared to the density of the two phases used for the fabrication of the composites. In actual composites, air voids are present, whereas, during theoretical calculation, it is not considered. This is the reason why measured densities are always less than the theoretical density.

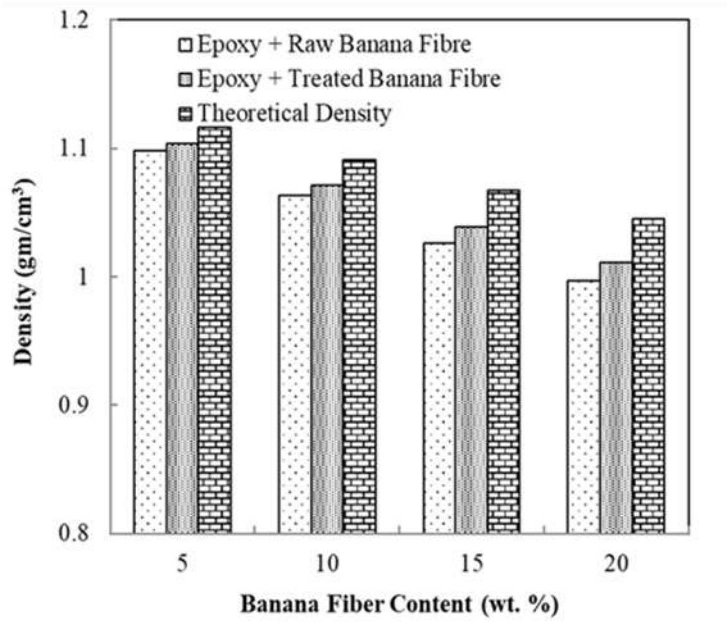

Fig. 1 - Variation of the theoretical and measured density

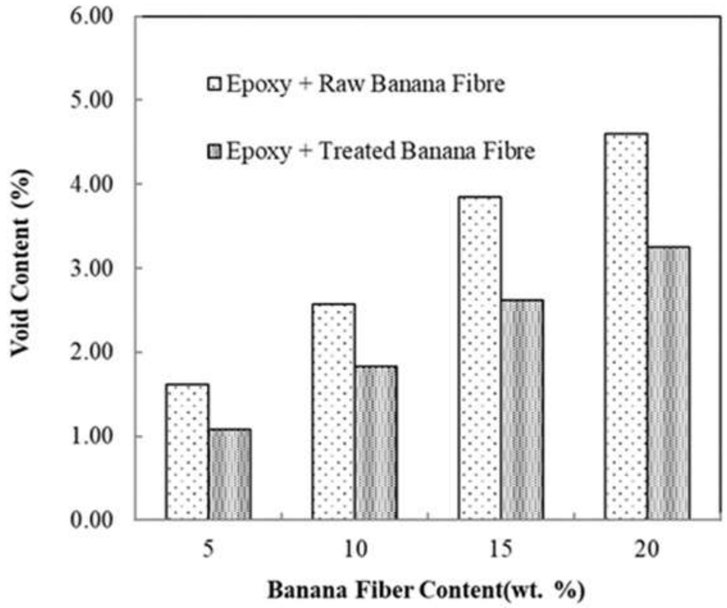

Fig. 2 - Variation of void content

It is further observed that each category of composite shows the different value of density for a given fibre loading. For category I composites, the minimum density obtained is 0.997 g/cm3, whereas, for category II composites, the minimum density obtained is 1.011 g/cm3. It is observed that the density of category I composites is less as compared to the density of category II composites. This is mainly because of the presence of a different number of voids in different categories of composites. The percentages of voids generated inside the composite body during its fabrication are shown in Figure 2. It can be observed from the figure that the content of voids increases with filler loading irrespective of the category of the composite. Also, the maximum voids are present in the category I composite for a given fibre loading.

The weight of all sets of specimens under observation is measured in dried condition, then specimens are dipped into distilled water. After every 24 hours, the samples are taken out from the distilled water. It was properly dried with the cotton cloth and again weights were taken. With the help of two weights, the water absorption rate was calculated. The various data obtained for all categories of the composites are presented in Figure 3 and Figure 4.

