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Experimental investigation on characteristics of sisal fiber as composite material for light vehicle body applications

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ABSTRACT

Sisal fiber composites became attractive due to their high specific strength, lightweight and biodegradability. The aim of this work is to examine characteristics of sisal fiber as composite material for light body vehicles on experimental basis. Composite materials prepared using biodegradable natural fibers are found to be most promising materials which can be used in vehicle body which results in reduction of overall weight of the vehicle. In this work sisal fiber was used. Sisal fiber was extracted using knife from the sisal plant leaves collected from Ethiopian highland. To remove cellulosic matter and improve surface roughness of the sisal fiber, it was immersed in sodium hydroxide solution for 24 h. The specimen of composite material is prepared using the general purpose resin as a matrix, the hardener and the sisal fiber as a reinforcement material with the fiber orientation of 0^0, $\pm45^0$, 0^0 & 90^0 by using experimental (hand layup fabrication technique). The specimen was prepared and tested as per ECAE and ASTM standard. From the test results it was found that sisal fiber composite is a good light weight replacement for conventional materials in vehicle body applications. From the experiment result it was observed that different orientation of fiber has shown enhanced mechanical properties of the sisal fiber composite material.

1. Introduction

In order to safeguard natural resources and economize energy weight reduction has been the main focus of vehicle manufacturers in the present situation. Weight reduction can be accomplished primarily by launching of better material, design optimization and better manufacturing processes. Even though there are several causes that influence entire product development process to recognize a lightweight vehicle, from the point of view of vehicle structural design, the main leading criteria for material choice are rigidity and strength properties that will determine the overall capability of the vehicle during static and dynamic loading conditions [1].

Conventionally, the materials used in the construction of vehicle bodies are mostly different grades in steel. Although aluminum-intensive body concepts were used starting from managerial class cars, and then later on applied to other car classes. Plastics mainly control the vehicle interior, their external application being mostly limited to non-load bearing components even though recently some modern plastic materials are being approved out on some automobile parts such as engine frame and forward bumpers subsystems to decrease the vehicle weight and get better the occupant and pedestrian safety. Composite materials made up of natural fibers like sisal are found to be more promising in reducing weight of the vehicle [1,2]. The objective of this experimental study is to prepare sisal fiber composite material with different fiber orientation and test its mechanical properties. Composites are like reinforced concrete where the rubber is implanted in an isotropic matrix called concrete. Their low-density values permit producing composites that unite

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Fig. 1. Fiber Orientation a .0^0 b. (0^0, 90^0) c. ±$45^{0.}$

a b

Fig. 2. a. Hand lay up using normal brush b. Hand lay up using Roller Brush.

Fig. 3. Mold under compression.

good mechanical properties with a small specific mass. In tropical countries fibrous plants are available in great quantity [3]. If composite materials are practical to automobiles, it is estimated that the vehicle weight, noise and vibration are reduced. In addition to that, composites have a very high resistance to fatigue and corrosion [4]. Hence, these composites have attracted much attention, and are becoming increasingly important to the production of a broad variety of cheap lightweight environment friendly composites [5,6]. The Alkali (NaOH) treated sisal fibres were used as unique reinforcement to attain the composites with self-synthesized epoxy resin as matrix. The fibres were arranged in randomly oriented manner. The compression moulding was used to prepare the composites [7]. Three cementitious composites containing different natural fibres (flax, hemp and sea-grass) were evaluated from an environmental perspective by means of Life Cycle Assessment (LCA) method applying the cradle-to-gate approach [8]. Composite is a material in which two or more constituent materials are combined and produce single material. The composite material provides the required physical and/or chemical properties. Moreover, composite materials are stronger, lighter, and less expensive than traditional materials [9]. Among many natural fibres like kenaf, jute, oil palm, cotton, flax, banana and hemp, sisal are gaining attention as they are abundantly available, cheaper, eco-friendly and possess remarkable and satisfactory mechanical properties to hemp, banana, and jute [10]. Oil Palm Empty Fruit Bunch (OPEFB) and sugarcane bagasse (SCB) fibres were treated with three types of chemicals: 2% silane, 4% H_2O_2 and 4% H_2O_2-2% silane for 3 h [11]. The effectiveness of various types and degrees of surface modification of sisal fibers involving dewaxing, alkali treatment, bleaching cyanoethylation and viny1 grafting in enhancing the mechanical properties, such as tensile, flexural and impact strength, of sisal-polyester biocomposites are studied [12].

