Production and characterization of bamboo and sisal fiber reinforced hybrid composite for interior automotive door panel application

By

Dawit Getu

A Thesis Submitted to

DEPARETEMENT OF MECHANICAL SYSTEMS AND VEHICLE ENGINEERING

School of Mechanical, Chemical and Materials Engineering.

Presented in *Partial Fulfillment of the requirements for the award of the Degree of Masters of Science in Automotive engineering*

Office of Graduate Studies

Adama Science and Technology University

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Advisor: Mr. N.Ramesh Babu (Asst Prof)

Co- Advisor: Mr. Muluken Masresha

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CANDIDATE’S DECLARATION

I hereby declare that the work which is being presented in the thesis entitled “production and characterization of bamboo and sisal fiber reinforced hybrid composite for interior automotive door panel application “in partial fulfillment of the requirements for the award of the degree of master science in automotive engineering is an authentic record of my own work carried out from October 2018 to June 2019 under the supervision of Mr. N.RAMESH BABU (Asst. Prof.) department of mechanical and vehicle engineering ,Adama Science And Technology University ,Ethiopia.

The matter embodied in this thesis has not been submitted by me for the award of any other degree or diploma all relevant resource of information used in this thesis have been duly acknowledged.

Name	Signature	Date
Dawit Getu	______________	_______________
(Candidate)		

This is certified that the above statement made by candidate is correct to the best of my knowledge and belief. This thesis has been submitted for examination with my approval.

Name	Signature	Date
Mr. N.Ramesh Babu (Asst Prof)	________________	_______________
(Advisor)		
Mr. Muluken Masresha	________________	_______________
(Co- Advisor)		

Approval of Board of Examiners

We, the undersigned, members of the Board of Examiners of the final open defense by Dawit Getu Mitiku have read and evaluated his thesis entitled "Production and characterization of bamboo and sisal fiber reinforced hybrid composite for interior automotive door panel application " and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements of the Degree of Master of science in automotive engineering.

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External Examiner	Signature	Date

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TABLE OF CONTENTS

CONTENTS PAGES

LIST OF FIGURE

FIGURE PAGE

LIST OF TABLE

TABLE PAGE

NOMENCLATURE

ρ_c	Density of composite
m_c	Mass of composite
m_r	Mass of resin
V_r	Volume fraction of resin
V_f	Volume fraction of fiber
m_b	Mass of bamboo fiber
m_s	Mass of sisal fiber
L	Support span length of specimen
b	Width of the specimen
w_b	Section modulus
M_{bmax}	Maximum bending moment
δ_{bmax}	Maximum bending stress

LIST OF ACRONYMS

ASTM	America Society for Testing and Material
BSFRHC	Bamboo Sisal fiber reinforced hybrid composite
BSFHC-TS	Bamboo/sisal fiber hybrid composite tensile specimen
BSFHC-FS	Bamboo/sisal fiber hybrid composite flexural specimen
BSFHC-IS	Bamboo /sisal fiber hybrid composite impact specimen
BSFRHC-HS	Bamboo/sisal fiber hybrid composite hardness specimen
Eq.	Equation
Fig.	Figure
FRP	Fiber Reinforced Polymer
Hr.	Hour
mm	Millimeter
NF	Natural fiber
PP	Polypropylene
UD	Unidirectional
UTM	Universal testing machine
VHN	Vickers hardness number

ABSTRACT

Natural fibers are emerging as low cost, lightweight and apparently environmentally superior alternatives to glass fibers in composites which are used in the aerospace, transportation and construction industries. The extensive research and development of new and improved materials such as composites is going on. Composite materials used for structural purposes often have low densities, resulting in high stiffness to weight and high strength to weight ratios when compared to traditional engineering materials. Composites are of low cost, bio degradable and easily can recyclable through thermal methods. In addition, to the high fatigue strength to weight ratio and fatigue damage tolerance of many composites also makes them an attractive option. The light-weight natural fiber composites improve fuel efficiency and reduce emissions in the use phase of the component, especially in auto applications. The main goal of this thesis is to develop and characterize the performance of bamboo and sisal fiber reinforced polyester hybrid composite (BSFRHC) with different fiber orientation of sisal and unidirectional (UD) bamboo fiber for interior automotive body application. Manual method of sisal fiber extraction from Dessie town and bamboo fiber extraction from Ethiopian highland bamboo 'Yushania Alpina' species was undertaken. A 5% sodium hydroxide was used for further lignin, hemicellulose and other fiber remnants removal for the improvement of bond & interfacial shear strength of the bamboo and sisal fiber for each. Next, BSFRHC was fabricated with 20 % total fiber volume fraction. Of this total fiber volume, the composite is fabricated in 3:1 bamboo to sisal fiber ratio using hand lay-up technique. Then tensile, compressive, impact and flexural tests were carried out. Unidirectional 90^0 fiber orientation was found to have a higher tensile and flexural strength whereas unidirectional 90^0 and bidirectional $(0^0/90^0)$fiber orientation nearly have the same value of tensile strength, whereas bidirectional $(0^0/90^0)$ was found to be having higher flexural strength than unidirectional 90^0 fiber orientation. Finite element analysis on internal door panel made of BSFRHC was done in ANSYS Software using impactor. Furthermore, it is found that the bamboo and sisal fiber reinforced hybrid composite in unidirectional 0^0 has a potential to be used for automotive interior door panel application.

Keywords: Sisal and bamboo fiber, Hybrid composite. Interior door panel, Polyester

CHAPTER ONE

1. INTRODUCTION

It is a natural phenomenon that human beings keep on moving here and there to perform their day to day activities within a given time range and vehicles are the dominant way of transportation system in many countries, including Ethiopia. Thus, researching on these area to design and provide a well improved, fast, economic and aesthetically attractive vehicles is a crucial idea for the development of these countries by providing fast, effective and sufficient way of transportation. To address this aim a wise material improvement and design Excellency are crucial mechanisms. A material for automotive industries has been improved frequently starting from the very earlier one (wood) to the latest and most sophisticated modern materials (Ermias G. Koricho, 2015).

The basic aim of developing new materials for automotive application is to enhance vehicle efficiency and fuel economy by reducing the dead weight of the vehicle. Moreover their aesthetical appearance should be upgraded by researching materials for this application too. A number of researches have been demonstrated that composite materials are lightweight, fatigue resistant and easily molded to any shape, in other words, a seemingly attractive alternative to metallic materials. If the benefits of composite materials in terms of light weighting, durability, good aesthetical value, high specific energy absorption ability and ease of forming are to be exploited more widely by the automotive industry, then there is a need to identify the critical technical barriers that must be overcome

In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile designers and manufacturers in the present scenario. Weight reduction can be achieved primarily by the research of better material, design optimization and better manufacturing processes. Due to rise in demand of lightweight and more efficient vehicles and better mechanical performance of materials in automotive applications, different material combinations such as composites, plastic and light weight metals are implemented on different structural parts of vehicles. Applications of composite materials in automotive industries already include some structural parts, such as dashboard, roof, floor, front & back bumper, passenger safety cell, and door panels (Ermias G. Koricho, 2015).

The Interior part of vehicle priorities for improving safety in the passenger compartment include making safety advances affordable through innovative design and more efficient manufacturing capabilities, designing for increased vehicle compatibility, accommodating an aging driver population, including more safety features in reduced package space, and enhancing safety belt designs **(**Szeteiová).

Composite materials made of natural fibers and polymer matrix provides synergistic properties, improving their strength and durability. These materials are suitable for achieving automotive interior components, where in addition to their low weight have also high rigidity and good thermal and sound insulation. The most important internal vehicle elements include car internal door panels.

1.1. Background

Now a days, substitution of conventional materials such as; steel, aluminum and other alloy materials by composite materials has grown significantly in aeronautic, automotive, naval, and civil construction sectors. This is due to their amazing properties, i.e. Composite materials have of high modulus to weight ratio and strength to weight ratio, excellent fatigue properties, and non-corroding behaviors. These advantages encourage the extensive application of composite materials in different areas including automotive industries

Traditionally, the materials used in the construction of vehicle bodies are mainly various grades of steel and aluminum. Moreover, plastics and some synthetic materials mostly dominate the vehicle interior parts. The manufacturers meet the requirements of a particular crashworthiness standard and fuel efficiency by making the approximate design change in their vehicle structure and by introducing necessary structural components that satisfy the overall design objectives.

