Investigation on the Mechanical Properties of Banana Trunk Fibre–Reinforced Polymer Composites for Furniture Making Application

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Investigation on the Mechanical Properties of Banana Trunk Fibre–Reinforced Polymer Composites for Furniture Making Application

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Abstract. The banana plant is unproductive after it has produced fruits once in its lifetime and the trunk commonly be disposed. Among the disposing methods used are by herbicide injection and burning using kerosene in which are unfavourable due to bad effects to the environment. Thus, the application of the unused banana trunk could be advantageous in saving the environment through its fibre properties as composite. Three tensile test specimens were prepared with each has different weight of banana fibres – 0, 0.45, and 0.9 g. The results demonstrated that the composite with high amount of fibre promoted superior maximum and break stress values. Also, the properties of the composite are convenient to be applied in furniture making as adequate stress level recorded in the numerical analysis.

1. Introduction

Banana plant is classified as a gigantic herb that springs from an underground stem to form a trunk with 3- to 6-meters high. It consists of several main parts such as stem or trunk, leaves, and fruits. The banana trunk which also known as pseudostem, formed by the tightly packed overlapping leaf sheaths. It continues to grow as the leaves emerge one after the other, and reaches its maximum height. Besides the fruit of banana plant can be eaten, its trunk may be used to make garment and natural craft materials [1]. Also, the banana trunk promotes several advantages in medical treatment application, as examples for digestion, detoxification, blood pressure, weight loss, and healing acidity and gastric problems.

The banana plant would only be productive once in its lifetime before it dies. It usually takes about 13 months for the plant to achieve maturity and the fruits are ready to be plucked. The dead plants are usually disposed through few methods. Among the methods are by herbicide injection, burning using kerosene, and cutting down using mechanical tools. The former methods are considerably unfavourable due to bad effects to the environment such as air pollution and toxicity. Therefore, the unproductive banana plant or particularly its trunk can alternatively be utilised for related potential applications owing to its fibre properties. To date, natural fibres are extensively used in many applications for the factors of low cost, low density, light weight, less pollution, and eco-friendly nature. Natural fibre is defined as substances that produced by the plants or animals which can be spun into filament, thread, or rope [2]. Banana trunk fibre is similar to that of natural bamboo, however, it has better fineness and spin ability.

Composite is described as a material made of two or more constituent materials (matrix and reinforcement) with significantly different physical or chemical properties, to produce a new material with characteristics different from the individual component. Typical engineered composite materials are reinforced concrete, composite wood, reinforced plastics, ceramic matrix composite, and metal matrix composite [3]. This study only focuses on the use of common organic matrix which is polymer, to be examined.

The present study, therefore, places a major emphasis on the investigation on the mechanical properties of banana trunk fibre–reinforced polymer composite for furniture making application. There is no study, as yet, found with regards to the use of the proposed composite in the making of furniture. Based on past findings, it was observed that rattan is commonly used as main parts of furniture since 1970s. The technique of weaving reeds and other natural fibres is one of the popular methods considered and used in constructing relevant furniture parts.

2. Materials and Methods

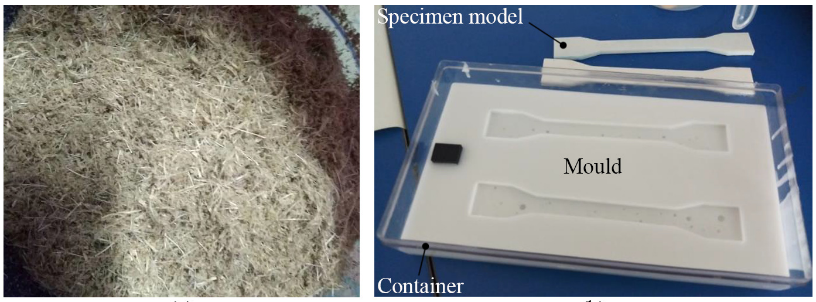
2.1 Banana Trunk Fibres Preparation

A banana trunk from an unproductive matured banana tree was collected from a farm. It was then cleaned and washed with water before cut into several small segments using a cutter, with each 50-mm thick. Only one segment was used and it was chopped into smaller pieces. The fibre was placed under the direct sunlight for 36 hours until it was completely dry or all moisture content is removed.