The objective of this work is to examine characteristics of sisal fiber with different fibre orientation, as composite material for light body vehicles.

2. Methodology

In this investigation which aims to substitute mild steel by sisal fiber composite material which is lightweight and biodegradable material. Different types of materials, chemicals and equipment were used in preparation and testing of sisal composite material to achieve the set objective.

2.1. Steps involved in the fabrication of sisal fiber reinforced unsaturated polyester composite

Matrix material is prepared by mixing GP resin and Hardener in standard proportion. Weaving of chemically treated sisal fiber in 0, 45 and 90 degrees orientation. Molding was done using hand layup technique. Curing was done by applying the necessary weight. After curing specimens of Sisal Fiber Reinforced Unsaturated Polyester Resin (SFRUPR). The specimens were cut as per standard dimensions. Testing of the specimens was done for tensile strength and bending.

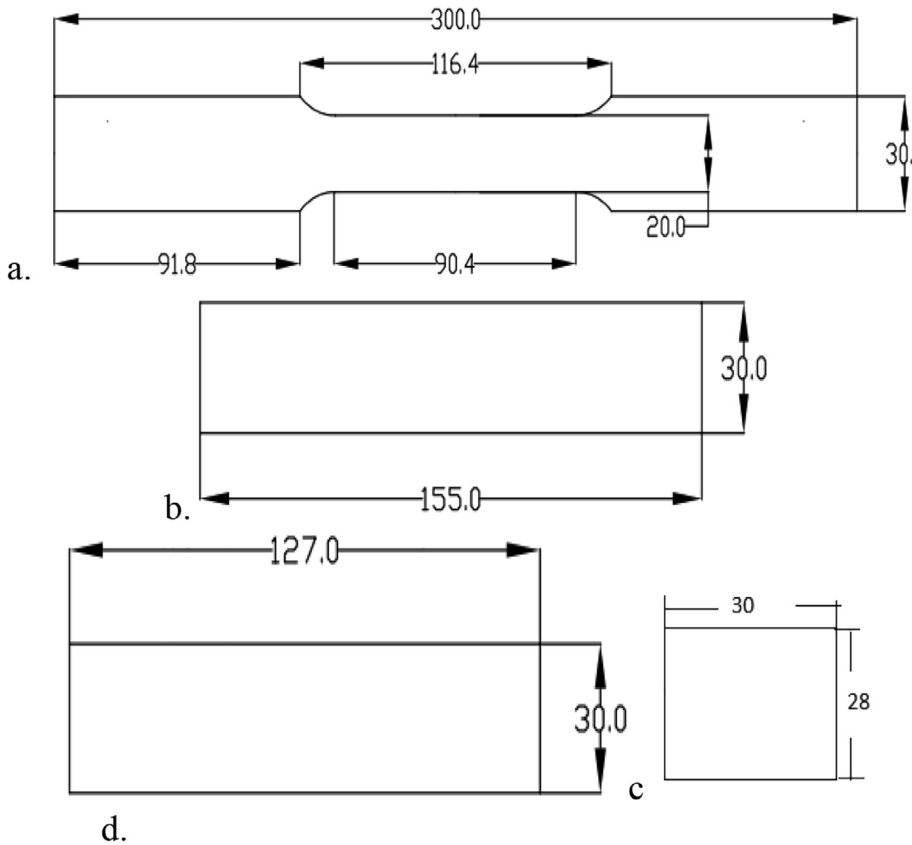

Fig. 4. Test specimen dimensions – (a) Tensile Test Specimen (b) Compression Test Specimen (c) Bending Test Specimen d. Water Absorption Test Specimen.