Composite materials are materials made from two or more than two materials with considerably differ in physical and chemical properties, that when combined, make a material with appearances different from the individual components. Composites comprise strong load carrying material is known as reinforcement and weaker materials is known as matrix. Reinforcement provides stiffness and strength which helps to support structural load .Composite materials do not lose their respective identities but still relate their properties to the product causing from their mixture .The benefits of composite materials have their great stiffness and strength. There are in many cases, the reinforcement is stronger, tougher, harder and stiffer than the matrix.

1.2. Statement of the problem

Weight reduction of the vehicle body is a major challenge faced by the industries .more weight of the vehicles causes more fuel consumption and higher harmful emissions at the moment light weight composite materials are prepared in the country using the imported synthetic fibers expensive and disposal of which causes environmental pollution. Replacement of interior non-structural parts of the vehicle is also another challenge.

1.3. Objectives

1.3.1. General Objective

The general objective of this thesis is to produce and characterize the bamboo/sisal fiber reinforced hybrid composite for interior automotive body application

1.3.2. Specific objectives

The specific objectives are

- To collect bamboo and sisal fiber from Ethiopian highland and treat it chemically improves its stiffness and interfacial adhesion
- To prepare the bamboo and sisal fiber reinforced hybrid with polyester resin composite with different fiber orientation
- To measure tensile, compressive, flexural and impact strength of the composite experimentally.
- To model and analyze the door panel using Ansys software
- To compare the structural performance of BSFRHC material and conventional door panel material.

1.4. Significance

The significance of this work is as follows

- Usage of natural fibers in the place of synthetic fiber reduces environmental pollution in preparation as natural fiber are biodegradable.
- It helps to reduction of importing, since natural fibers are available with in the country.
- Using natural fiber composites in vehicle body construction reduces the weight loading to the reduction of fuel consumption and related harmful exhaust emissions

With this automotive industries, researchers in the field, society and the country as a whole get benefited.

1.5. Scope (delimitation)

This thesis work includes preparation of hybrid composite with bamboo and sisal fiber reinforcement characterization of the composite samples with different fiber orientation is covered in this work. Modelling and FEM analysis of door interior panel with composite and conventional material is also included in this work.

1.6. Limitation

Among the many, major obstacles faced while executing this work are as follows

- Fabrication of composite with hand layup process is a very tough task
- No specific machine available for the preparation of composite material
- The testing machine for characterization of composite material are scattered and locating them was another time consuming process

1.7. Organization of the thesis

Chapter 1: Introduces the background of natural fiber composite materials, Objectives, Statement of the problem, Scope and limitations

Chapter 2: It covers the reviews of relevant research papers regarding natural fiber composite materials, Ranging from polymer types, fiber types, and composite's chemical, mechanical properties. Recent researches on natural fiber reinforced hybrid composite and review on interior door panel also covered in this chapter.

Chapter 3: Materials required for sample preparation, experimental set up, methods for Fabrication are given for this chapter. The experimentation of measuring, flexural, tensile, impact and compressive strength are also given in this chapter

Chapter 4: Result and discussion on characterization of composite materials, modelling and FEA analysis is given in this chapter

Chapter 5: This Chapter deals with the aspects like summary, conclusion, recommendation and future work

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Composite material

Composites are multifunctional materials consisting of two or more chemically distinct constituents, on a macro-scale, having a distinct interface separating them. More than one discontinuous phase are embedded in a continuous phase to form a hybrid composite. The discontinuous phase is usually harder and stronger than the continuous phase and it is called the hybrid reinforcement and the continuous phase is termed the matrix (Pramendra & Inderdeep, 2012).

The reinforcing phase can either be fibrous or non-fibrous (particulates) in nature and if the fibers are derived from plants or some other living species, they are called natural fibers. The environmental issues have resulted in considerable interest in the development of new composite materials with addition of more than one reinforcement that are biodegradable resources, such as natural fibers as low-cost and environment-friendly alternative for synthetic fibers .

The fibers made from chemicals are called synthetic fibers and it may be glass, carbon, aramid, boron, ceramic fibers and etc (TP Sathishkumar et al,2014).

2.2. Characteristics of composite

Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the ‘reinforcement’ or ‘reinforcing material’, whereas the continuous phase is termed as the ‘matrix’. Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them. The composite properties may be the volume fraction sum of the properties of the constituents or the constituents may interact in a synergistic way resulting in improved or better properties. Apart from the nature of the constituent materials, the geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a great extent. The concentration distribution and orientation of the reinforcement also affect the properties (D. Chandramohan & K. Marimuthu, 2011).

The shape of the discontinuous phase (which may by spherical, cylindrical, or rectangular cross-sectioned prisms or platelets), the size and size distribution (which controls the texture of the material) and volume fraction determine the interfacial area, which plays an important role in determining the extent of the interaction between the reinforcement and the matrix. Concentration, usually measured as volume or weight fraction, determines the contribution of a single constituent to the overall properties of the composites. It is not only the single most important parameter influencing the properties of the composites, but also an easily controllable manufacturing variable used to alter its properties (Honey Banga, 2015) (D. Chandramohan & K. Marimuthu, 2011).

2.3. Classification of composites

Composite materials can be classified into many categories

Based on dispersed phase

Based on matrix material

2.3.1. Based on dispersed phase

Fig 2.1. Shows classification of composite based on dispersed phase

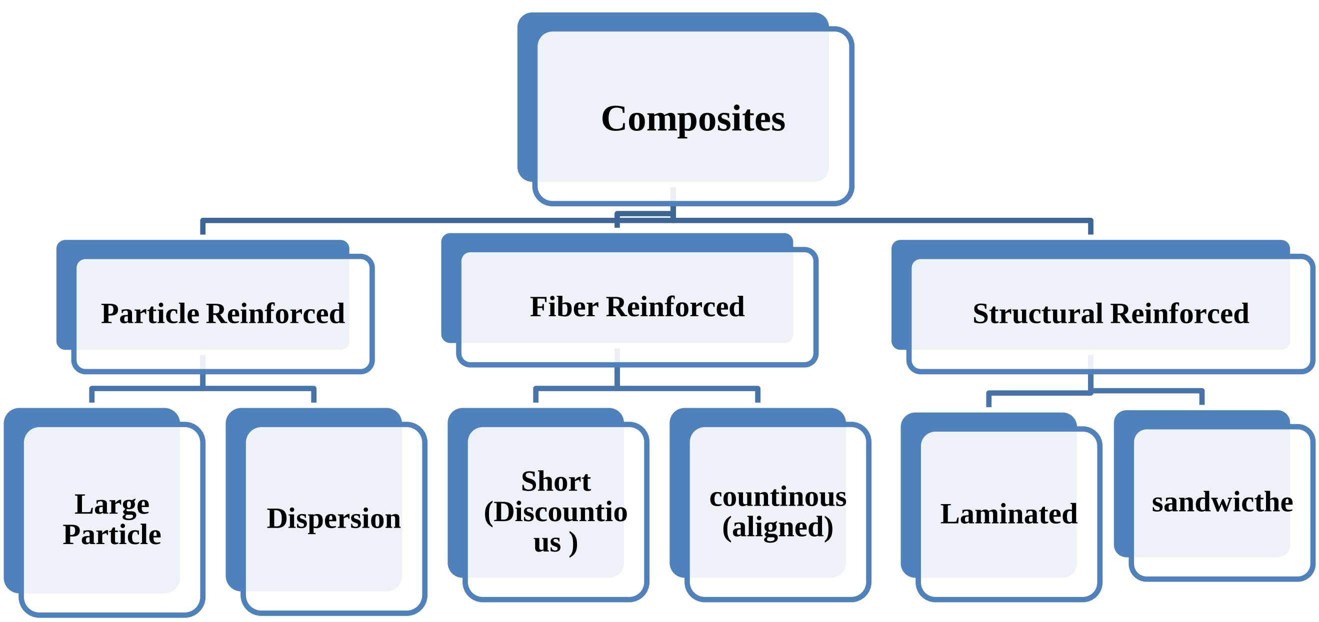


Figure 2.1: Classification of composite material based on dispersed phase

Particle-reinforced composite

The role of reinforcement in composite materials is primarily to add mechanical properties to the material such as strength and stiffness. Thus, particles are used to increase the modulus of the matrix, to decrease the permeability of the matrix, or to decrease the ductility of the matrix. Particle reinforced composites support higher tensile, compressive and shear stresses. Particles used for reinforcing include: ceramics and glasses, metal particles, and amorphous materials (Callister, 2005). Fig 2.2 shows particle and fiber reinforced composite material.

