Experimental Investigation of Tensile and Compression Properties of Unidirectional Sisal Epoxy Resin Composite

Habtamu Dagne*, Amar Yimam

Abstract— The applications of natural fiber are becoming very significant reinforcement for polymeric composites vis-a-vis different applications due to their advantageous properties such as low cost, environmental friendly, good mechanical performance and so on. The present work investigate the tensile and compression properties of the unidirectional sisal fiber reinforced epoxy resin composite by using a Vacuum Bagging Assisted Hand Lay-up Technique (VBAHT). The sisal fiber has been used as the reinforcement, which were treated with 8% NaOH solution for removing the moisture contents thereby enhancing the bonding strength between fiber and resin. Experimental samples of unidirectional sisal fiber reinforced composites were fabricated by using the VBAHT with 40% volume fraction of fiber. The mechanical properties of the sample composites were investigated and the results predicts that the unidirectional sisal fiber reinforced epoxy resin composite material has significantly good tensile and compressive properties.

Index Terms— Sisal fiber, vacuum bagging assisted hand lay-up technique, tensile, compression

1 Introduction

Over the recent years, the natural fiber have received more attention from automotive industries because of their advantageous properties when compared with the synthetic fibers (glass, carbon and etc.). Their low density, neutral to Co2, recyclable, biodegradable, renewability, eco-friendly, availability and price as well as satisfactory mechanical properties make them an attractive ecological alternatives to synthetic fibers that used for manufacturing of composite materials [1]-[4]. For example, the use of plant fiber based automotive parts such as various panels, shelves, trim parts and brake shoes are attractive for automotive industries worldwide because of its reduction in weight about 10%, energy production of 80% and cost reduction of 5% [5].

Sisal fiber is one types of plant fiber that obtained from the leaves of the plant Agave sisalana, which was originated from Mexico and is now mainly cultivated in East Africa, Brazil, Haiti, India and Indonesia [2]. The composition of sisal fiber is 60-80% cellulose, 5-20% lignin and 20% moisture content. Sisal (agave sisalana) can be extracted from its leaves by retting and mechanical extraction methods [3], [7].

Sisal fiber has numerous advantage including high specific properties, low density, less abrasive behavior to the processing equipment, good dimensional stability and harmlessness. Also Sisal fiber is a low cost eco-friendly, product and is abundantly available , easy to transport and has superior drivability. It is widely being used traditionally as a natural choice for ropes, carpets and other reinforcement materials. Due to sisal low density combined with relatively stiff and strong behavior, the specific properties of sisal fibre can compare to those of glass and some other fibres [1]. Beside this advantageous properties, sisal fiber has some disadvantages like any hydrophilic lignocellulosic natural fibers, such as a poor compatibility with a matrix of hydrophobic polymer. However, in order to improve their compatibility different techniques was used by different literature including chemical treatments alkali treatment or mercerization, silane and acids [1]-[5].

- *Habtamu Dagne(Msc) ,Department of Mechanical Engineering, Debre Berhan University,Debre Berhan ,Ethiopia , PH-+251920361233. E-mail: Dagnehabtamu63@gmail.com*
- *Amar Yimam(Msc) Department of Mechanical Engineering, Debre Berhan University,Debre Berhan ,Ethiopia , PH-+251912787918. E-mail: Amaryimam12@gmail.com*

2. METHODS AND MATERIALS

The sisal fiber and epoxy resin with hardener were used in order to manufacture the composite material specimen, and sodium hydroxide (NaOH) and distilled water were used in order to treat the sisal fiber to improve the interfacial adhesive property. The sisal fiber are extracted from the sisal plants (Agave Sisalana) demographically from the region of Derban Town, Ethiopia and the epoxy resin with its hardener were obtained from Dejen Aviation Industry (DAVI), Debreziet, Ethiopia.

Matrix and Hardener

Epoxy is a thermosetting polymer that cures the fiber when mixed with the hardener/curing agent. The hardener that has been used in the present study were manufactured by fiber Glast development Corporation Company with a brand name of HARDNER MAS and the liquid Epoxy resin with a brand name of EPOXY MAS RESIN. The epoxy resin to hardner (curing agent) ratio of 2:1 were used in the present study as recommended.

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Extraction of Sisal Fibers

Sisal fibers were extracted from the sisal plants (Agave sisalana) using manual extraction techniques. The lower leaves of the plant, which are standing at an angle of more than 45 degrees to the vertical, are cut away from the bole of the plants with a sharp flexible knife. Then the leaves are trimmed in a longitudinal direction into different strips for ease of fiber extraction. The peeling part are clamped between the wooden table and the knife. Then they are hand-pilled gently along the longitudinal direction in order to remove the resinous materials. Then the extracted fiber are washed gently with pure water in order to loosen and separate the fiber until the individual fibers are obtained. Finally, the extracted fibers are dried in the sunlight for three days as shown in Figure 1.