In this study, the effect of banana trunk fibre quantity (weight) embedded in the polymer matrix on the mechanical properties was a major concern. Thus, it is noteworthy that the size of the fibre was set similar (0.5 mm) among the specimens. For the matrix's material, epoxy resin was chosen to bind all the fibres fixedly together. In total, there were three specimens prepared; 1) Specimen 1: Without fibre (pure epoxy resin matrix), 2) Specimen 2: 0.45 g fibre (14.6 ml epoxy resin matrix), and 3) Specimen 3: 0.9 g fibre (14.6 ml epoxy resin matrix). A manual sifter with the hole size of 0.5 mm was used to filter out all the required fibre size.

2.2 Specimen Mould Preparation

Before proceeding to the testing specimen fabrication, it is a necessary to create its mould first. Hence, a three-dimensional (3-D) model of dumbbell shape representing the specimen's design and dimension, was developed using SolidWorks software and then printed using a rapid prototyping machine. The dimensions of the model are 150, 20, and 4 mm for the length, width, and thickness, respectively. The model acts as the basic shape used to cast the specimen's mould. Silicon rubber and hardener are the type of materials utilised to build the mould with the ratio of 25:1. The silicon rubber offers several advantages over any other materials included its good elasticity and heat resistance. As the mixture of both materials were prepared, it was poured into a container. The printed specimen models were then placed into the solution and the mould was let dry and harden. Figure 1 depicts the dried banana trunk fibres and the hardened silicon rubber mould.



(a) (b)

Figure 1. (a) The dried banana trunk fibres. (b) The hardened silicon rubber mould.

2.3 Tensile Test Specimens Fabrication

To fabricate the testing specimens, a mixture of epoxy resin and hardener was prepared at a ratio of 2:1 to be as the composite matrix, and it was poured into three different containers. Different weights of the fibre – 0, 0.45, and 0.9 g – were inserted into each container separately and stirred evenly. Then, the composite mixture was flowed into the mould and dried at room temperature for about 24 hours. For testing, the tensile test machine was initially calibrated to avoid any errors which could jeopardise the results and the speed of the stroke was set to 30 mm/min.

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2.4 Computational Analysis of Furniture

A numerical analysis was performed on a furniture model to investigate its performance with regards to the properties of the composite obtained from the experimental testing. The 3-D model of a coffee table was therefore designed using SolidWorks software and exported into Abaqus software for the finite element analysis (FEA). Finite element analysis plays an important role in solving mathematical modelling problems in various fields of science, technology, and industry [4-15].

3. Results and Discussion

3.1 Maximum and Break Stress Values

Figure 2 exhibits the specimens condition after the tensile test was performed as well as the comparison of the maximum and break stress values recorded. It was evident that the maximum stresses were significantly increased as the amount of fibre increased. The maximum stress magnitude was slightly lower for both Specimen 1 (0 g fibre) and Specimen 2 (0.45 g fibre) as compared to that for Specimen 3 (0.9 g fibre) with differences of 23.5 and 12.4%, respectively. Similar observations were seen for the break stress results wherein Specimen 3 (29.8 MPa) still superior with approximately 1.3- and 1.1-fold greater break stress value than Specimen 1 (22.1 MPa) and Specimen 2 (26.1 MPa), respectively.