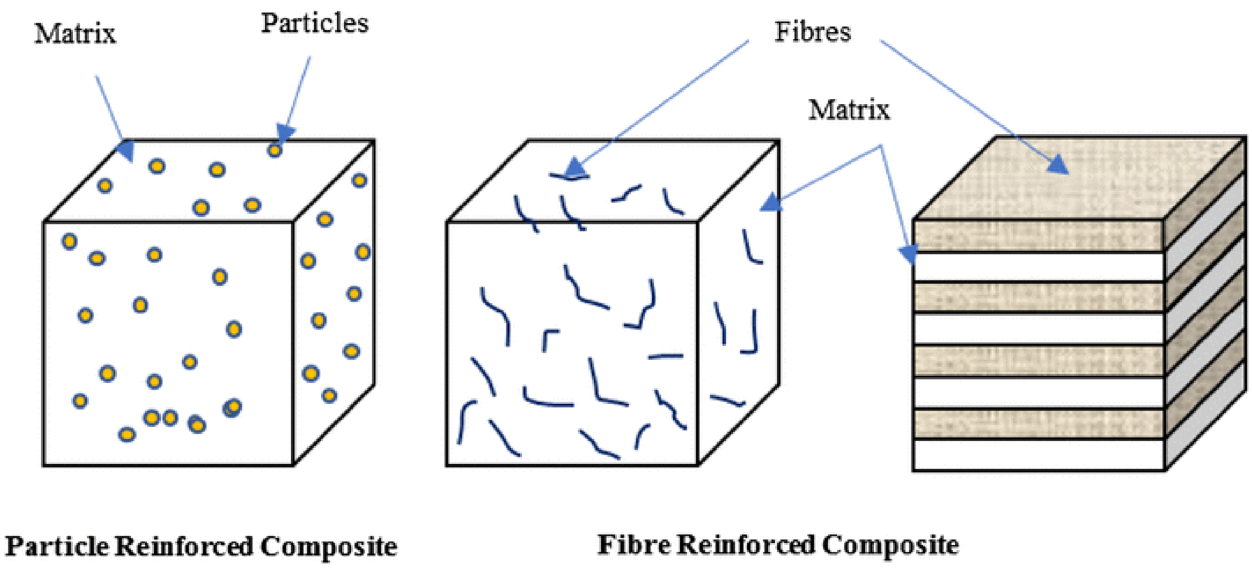


Figure 2.2: Particle and fiber reinforced composite material

Fiber-reinforced composites

Fiber reinforced composites provide improved strength, fatigue resistance and strength to weight ratio over the constituent materials. Reinforcing fibers are responsible to increase the modulus of the matrix material in the composite. The strong covalent bond along the fiber's length gives them a very high modulus in this direction because to break or extend the fiber the bonds must also be broken or moved (Kaw, 2006). fig 2.3 shows different forms of fiber reinforced composites.

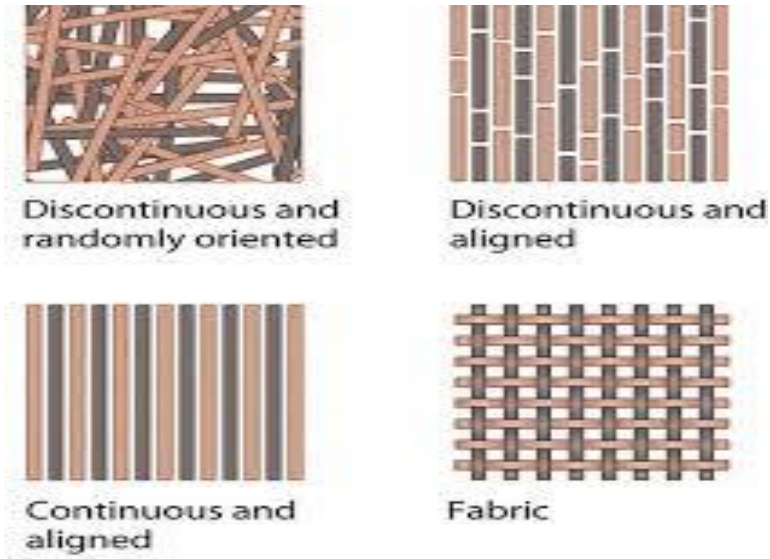


Figure-2.3: Fiber reinforced composites

The arrangement or orientation of the fibers relative to one another, the fiber concentration, and the distribution all have a significant influence on the strength and other properties of fiber reinforced composites. (Pramendra & Inderdeep, 2012)

Structural composites

Composite Laminate

Laminates are sheet constructions which are made by stacking layers (also called plies or lamina) in a specified sequence. The layers are often in the form of prepare" (fibers pre impregnated with partly cured resin) which are consolidated in an autoclave. A laminate may have more than 4 layers and the fiber orientation changes from layer to layer in a regular manner through the thickness the laminate. The figure 2.4 shown describes how the laminate is formed from the ply or lamina (Kaw, 2006).

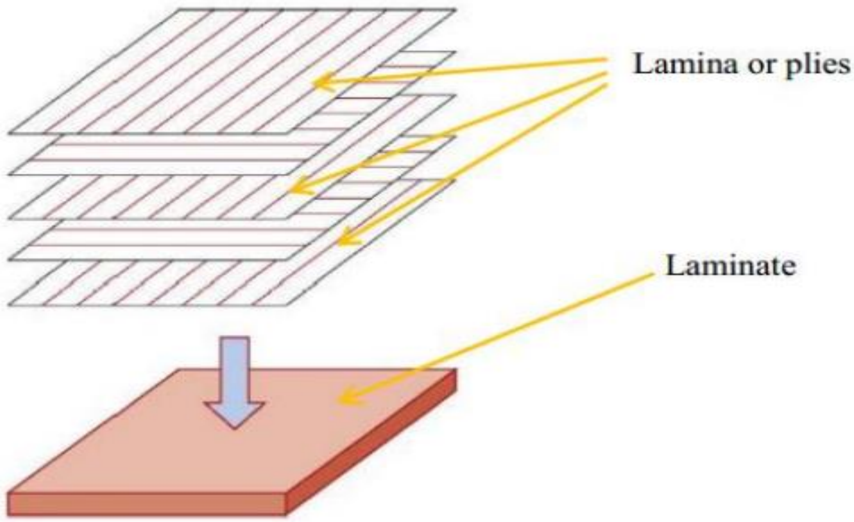


Figure 2.4: Composite lamina

Sandwich panels

These composite polymer matrixes have low density, honeycomb core as a reinforced bonded with the face sheet matrix by adhesive layers. Sandwich panels have the benefits of light weight, large bending stiffness and energy absorption (Callister, 2005). The figure 2.5 shown describes how Sandwich composites is formed.

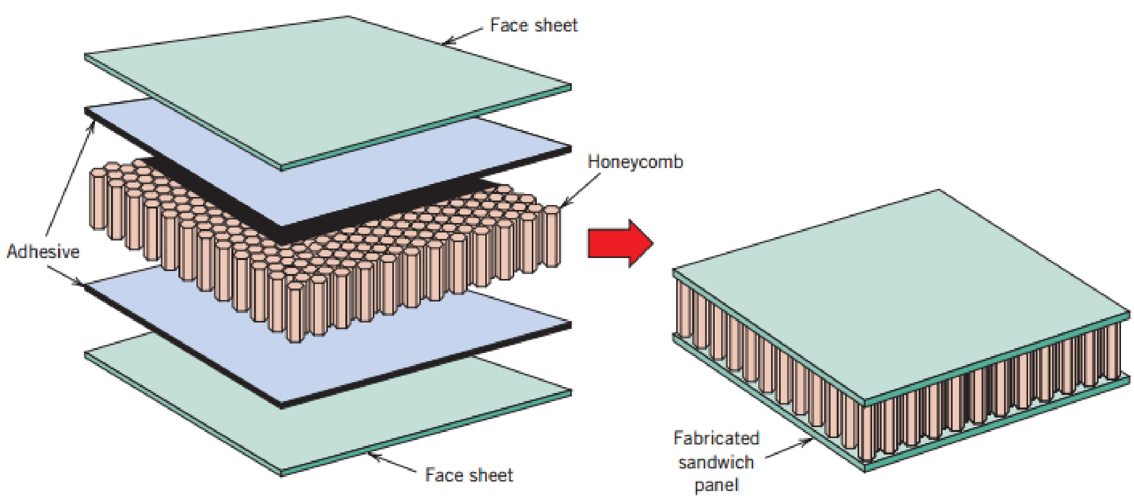


Figure 2.5: Sandwich composites

2.3.2. Based on matrix material

Another way of classifying composite materials is focusing on the type of its matrix component of the composite. Based on this measurement, composite materials can be arranged as shown fig.2.6