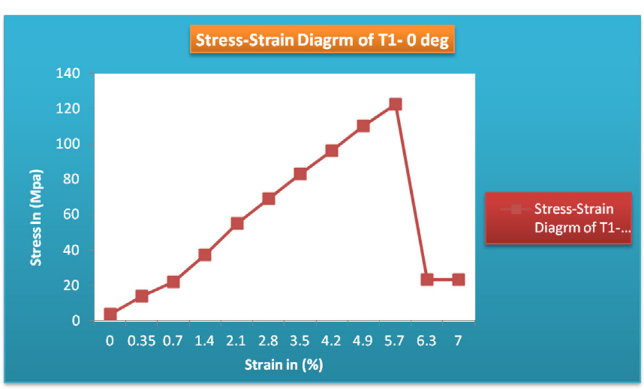

Fig. 5a. T1 (47.8 mm × 17.85 mm × 4 mm) – 0^0 fiber orientation (T_{str} = 93 MPa).

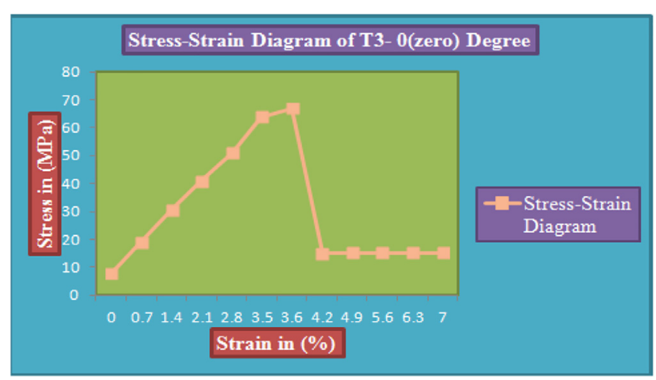

Fig. 5c. T3 (57.5 mm × 21.37 mm × 4 mm) – 0^0 fiber orientation (T_{str} = 62 MPa).

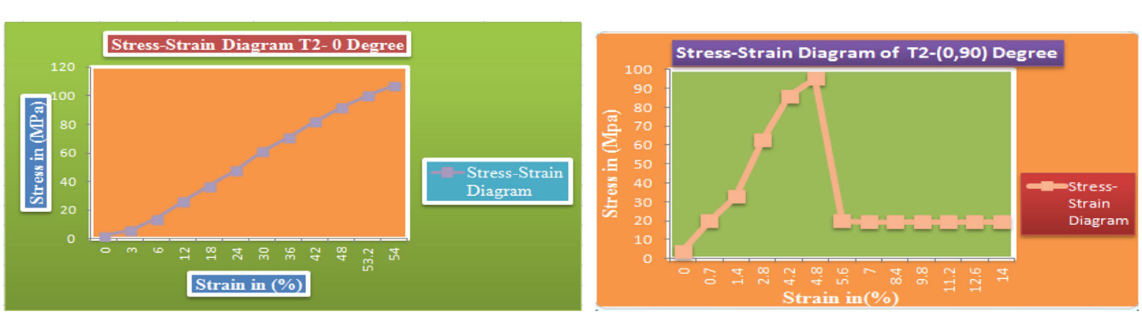

Fig. 5b. T2 (57 mm × 21.15 mm × 4 mm) – 0^0 fiber orientation (T_{str} = 111 MPa).

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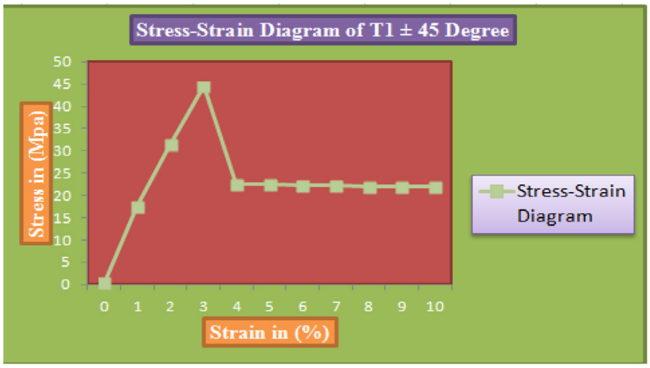

Fig. 6. T1 (60 mm × 20.5 mm × 4 mm) ± 45^0 fiber orientation (T_{str} = 39 MPa).