Figure 1: Extracted and dried sisal fiber

Chemical treatment of fiber

The dried individual sisal fiber were chemically treated using a NaOH solution. For this study the sisal fiber were immersed into 8% NaOH solution as shown in Figure 2, for 4 hours at the ambient temperature (220C). Then they are washed several time with distilled water in order to neutralize the fibre. And lastly, the chemically treated fibers were allowed to dry in the sunlight for at least 3 days.

Figure 2: Soaking of Sisal fiber in NaOH

3. COMPOSITE PREPARATION

For the characterization of mechanical properties of the fiber composites, it is very crucial to keep the fibers alignments at the desired direction as well as the placement of the fibers. However due to the natural properties of the sisal fiber, its alignment at desired direction is significantly difficult, hence, different dimensioned metallic frames were used for keeping the fiber at desired alignments both for tensile as well as compression test as shown in Figure 3. Then the composite [00]6 laminates with 40% volume fraction of sisal fibers and 60% volume fraction of the matrix (epoxy resin and hardener) with the overall thickness of 3.24 mm were fabricated by using the VBAHT. The epoxy resin and the hardener were mixed gently by hands for 5 min at an ambient temperature of 20 degree celsius.

In VBAHT process, firstly the moulds are cleaned gently (3-4 times) by using a mould release agent such as wax, in order to preventing the epoxy-hardener mixture from sticking to the mold and then sealed it by using a vacuum tape. Secondly, the unidirectional sisal fibers are placed in the mould and impregnated it with the mixture of epoxy resin and hardener by using hand layup process. Thirdly, through the full hand layup processes, the dimensioned release peel ply, release film, breather fabric and vacuum bagging film are orderly placed over the composite layups as shown in Figure 4.

Figure 3: Unidirectional sisal fiber with frame

And finally, the vacuum pumps and the reservoir are connected with the vacuum hose and T-shaped vacuum ports. The vacuum bagging film are then attached with the mold by using a vacuum tape in order to create vacuum inside the mould area. By opening the vacuum bagging switch, the process can be checked for partial air draw from the vacuum bagging film. Then after 12 hours of curing, the fabricated composite laminate were cut off according to their ASTM standards using Band Saw machine

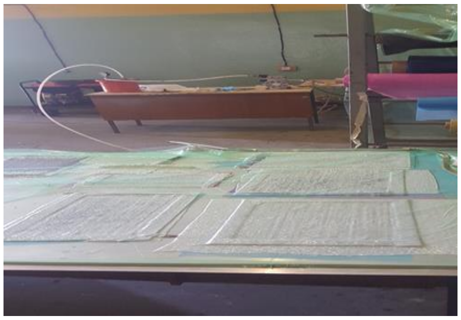

Figure 4: Composite fabrication process using VBAHT.

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4. TESTING PROCEDURE

4.1. Tensile Testing

The tensile test specimens as shown in Figure 5 are prepared according to the ASTM D3039 standard with the overall dimension of 175 x 25 x 3.24 mm^3. The tensile testing specimen are then placed under a universal testing machine and pulled at a cross-head speed of 0.5 mm/min. The specimens are loaded under the uni-axial tensile loading until it fractures. A continuous record of load and deflection are obtained by a digital data acquisition system.

Figure 5: Different tensile testing specimen samples

4.2. Compression Testing

The Compression tests were done by mounting the specimen as shown in Figure 6 on a universal testing machine according to the standards of ASTMD3410 with an overall dimension of 15 x 10 x 3.24 mm^3. In conjunction with tensile testing, similarly the specimens are loaded under the uni-axial compression loading until it fractures. A continuous record of load and deflection are obtained by a digital data acquisition system.

Figure 6: Different compression testing specimen samples.

5. Result And Discussion

5.1. Tensile Test

The different composite specimen samples were tested on the universal testing machine. The experimental data recorded from the individual testing specimens were ascertained and the average force with respect to displacement graph were plotted as shown in Figure 7. Also the average stress-strain curve were plotted for the determination of the ultimate tensile strength and its young's modulus. As observed from Figure 7 and 8, the force-displacement and stress-strain behavior for longitudinal and transverse tensile testing specimens were found to be linear and the final failure occurs catastrophically, however most of the specimens failed at an acceptable mode in the gauge section.