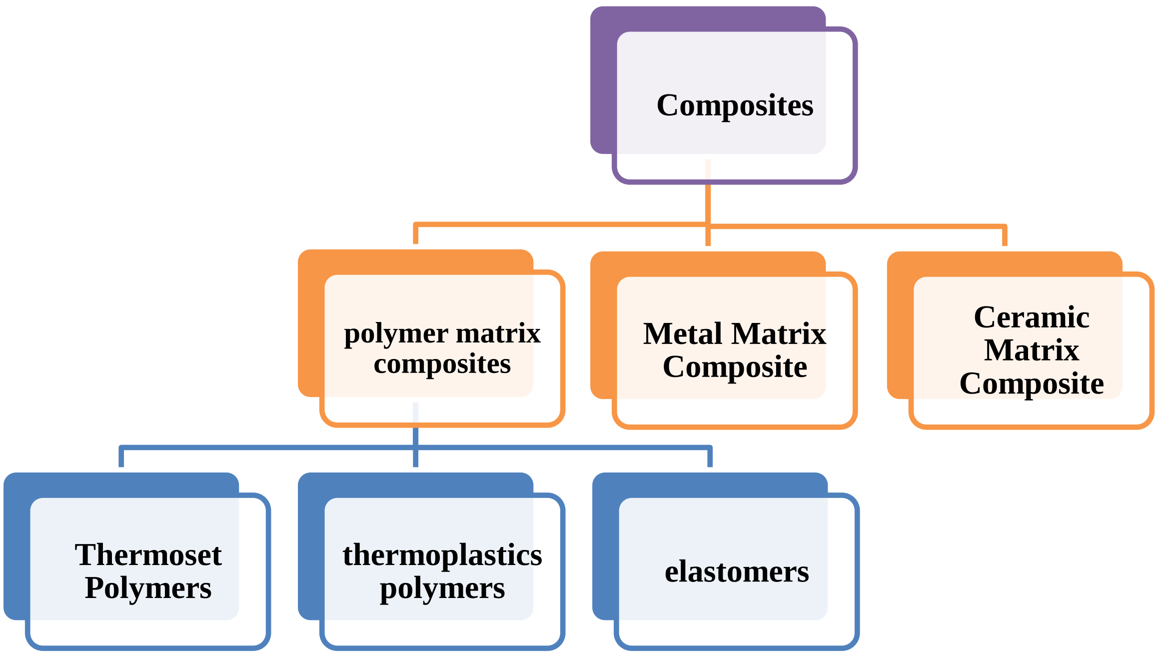


Figure 2.6: Classification of composite based on matrix material

Here in this paper, we are interesting on the polymer matrix composite materials only. They are composed of long chain-like molecules consisting of many simple repeating units. The most commonly adopted polymer composites in more industries are thermosetting and thermoplastic polymer matrix composites. These fiber-reinforced polymer composites can be found in products that people interact with every day, including cars and sporting goods.

Thermoset polymers are polymers that are cured into a solid form and cannot be returned to their original uncured form. Composites made with thermoset matrices are strong and have very good fatigue strength. They are extremely brittle and have low impact -toughness making. They are commonly used for high-heat applications because the thermoplastics. Thermoset composites are generally cheaper and easier to produce because the liquid resin is very easy to work with. Thermoset composites are difficult to recycle because the thermoset cannot be remolded or reshaped; only the reinforcing fiber used can be reclaimed (Cheung, 2009).

Thermoplastic polymers are polymers that can be molded, melted, and remolded without altering its physical properties. Thermoplastic matrix composites are tougher and less brittle than thermoset, with very good impact resistance and damage tolerance. Thermoplastic composites are less dense than thermosets making them a viable alternative for weight critical applications. The thermoplastic composites manufacturing process is more energy intensive due to the high temperatures and pressures needed to melt the plastic and impregnate fibers with the matrix. The energy required makes thermoplastic composites more costly than thermoset. These two similar materials have such different properties that both will continue to be used in different applications for very different reasons and the products of the future will likely be a combination of both (Patil, 2012).

2.4. Hybrid composite

When more than one type of fibers are reinforced into a common matrix, the resulting composite is called hybrid composite. Hybrid composites provide greater freedom when it comes to designing composites for specific properties as compared to single fiber reinforced composites. Recently, natural fibers such as bamboo, jute etc. Have been mixed with synthetic fibers such as glass or to other natural fibers to form hybrid composites with desired properties at low cost. The behavior of hybrid composites is a weighed sum of individual components in which there is a more favorable balance between the inherent advantages and disadvantages (Rajesh D, 2014).

By using hybrid composites, the advantages of one type of fiber could compliment what is lacking in the other fiber. The properties of hybrids are decided by many factors such as fiber content, fiber length, orientation, extent of intermingling of fibers, fiber to matrix bonding etc.

Even though natural fibers have many advantages, their use is restricted because of several limitations. They are incompatible with some polymeric matrices, have high absorption and have poor wettability. These are the problems faced even when the natural fibers are used in hybrid composites. In order to overcome these problems, chemical treatments are done. Is end, the present research work is undertaken to study the effects of chemical treatments on the mechanical properties and performance of bamboo-sisal fiber reinforced polyester based hybrid composite.

2.5. Natural fibers

Natural fibers are bio sourced materials extracted from plants (lingo cellulosic) or animals Lingo cellulosic fibers are produced by plants for which, on a dry basis, the cell walls are mainly composed of cellulose, with hemicelluloses, lignin, pectin and extractives in lower amounts. Chemical composition and distribution mostly depend on fiber source and varies with in different parts even of the same type or family (Aira Taj, 2010).

2.5.1. Natural Fiber Reinforced Composite

Plants, such as flax, cotton, hemp, jute, sisal, pineapple, ramie, bamboo, banana, etc., are used as a source of lignocellulose fibers, and are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites (K.L. Pickering, 2015).The natural fiber-containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling paneling, partition boards), packaging, consumer products, etc**.** (D. Chandramohan & K. Marimuthu, 2011)**.**

Composites are widely used in our day to day life. Due to their low weight and ability to be handmade for specific end use they have gained a considerable ground in the high performance applications, such as aerospace and automobile (D. Chandramohan & K. Marimuthu, 2011)**.** However, the use of polymers that can be recycled when used with carbon and other niche fibers renders the composite non-recyclable. This has become a major issue as the landfills are filling up at a faster pace along with the need for going green due to global warming (TP Sathishkumar, 2014).

2.5.2. Classification of Natural Fibers

Natural fibers in general can be classified based on their origin, and the plant-based fibers can be further categorized based on part of the plant they are recovered from (D. Chandramohan & K. Marimuthu, 2011).Generally they are divided in to three major groups that are plants, animals and minerals fiber. In this paper focused on the plant fibers only. A general classification for natural fibers is provided in Fig. 2.7.