A possible explanation for the higher stress levels generated in the specimen with increased amount of fibres is due to the high fibre-to-matrix contact area. The increase in fibre numbers has increased the contact area accordingly. In comparison, it was noteworthy that there was no difference observed between the maximum and break stress magnitudes for Specimen 2 and Specimen 3. In contrast for Specimen 1, the maximum stress was slightly greater than the break stress level by about 3%. This could be owing to the brittleness of the materials possessed which has resulted in no plastic deformation or strain hardening phenomenon occurrence before fracture. The results were in agreement with the type of specimen fracture shown in Specimen 2 and Specimen 3 by which no constriction or necking found to indicate the elongation under the application of tensile load.

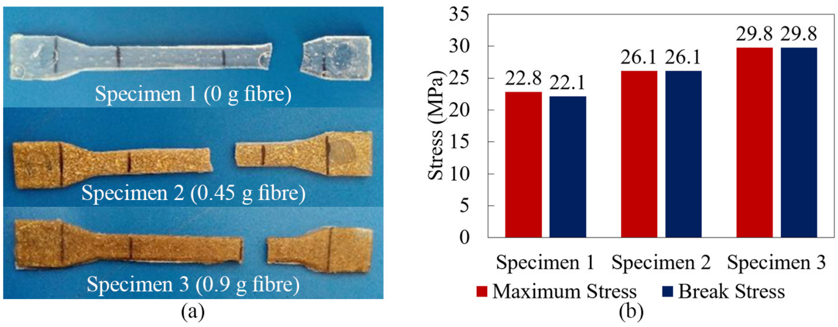

Figure 2. (a) The condition of specimens after tensile test. (b) The comparison of maximum and break stresses among all specimens.

3.2 Maximum von Mises Stress Distribution in Furniture Model

The results of FEA in form of von Mises stress dispersion within the coffee table model are illustrated in Figure 3. Based on the tensile test outcomes, it was recorded that the elastic modulus, E of the tested composite is about 2 GPa with Poisson's ratio, v of 0.3 assumed. These material properties had been considered in the pre-processing settings of the analysis which were assigned for the table legs. The model was meshed with four nodes solid tetrahedral elements and a load of 981 N was applied onto the top surface of the table.

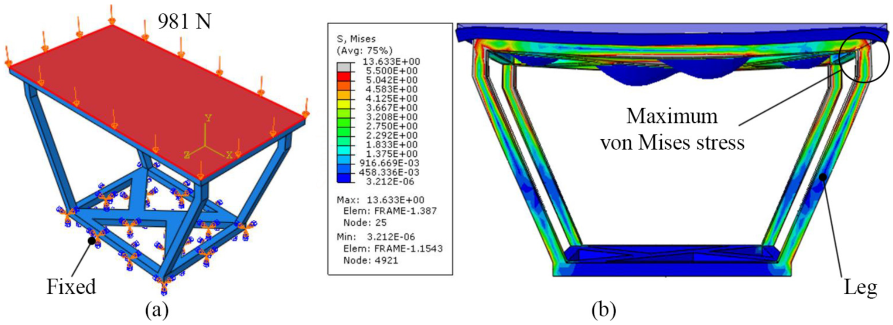

Figure 3. (a) The applied loading and boundary conditions on the FEA model. (b) Von Mises stress plot for the table model that assigned with the composite properties.

The findings demonstrated that the load was evenly distributed through out the legs with high stress concentration discovered at the top regions. The maximum von Mises stress value generated in the table was 13.6 MPa shown in grey colour contour plot. The value seems considerably way lower than the typical range of ultimate tensile stress value of the natural fibre–reinforced polymer composite. It may therefore be claimed that the properties of banana fibre–reinforced epoxy resin composite are favourable in producing encouraging stress level within the furniture.

4. Conclusions

The results of this study support the following conclusions. The mechanical properties of banana fibre–reinforced epoxy resin composite was remarked to be satisfactory in furniture making application as it predicted promising mechanical stress level through computational analysis. Moreover, the properties of the composite were evident to significantly be improved with the increase in the amount of fibre embedded within the polymer matrix.

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