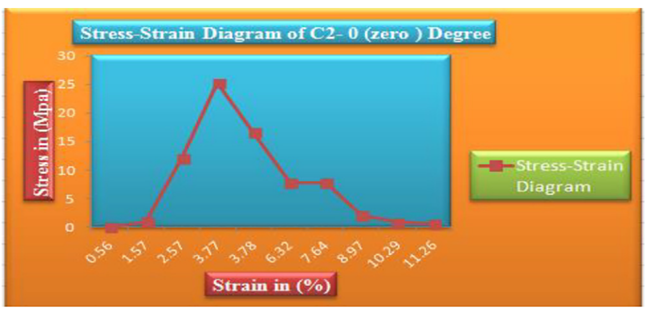

Fig. 7. T2 (60 mm × 20.5 mm × 4 mm) ± 45^0 fiber orientation (T_{str} = 35 MPa).

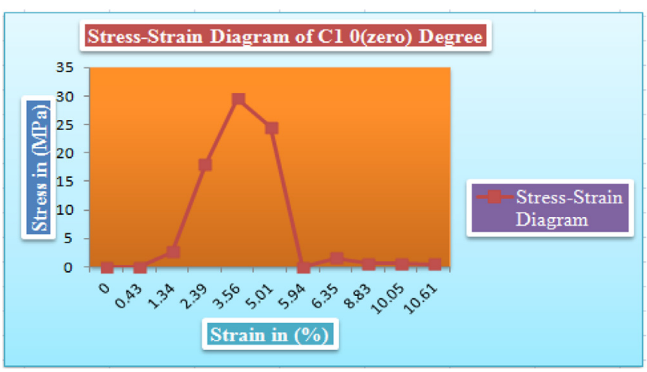

Fig. 8a. C1 (155 mm × 30 mm × 4 mm) 0 (zero) degree fiber orientation (C_{str} = 29.58 MPa).

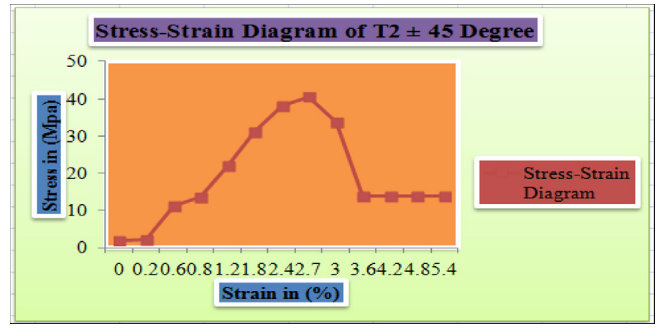

Fig. 8b. C2 (155 mm × 30 mm × 4 mm) 0 (zero) degree fiber orientation (C_{str} = 25.25 MPa).

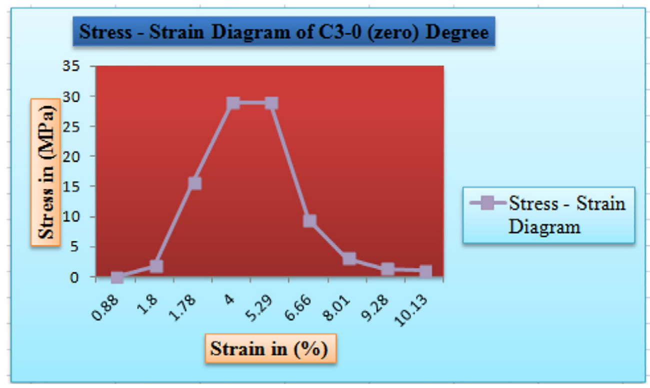

Fig. 8c. C3 (155 mm × 30 mm × 4 mm) 0 (zero) degree fiber orientation (C_{str} = 28.92 MPa).

2.2. Preparation of unsaturated polyester resin (General purpose resin) and hardener

For preparing composite General purpose resin (GP) and hardener were used. The mass ratio of mixture of resin and hardener is 100: 1. Hardeners include acids amines, polyamides, dicyandiamide etc. Mixing was done for one minute with stirrer to ensure thorough mixing of resin and hardener. The mixing was performed in the mixing containers (bowl) The bowl made of Nickel to prevent melting of the Bowl of the exothermic reaction.