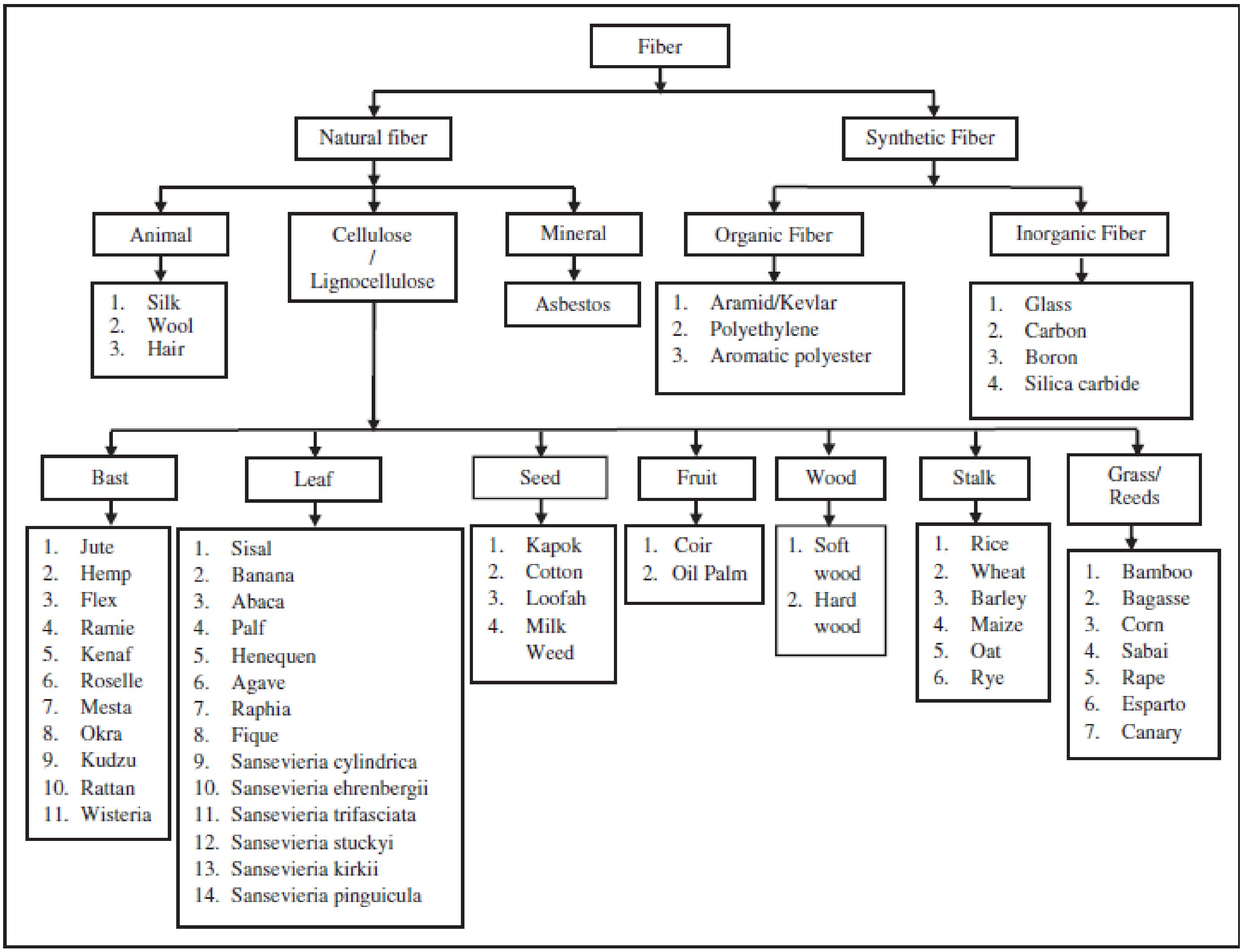


Figure 2.7: Classification of natural and synthetic fibers

(TP Sathishkumar, 2014)

2.5.3. Advantages of Natural Fiber Composites in automotive applications

- The natural fiber composite mainly have the following advantages its low specific weight, higher specific strength and stiffness than glass fiber (D. Chandramohan & K. Marimuthu, 2011).
- It is a renewable source & it is biodegradable (if proper matrix is used)
- We can produce these composites with low investment at low cost, which makes the material, an interesting product, for low developing countries.
- It possesses reduced wear of tooling, healthier working condition, and no skin irritation. Here thermal recycling is possible.
- Relative cost advantages compared to conventional constructions
- Low energy consumption
- It provides better thermal and acoustic insulation properties, especially as an automotive interior or construction material part, due to presence of lumen/void in the fiber
- Low density and lightweight leading to the weight reduction of 10–30% in comparable parts in automotive application (A. Lakshumu Naidu, 2017).
- Good mechanical and manufacturing properties (Witayakran, 2017).
- Relatively good impact performance
- Low energy consumption (Witayakran, 2017)
- Occupational health advantages in assembly and handling compared to glass fiber

2.5.4. Disadvantage of natural fiber composite in automotive application

One of the major difficulties of natural fibers is that their properties are basically dependent on where they are grown (locality), what part of the plant they are harvested from (leaf or stem), the maturity of the plant (age) and how the fibers are harvested and preconditioned in a form of mats or chopped fibers, woven or unwoven. These factors result in significant variation in properties compared to their synthetic fiber counterparts (glass, aramid and carbon) (Aira Taj, 2010).Obviously the production and application of natural fiber reinforced parts also brings along some difficult

- Concerns over the unevenness of the fiber supply and long
- Extremely sensitive to moisture and temperature

- Could be more expensive if fully bio-based and biodegradable
- High variability properties
- Uncontrolled biodegradable can occur (Witayakran, 2017).

From the classification of natural fiber I select plant fiber source under leaf category sisal plant and grass/reed category bamboo plant used bamboo fiber is selected for this project due to the numerous advantage of bamboo fiber over other natural fiber

- It has elevated mechanical strength.
- It has low specific weight too.
- It has high tensile strength.
- It has better modulus of elasticity than any other natural material.
- Easily and locally available material (Tara Sen, 2011).

2.6. Bamboo Plant and its fiber

Bamboo is a tropical or warm temperate member of grass family Poaceae (Gramineae) belonging to the sub-family Bambusoideae. It is a multipurpose plant with significant economic and environmental value. It grows in temperate, subtropical and tropical areas of all continents except Europe. (Forest types in Ethiopia, 2011) There are more than 1,575 species of bamboo belonging to 111 genera reported from all over the world . These resources are distributed from 46° north to 47° South latitude with altitudes ranging from sea level to over 4,000 m in equatorial highlands . About 80% of bamboo forestland and species in the world are distributed in Asia and Pacific regions. Latin America also has a high biodiversity of bamboos with approximately 400-500 species (Forest types in Ethiopia, 2011).The lowest diversity of bamboos is found in mainland Africa where five species naturally occur. Africa possesses about 43 species of bamboo under 11 genera, covering an area of over 1.5 million hectare . The most widely distributed African bamboo is categorized under three genera: Arundinaria, Oreobambos and Oxytenanthera.

2.7. Bamboo resources in Ethiopia

Ethiopia has two indigenous bamboo species the highland bamboo (Arundinaria alpina K. Schum. synonym: **Yushania** alpina) and the monotypic genus lowland bamboo Oxytenanthera abyssinica

(A. Rich.) Munro. These species of bamboo are indigenous to Ethiopia and endemic to Africa. The Ethiopian natural bamboo forest is estimated to have been about one million ha before 14 years. (Forest types in Ethiopia, 2011).It is very important to point out that Ethiopia is the only country in Africa which has over 850,000 hectare of Oxytenanthera abyssinica natural bamboo forest. Oxytenanthera abyssinica is a clumping (sympodial) type bamboo with "solid" culm at maturing age. It has an average culm diameter of 5 cm and height of 7 m. This species grows at an elevation between 1,000 to 1,800 m above sea level and is widely distributed in the western lowland areas of the country. Table 2.1 shows major low and high land bamboo growing areas.

Table 2.1: Major high land and low land bamboo growing areas in Ethiopia

Site (growing) Location	Region	Stand Type
Injibara	Amhara	Homestead high land bamboo
Chencha	SNNPR	Homestead, natural High land bamboo
Hagre selam	SNNPR	Homestead High land bamboo
Bale mountains	Oromia	Natural High Land Bamboo
Masha	SNNPR	Natural High Land Bamboo
Gembi/Dedesa	Oromia	Natural low land bamboo
Assosa	Benshangul Gumuz	Natural low land bamboo

From the above Assosa, Injibara, Gimbi, Bale, Masha, Chencha and Hagere-Selam are rich in bamboo sources. The largest source of bamboo plant present in Assosa is lowland type which has solid culm at maturating age. Due to its solid culm at maturating age it is not preferable to use bamboo splits for fiber extraction process. This is because as culm diameter increase the internal softness part thickness will increase. Consequently the amount of fiber obtained and even the strength of the fiber will be decreased (Forest types in Ethiopia, 2011)**.** Bamboo plant used as raw material for furniture makers. Indeed, about 80% of all raw highland bamboo for furniture makers comes from farmers homestead plantation. However, there is no sufficient inventory for bamboo stands on farmers homestead.

The density of bamboo growth can vary from place to place based on the site conditions and extent of disturbance. Even aerial photos can only discern large disturbed areas where the bamboo grows densely. Past attempts at estimating Ethiopian and merely estimated the distribution of bamboo in four regions where bamboo occurs significantly (Forest types in Ethiopia, 2011).Therefore, due to its abundance, highly dense fibers present along the culm and naturally its thin wall thickness, bamboo species from the highlands of Ethiopia was selected for this investigation.