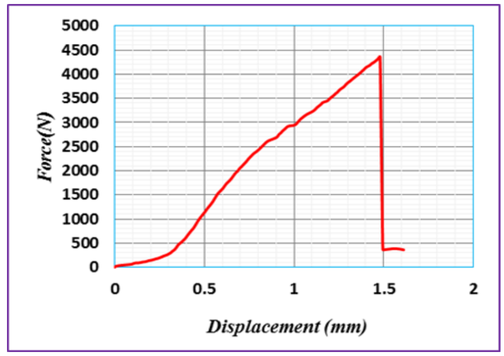

Figure 7: Force –displacement graph for tensile specimens.

The Maximum tensile force of 4.32 *KN*, an ultimate tensile strength of 102.53 *MPa* and an elastic modulus of 4.56 *GPa* were obtained from the experimental data of force-displacement and stress-strain relationship respectively.

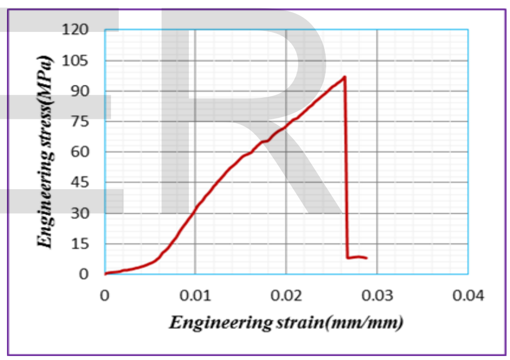

Figure 8: Average engineering stress-strain graph of the tensile.

5.2. Compression Test

As shown in Figure 8 and 9, the force-displacement and stress-strain curve for the compression test, the compressive strength increases with an increase in load until it reaches the ultimate compressive strength of the material, after which it fails catastrophically as evident from the figures.

The Maximum compressive break force of 0.323 *KN* and an ultimate compressive strength of 11.494 *MPa* were obtained from the experimental data of average force-displacement and stress-strain relationship respectively.

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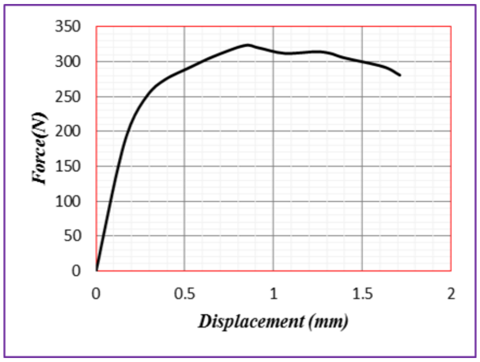

Figure 9: Average force-displacement curve for compression specimens.

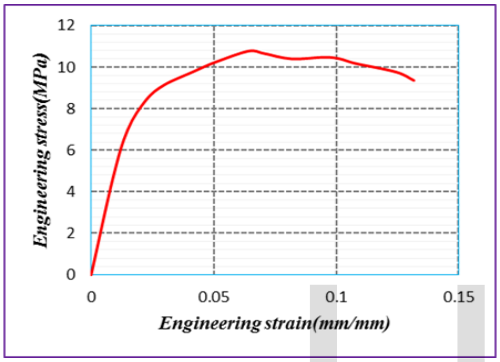

Figure 10: Average engineering stress-strain curve for compression Specimens.

Table 1, presents the full experimental results of the tensile and compression testing specimens.

Table 1: Experimental result of the tensile and compression testing

	Tensile Test	Compression Test
Modulus of Elasticity (GPa)	4.56	0.387
Ultimate Strength (Mpa)	102.53	11.494
Break Load (kN)	4.32	0.323
Maximum Displacement (mm)	1.612	1.712
Elongation at Break (%)	2.88	13.22

6. Conclusion

The present research work successfully instigated the mechanical properties of a unidirectional sisal fiber reinforced epoxy resin composite material by using a hand layup insisted vacuum bagging techniques (VBAHT). The tensile and the compression properties of the composite material were analysis experimentally based on the ASTM standards. From the experimental analysis and testing, the following conclusion were drawn. It has been observed that 40% volume of sisal fiber and 60% volume of matrix has tensile modulus and ultimate tensile strength of 4.56 *GPa* and 102.53 MPa respectively. Also it has been observed that the value of compressive modulus and ultimate compressive strength are found to be 0.387 *GPa* and 11.494 *MPa* respectively. From the experimental testing result, henceforth, can conclude that the unidirectional sisal fiber reinforced epoxy resin composite material have significantly good mechanical properties, along with the inherent advantages being environmental friendly, low specific to weight ratio, cost effectiveness and so on for various application.

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