2.3. Cutting and weaving

The longer sisal fibers were cut into the required sizes. Weaving was done using the locally built weaving loom. Weaving was done with fiber orientation of 0^0, (0^0, 90^0) and ± 45^0 using a pair of sisal fiber as shown in Fig. 1. The prepared resin and hardener mixture were smeared evenly on the fiber using hand layup process (Fig. 2). After that, a plastic sheet was put on the mold. Care must be taken to avoid formation of air bubbles during pouring. Next Pressure is applied on the top and the mold was allowed to compress at room temperature for 24 h (Fig. 3). After 24 h the composite was taken out from the mold. It was cut in the required shape.

2.4. Dimension of test specimens

The appropriate Ethiopian Conformity Assessment Enterprise (ECAE) Testing material (ISO 6892-1) standards were followed while preparing the specimens for SFRUPR composite for tensile test. The standards of specimens are illustrated in the Fig. 6. Specimens for bending, compression and water absorption test were prepared using American Society of Testing Materials (ASTM) standards ASTM D-790, ASTM D 3410 and ASTMD-570 respectively (Fig. 4).

3. Experimental results

3.1. Tensile test

The specimen for tensile test was prepared and tested according to Ethiopian Conformity Assessment Enterprise (ECAE) Testing material (ISO 6892-1) standards. According to the ISO 6892-1 standard the dimensions of specimen used are 300x30 mm. There were 3 specimen groups of each fiber orientation (0^0, 0,90)^0 and ±45^0) total of 9 specimens. The typical stress vs strain diagram of SFREC under tensile loading with different sisal/general purpose resin composite specimens are given in the following figures.

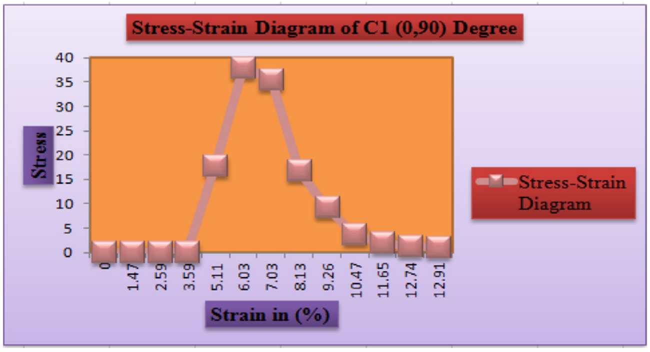

Fig. 9a. C1 (155 mm × 30 mm × 4 mm) (0, 90) degree fiber orientation (C_{str} = 37.92 MPa).

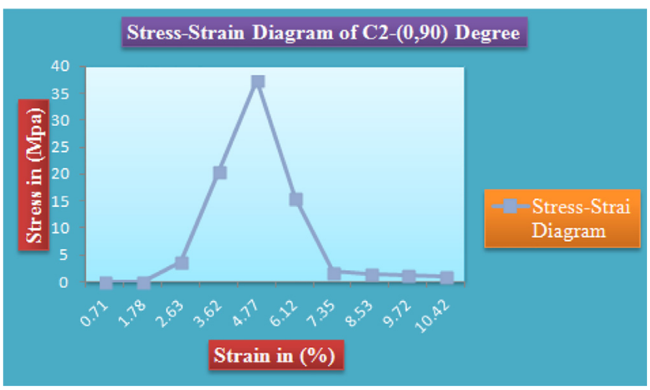

Fig. 9b. C2 (155 mm × 30 mm × 4 mm) (0, 90) degree fiber orientation (C_{str} = 37.42 MPa).

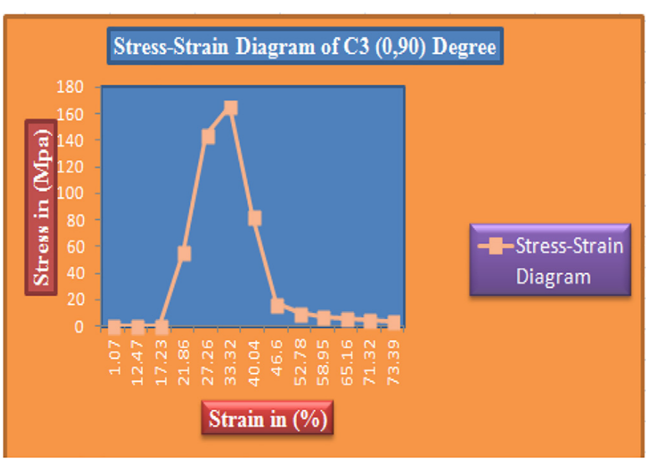

Fig. 9c. C3 (155 mm × 30 mm × 4 mm) (0, 90) degree fiber orientation (C_{str} = 165.52 MPa).