2.8. Bamboo Fiber

The bamboo culm, which is the above-ground stalk of the plant, is made up of segments called internodes. The boundaries between the internodes are the nodes. (See Figure 2.8).The fibers are located in the internodes of the bamboo culm. The length of the fibers is the entire length of the internode. The natural aspect ratio of the fibers is between 150:1 and 250:1, depending on the plant. There is a variety between different culms on stiffness, strength and fracture toughness. The culm of a bamboo plant is a lingo-cellulosic natural functionally graded composite material

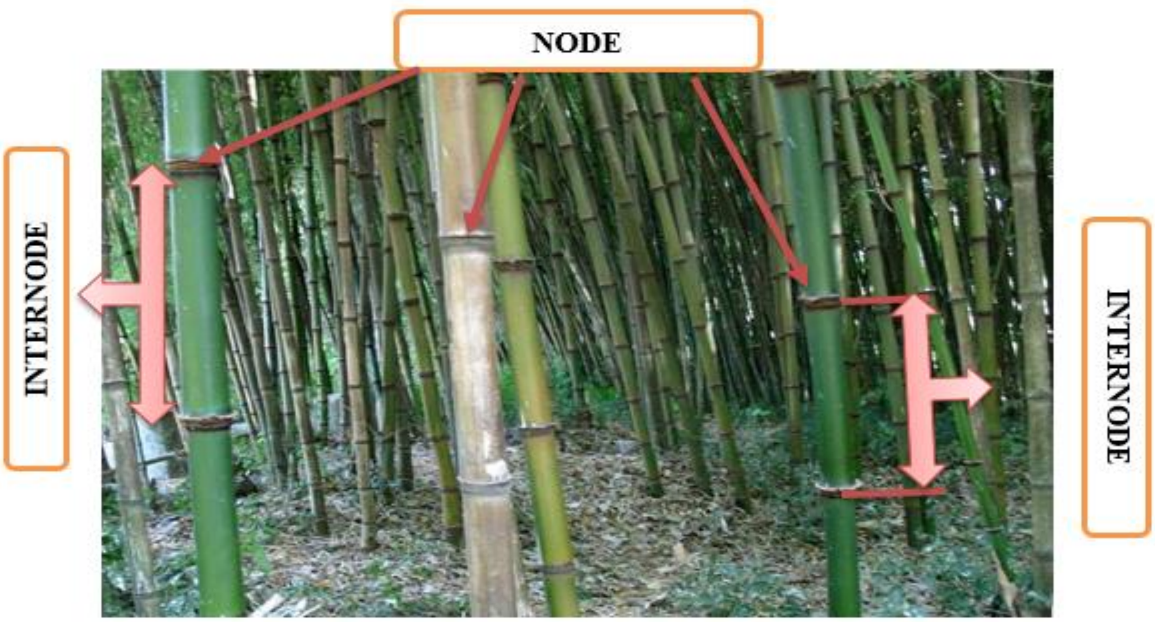


Figure 2.8: Bamboo culm with node and internode locations.

Bamboo fibers are found inside the internode. [**Source:** Guidelines for cultivating Ethiopian High land Bamboo]

2.8.1. Chemical constituents of bamboo

The chemical constituents of bamboo are primary cellulose, hemi-cellulose and lignin. The Bamboo has 60% cellulose and a considerably high percentage of lignin (about 32%)

Cellulose is the primary structural component of plant fibers and the most abundant naturally-occurring polymer on Earth. It is a polysaccharide polymer with the tendency to form intra- and intermolecular hydrogen bonds, so it can be found with high crystallinity.

Hemicelluloses are polysaccharide polymers comprised of shorter polymer chains than cellulose.

Lignin is an amorphous polymer of phenol-propane units. It is an encrusting agent that gives plant cell walls their rigidity.

2.8.2. Mechanical Properties of Bamboo Fiber

In addition to their biodegradability and availability, bamboo fibers have advantageous mechanical properties. The tensile properties of bamboo fibers and other natural fiber are listed in fig 2.9 Bamboo fibers have a lower strength than several of the fibers in the list, but they have nearly the highest specific strength, which is the ratio of strength to density. Like any natural fiber, the properties of bamboo fibers are somewhat unpredictable because they vary based on the growing season, age of the plant, nutrients available in the soil, as well as other environmental factors. (Royse, 2012)

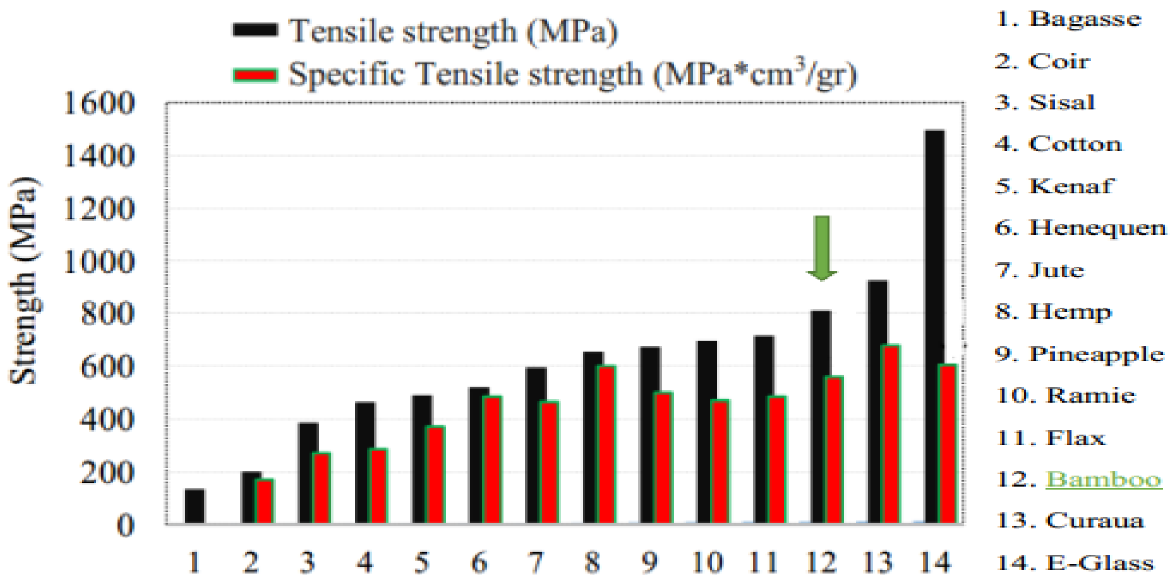


Figure 2.9: Comparison of Natural fibers strength and specific strength

2.8.3. Extraction method of Bamboo fiber

Bamboo fibers can be extract in different ways. Some of them are explained below

Steam-explosion processing: Raw bamboo was first cut into bamboo culms with 70-80cm in length by saw machine, and put into an autoclave with over-heated steam at 1750C and 0.7-0.8 MPa for 60 minutes. Then, the steam was suddenly released for 5 minutes and the cycles of sudden-steam release were continuously repeated for 9 times to assure the complete facture of cell walls. Finally, they were washed in hot water with addition of soap at 90-950C for 15 minutes to remove ash and dried in the oven for 24 hours at 105 C^0 (Phong, 2012)

Chemical Processing: It is basically hydrolysis alkalization. The crushed bamboo is "cooked" with the help of Sodium hydroxide (NaOH) into a form of regenerated cellulose fiber. Hydrolysis alkalization is then done through carbon disulfide combined with multi-phase bleaching. Although chemical processing is not environmental friendly but it is preferred by many manufacturers as it is a less time consuming process (Phong, 2012)

Mechanical Processing: In this method, the crushed bamboo is treated with biological enzymes. This breaks the bamboo into a mushy mass and individual fibers are then combed out. Although expensive, this process is eco-friendly (Phong, 2012).

2.9. Sisal plant

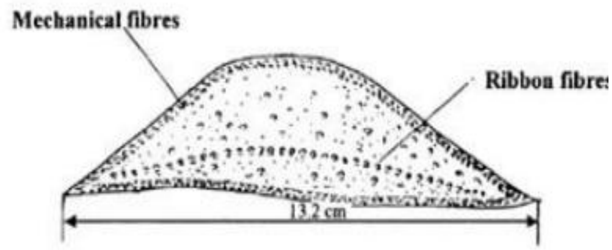
Sisal fiber is a hard fiber extracted from the leaves of the sisal plant (Agave sisal Ana). Though native to tropical and sub-tropical North and South America, sisal plant is now widely grown in tropical countries of Africa, the West Indies, and the Far East. Sisal fibers are extracted from the leaves.