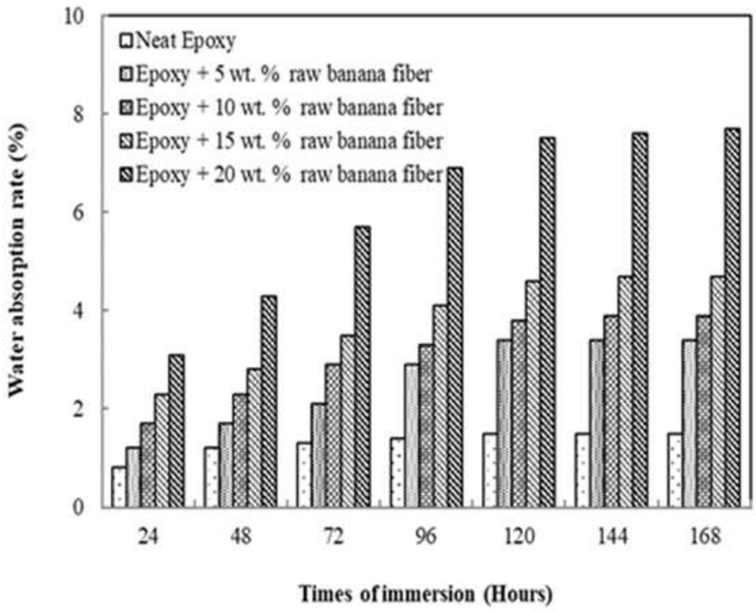

Fig. 3 - The water absorption rate of epoxy/raw banana fibre composites

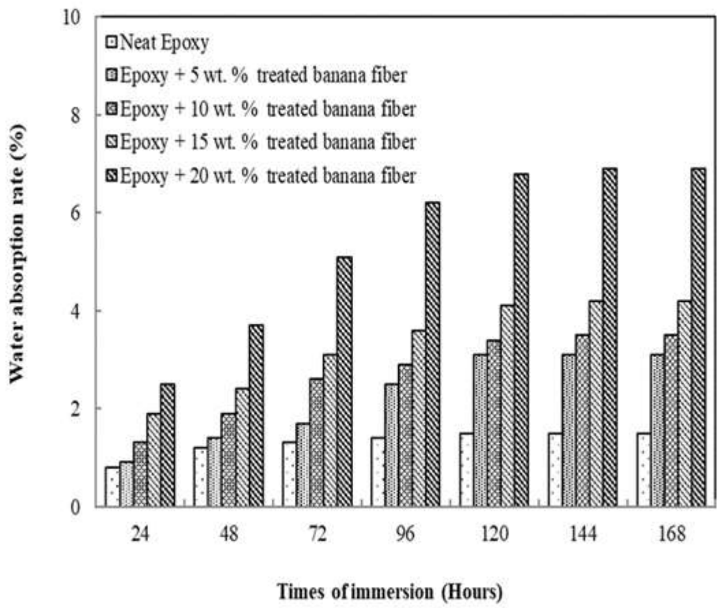

Fig. 4 - The water absorption rate of epoxy/treated banana fibre composites

It can be seen from the figures that as the fibre loading and immersion time increases, water absorption increases irrespective of the category of the composites. The maximum water absorption rate is obtained for the maximum fibre loading and maximum immersion time in all categories of composites. The maximum water uptake recorded for the Category I composite is 7.7 %, and for the Category II composite is 6.9 % for the fibre content of 20 wt. % and immersion time of 168 hours. It is observed that the minimum water absorption is registered for category II composites

6. Conclusion

This experimental investigation on banana fibre-reinforced epoxy composites has led to the following specific conclusions:

1. The density of the fabricated composites decreases with an increase in the weight fraction of the fibre content. The reduction in density is mainly because of the low density of the banana fibre. With an increase in fibre content, the void content of the composite also increases.

2. The water absorption rate increases with an increase in fibre content and duration of immersion of the composite body inside the water. The maximum water absorption rate reported is 7.7 % for Category I composites and 6.9 % for Category II composites.

3. The composites prepared with treated banana fibre deliver better physical properties than those prepared with raw banana fibres.

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