Fig. 5a presents the result concerning tensile strength test, the strain increased up to 5.7% linearly. After 5.7% strain failure of the specimen occurred.

Fig. 5b shows the result of tensile strength test for 0-degree fiber orientation, the percentage strain rate increases for the first elongation from 0% up to 53.2% and *afterwards failure happened.*

Fig. 10. Prototype of fender.

Fig. 5c shows the result of tensile strength test of 0 degree fiber orientation, the percentage strain rate increased for the primary elongation from 0% up to 3.6% the failure occur after 3.6% strain.

Fig. 6 presents the result of tensile strength test of ±45^0 fiber orientation. The strain increased up to 3%, beyond which it failed.

Fig. 7 presents the result of tensile strength test of ±45-degree fiber orientation. The percentage strain rate increased up to 2.7% linearly with stress, later it was failed.

3.2. Compression test

Compression tests is defined as the load carrying ability of the material. Compression testing for SFREC was important to establish crash limits as well as material quality control. The composite was tested under compression. The specimen was prepared as per ASTM 3410 and its dimensions are 155 mm long, 30 mm wide and 4 mm thickness. Nine specimens were prepared for compression test with fiber orientation of (0^0, (0,90)^0 and ±45^0).

Fig. 8(a)) shows compressive strength test of 0-degree fiber orientation the compressive strength follows an increasing trend from 0% to 3.56% after 3.56% failure happened.

Fig. 8(b) shows the compressive strength test results of the sample with 0 degree fiber orientation. The compressive strength follows an increasing trend from 0% to 3.77% after 3.77% failure happened.

Fig. 8(c) presents the result of compressive strength test of 0 degree fiber orientation. The compressive strength follows an increasing trend from 0% to 4% after 4% failure happened.

Fig. 9(a) shows compressive strength test of (0, 90) degree fiber orientation. The compressive strength follows an increasing trend from 0% to 6.03% after 6.03% the specimen failed.

Fig. 9(b) demonstrates the compressive strength test result of (0,90) degree fiber orientation. The compressive strength follows an increasing trend from 0% to 4.77% after 4.77% specimen failed.

Fig. 9(c) presents compressive strength test results of (0, 90) degree fiber orientation. The compressive strength follows an increasing trend from 0% to 33.32% after 33.32% failure occurred.

3.3. Preparation of fender prototype

Based on the results obtained from the mechanical and physical laboratory tests of tensile, compressive, bending and water absorption tests, it is found that sisal fiber composite with 0, 90 degree fiber orientation is best suitable for vehicle body panels especially fender, which normally experiences less stress. The prototype of the vehicle fender is molded using hand layup method by applying resin and hardener mixture uniformly. The part is cured 24 hrs at room temperature while applying sufficient weight (Fig. 10). Once cured it is evacuated from mold. The selected fiber orientation exhibited good strength in all mechanical properties.

4. Conclusions

Based on the tensile, compression, flexural and water absorption test results, it can be concluded as follows:

- From the experiment result it was observed that different orientation of fiber has shown enhanced mechanical properties of the sisal fiber composite material.
- From the Tensile Experimental test results, it was found that 0^0 and 90^0 (bidirectional) treated sisal fiber reinforced unsaturated polyester resin composite have better tensile strength than 0^0 and $\pm 45^0$.
- From the flexural experimental test results, it was found 0, 90 treated sisal fiber reinforced unsaturated polyester resin composite have better flexural strength than 0^0 and $\pm 45^0$.
- The effect of moisture content obtained from water absorption test is within the specifications and has minimum water absorption for auto body panels.

Here with we state that the work presented in the paper is original research done by us. The paper was considerably improved as per the comments given by the reviewers.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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