Sisal fiber is one of the most widely used natural fibers and is very easily cultivated. It has short renewal times and grows wild in the edges of fields. Tanzania and Brazil are the two main producing countries. A sisal plant produces about 200-250 leaves and each leaf contains 1000-1200 fiber bundles which are composed of 4% fiber, 0.75% cuticle, 8% dry matter and 87.25% water. So normally a leaf weighing about 600 g will yield about 3% by weight of fiber with each leaf containing about 1000 fibers. Fig. 2.10 shows sisal plant.

Figure 2.10: Sisal plant

The sisal leaf contains three types of fibers, mechanical, ribbon and xylem. The mechanical fibers are mostly extracted from the periphery of the leaf. They have a roughly thickened-horseshoe shape and seldom divide during the extraction processes. They are the most commercially useful of the sisal fiber. Ribbon fibers occur in association with the conducting tissues in the median line of the leaf. Fig. 2.11 shows a cross-section of a sisal leaf and indicates where mechanical and ribbon fibers are obtained. The related conducting tissue structure of the ribbon fiber gives them considerable mechanical strength. They are the longest fibers and compared with mechanical fibers they can be easily split longitudinally during processing. Xylem fibers have an irregular shape and occur opposite the ribbon fibers through the connection of vascular bundles as shown in Fig. 2.12. They are composed of thin-walled cells and are therefore easily broken up and lost during the extraction process.

(a) Sisal leaf



(b) Photograph of a sisal plant

Figure 2.11: Sketch of sisal plant and the cross-section sisal plant

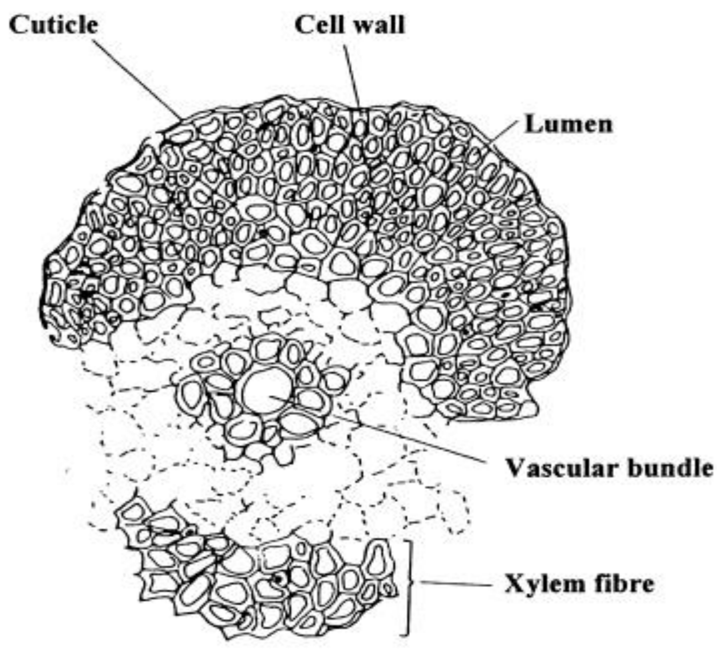


Figure 2.12: Cross-section of a ribbon-fiber bundle.

2.10. Sisal fiber

Sisal fiber is a kind of natural fiber, which possesses high specific strength and modulus, low Price, recyclability, easy availability. Using sisal fiber as reinforcement to make sisal fiber. Reinforced polymer composites has aroused great interest of materials scientists and engineers all over the world (Jackson & Samanta, 2014).

2.11. Chemical treatment of natural fiber

C. Ilaiya Perumal,et al.(2018). This review explained improvement in properties of natural fiber reinforced polymer composites along with its application, the chemically treated natural fiber shows better improvement in properties than untreated fibers. The chemically treated natural fiber has improved interfacial adhesion between fiber surface and polymer matrix. Natural fiber reinforcements have shown better results in impact toughness and fatigue strength**.**

Mohit Sooda et al.(2017). Explained alkali treatments can be used as primary treatments for all type of fibers due. Treatments with 5%, 6% and 10% strength of NaOH solution improvement in flexural properties has been observed. Combinations of treatments like alkali + silane shows higher flexural properties than single treatment.

Layth Mohammed, et al. (2015). Evaluated the characteristics and properties of natural fiber reinforced polymer composites: mechanical, thermal, energy absorption, moisture absorption, biodegradability, flame retardancy, tribology properties. Viscoelastic behavior and relaxation behavior of NFPCs are researched. Also the application of NFPCs in automobile and industry is reported. The effects of chemical treatment of the natural fiber properties were also addressed. The physical and mechanical properties of these NFPCs can be further enhanced through the chemical treatment, while moisture absorption of the NFPCs can be reduced through surface modification of fibers such as alkalization and addition of coupling agents

2.1.2. Previous Works Related to Natural Fiber reinforced Hybrid Composites

H. Raghavendra Rao, et al. (2014). Studied the impact properties of the composites and the effect of alkali treatment of bamboo fibers on these properties. It was observed that the impact properties of the hybrid composites increase with glass fiber content. These properties found to be higher when alkali treated bamboo fibers was used in hybrid composites. The hybrid fiber composites showed better resistance to the chemicals. The elimination of amorphous hemi-cellulose with alkali treatment leading to higher crystallinity of the bamboo fibers.

Sandhya Rani Borukati et al. (2018). Studied mechanical characterization of new polymer composites consisting of glass fiber reinforcement, epoxy resin, and sisal fiber. The developed composites are characterized for their mechanical properties and Experimental investigation like the tensile test, compression test, hardness test and impact test was conducted to find the significant influence of sisal fiber on mechanical characteristics of Glass Fiber Reinforced Polymer composites. From experiment conclude that the Hardness, tensile, compression, impact characteristics of E-Glass fiber reinforced sisal composite material gives better results compare to ordinary E-Glass fiber composite material hardness, tension and compression values are better than normal E Glass fiber matrix material by adding natural fiber (Sisal fiber).

Sudhir.A, (2014). In this study was described the development and characterization of new set of hybrid natural fiber composites. It is made by reinforcing sisal/ jute fibers with epoxy resin in matrix by using hand layup technique. The natural fibers were extracted by retting and combing process manually. Hybrid composites were prepared using sisal/jute fibers of 0/40, 10/30, 20/20, 30/10, 40/0 weight fraction ratios while overall fiber weight fraction was fixed as 0.4 weight fraction. The tensile and flexural properties were carried out using hybrid composite samples. The results indicated that addition of sisal fiber in jute/epoxy composites up to 50% weight fraction results increasing the mechanical properties

Madhu Vani. A,et al. (2016). Studied development of bio-degradable composites using Epoxy resin and Sisal/Jute fibers. The fibers are chemically treated at different percentages of NaOH i.e., 3%, 6% and 9%. Tensile and flexural strength of the composites was determined using UTM and Hand layup technique is used to prepare the composite. the study conclude that , the density of the composites decreases by increasing in the percentage of alkali treatment, the tensile strength and flexural strength of the composites increases by increasing in the percentage of alkali treatment.

G.Velmurugan, et al. (2014). This study Evaluated of mechanical properties such as tensile strength, flexural strength and impact strength for different fiber length and fiber volume fraction Specimen1 [3mm] Sisal (25%) - coir (15%), Specimen 2 [3mm] Sisal (20%) - coir

(20%), Specimen 3[5mm] Sisal (20%) - coir (20%). Sisal and coir fibers used as reinforcement materials with matrix of Epoxy resin to manufacturing of composite plate by hand lay-up process and cut into that as per ASTM for testing the materials. The results obtained from this study conclude that 20% sisal and 20% coir having 3mm fiber length is suitable for light weight and low load applications.

Vikas Sahu, et al.(2015). Investigated hybrid composites were prepared using sisal/pineapple fibers of 100/0, 70/30, 50/50, 30/70, and 0/100 Weight fraction ratios, while overall fiber weight fraction was fixed as 20gram. Samples are prepared using Hand layup method, specimens are prepared , fibers are arranged in unidirectional manner and tests are carried out , which shows tensile and bending strengths. The investigation conclude that from test result the composite made by 50/50 fibers weight fraction of sisal & pineapple fiber has been shown best impact strength 47.2 $^{N}/_{mm^2}$ as compare to other constitutes of sisal & pine fibers. This constitute have good tensile & bending strength & their density is also less than sisal fibers.

S. Nageswara,et al. (2016). In this experiment glass fiber/bamboo /sisal reinforced epoxy composites were prepared and studied their mechanical properties experimentally and compare them. The prepared composite specimens by using the raw materials by varying weight (10% to 40%) content ratio. Test the composite specimens by using the Instron 3369 model UTM and find out the tensile and flexural properties of the composite. The reported results showed that the tensile strength is increasing with increase of glass fiber content in the composites. Finally conclude that the mechanical properties are high for glass fiber and bamboo compared to the sisal.

Mahesh & Rao,(2017).This research investigated the fiber orientation reinforced hybrid polymer Nano composites that combine with hybrid composites i.e. BAMBOO/E-GLASS and epoxy polymer in the ratio of 0.1wt %, 0.2 wt% and 0.3 wt% percent of volume are to be considered. The mechanical properties are to be calculating by carrying out tests on specimens intension, compression and flexure in accordance with the test procedure laid down in ASTM standards. And from the result concluded that The tensile modulus, micro-hardness and density of the composites are also greatly influenced by the type and content of fillers. The particulate filled bamboo-epoxy composites possess higher hardness values compared to the glass-epoxy composites irrespective of the filler type.

Naidu, et al.(2011). In this paper was studied hybrid composites of unsaturated polyester based sisal/glass fiber hybrid composites were prepared. A significant improvement in tensile and flexural properties of sisal/glass fiber hybrid composites was found. The chalk powder (additive) is also added to the resin (unsaturated polyester) in proportions of 1%,2%,3% by weight of resin Respectively and sisal/glass fiber hybrid composites were prepared by using this resin to study the effect of chalk powder on tensile and flexural properties of these hybrid composites**.**

Kai Zhang et al. (2018). Investigated the effect of fiber content and fiber length on the mechanical behavior of bamboo fiber reinforced epoxy composites. in order to find suitable NaOH concentration for bamboo fiber treatment, bamboo fibers were treated with 2 wt. %, 6 wt.% and 10 wt.% NaOH solutions for 12 h, respectively. We determined that 6 wt. % NaOH treated bamboo fibers were optimal for the fabrication of bamboo fiber composites by single fiber tensile test, single fiber pull-out test, The results confirmed that fracture toughness and flexural modulus of the composites monotonically increased with fiber length and content**.**

V.K. Singh et al. (2015). Investigated experimentally the effect of bamboo fibers at different weight percentages (20, 30 and 40) to modify epoxy resin. Tests are conducted on 100 KN servo hydraulic universal testing machine under displacement mode of control, digital Rockwell hardness testing machine and impact testing machine. Modifying epoxy resin through bamboo fibers and improve mechanical properties is main focus of this study. Bamboo fibers at different wt.% (20, 30 and 40) are filled in epoxy resin and the effects of mixing bamboo fibers on mechanical and physical properties and mechanical testing results it is found that 30 wt.% of bamboo fiber mixed epoxy is giving optimum mechanical properties**.**

Mr. R Manjunath, (2018). The mechanical behavior of natural fiber reinforced hybrid epoxy composites. The glass fiber, Cotton and silk were used to fabricate hybrid natural composites. With varying the fiber percentage from 2-6%. The maximum compressive strength of 0.402 kN/mm^2 was found for the fiber loading (mass fraction) of 6% for both glass fiber, Cotton and silk fiber hybrid epoxy composite., Cotton and silk fiber hybrid epoxy composite. The maximum bending strength of 1.0395 kN/mm^2 was found for the fiber loading (mass fraction) of 6% for both glass fiber, cotton and silk fiber hybrid epoxy composite.

K. Velmurugan,et al (2015). In this study was presented experimental analysis of fiber loading on mechanical properties of jute/glass/kenaf fiber reinforced epoxy based sandwich composite. After fabrication and testing the result shows that the tensile strength 62.44Mpa, flexural strength 283.77Mpa, and compression strength 53.98 Mpa.It has more tensile strength than any other composites materials (banana, sisal, coir etc.) generally concluded polymer reinforced natural fiber sandwich composites is the best natural composites for manufacturing of automotive seat shells among the other natural fiber combination of kenaf, jute and E-glass.

2.1.3. Automotive door panel materials and analysis in the past

Ermias G. Koricho et al. (2015). This paper investigated Experimental characterization of the mechanical properties of E -glass/Epoxy & E-glass/Polyester composite. The specimen was prepared and E-glass/polyester laminates were obtained by compression molding process and E -glass/epoxy laminate by hand lay-up vacuum assisted technique is used to fabricate the specimen and investigation has done with the testing of tensile, compression, shear and flexural strength on a universal testing machine. The effect of strain rate on E-glass/epoxy and E-glass/polyester has been investigated & experimentation was performed to determine property data for material specifications. And conclude that the compressive, shear and flexural properties of E-glass/Epoxy composite have an increasing trend when the strain rate is increasing; whereas the tensile strength decreases as the strain rate increases. In case of E-glass/polyester composite, the tensile strength and compressive strength increases as the strain rate increases and the in-plane shear and flexural strength show a decreasing trend as the strain rate increases.

Vijayan.P,(2016). In this project Design and analyze the Side impact on the light weight car door panel assembly with present using material of Steel replaced with the mono and hybrid construction of lightweight Aluminum alloy, Magnesium Alloy and Steel. Impact Analysis has done with different speed and the crashworthiness is studied.

Analysis is done with different speed and the crashworthiness is studied. Final analysis results are compared with Federal Motor Vehicle Safety Standard for crashworthiness and best of the result will be with respect to light weight design. The car door model assembly of outer and inner panel is done using modeling software CATIA P3 V5R14 and also analyzed using it.

Conclude, that the maximum allowed crush resistance for FMVSS standard is 152 mm at initial load condition of average 1020kg load condition.

Based on the analysis report of the car door panel, that the concept 2 of magnesium alloy of mono construction and concept 4 of hybrid construction are light weight and satisfy the crash standard of resistance at maximum Distributed force of 4742N.

Ganti Satya Prakash et al. (2014). Researched on design and impact analysis of a car door. The aim of this work was to analyze the car door with existing material and replacing with different composite materials like Carbon Epoxy, S-glass epoxy, and E-Glass epoxy. Impact analysis was conducted on door for different speeds by varying the materials. This work was going to reduce weight of the door by using composite materials replacing with steel and reduce the damage percentage of the car and passenger protection. The car door was modeled using parametric modeling software Pro/Engineer.

The strength of the door is increased by change of material from steel to E-glass epoxy and S-glass epoxy composites. However the glass fiber is denser than natural fibers, so that the weight of the door panel can be further reduced when we use bamboo fiber composites. Since the bamboo fiber has almost equivalent strength with that of glass fiber, we can improve the vehicle by reducing its dead weight

Chandru B. et al.(2014). Performed dynamic modal analysis to determine the lowest natural frequency of the car door. First, car door geometry is modeled in cat and meshed in hyper mesh software. Then, a modal analysis between 0-50 Hz is done by hyper mesh. A frequency map of the door is extracted and compared with a reference map to identify shortcomings .An algorithm is proposed to improve the car NVH behavior. Modal analysis results is obtained for 10 different modes.in that first 5 modes are local modes and remaining is global modes.

From the result conclude that the modal frequencies are obtained is >20 Hz which well away from the engine excitation of 16Hz, This result is for ideal condition of engine. (Engine at 1000 rpm and load at ideal) .Harmonic analysis is performed with and without stiffener for automotive car door. In harmonic analysis displacement were obtained for both condition and with stiffener displacement were less and safe design.

Mr.Sandeep Bundele& Dr. (Mrs.) Rupa S. Bindu(2012). This study described the drawbacks of existing automotive door structure and suggest design changes to overcome the present drawbacks**.** Some of the major problems in automobile door are taken as problem for this research paper and those problems like high weight, high cost, excessive reinforcements, and water leakage.

In this paper design new front door assembly components with tailor welded blank technology for reducing weight and cost of door assembly. Tailor-welded blanks allow combining different strengths of steel in one part without adding complications at the joints. Weight of a door assembly is reducing by 0.4 kg, by reducing weight of a door inner panel by using less thickness high strength material; reduce cost by replacing molded trim with hard pad. It was successfully solved water leakage problem by modeling front door inner panel correctly. However, the weight of the door panel can be further reduced by selecting lighter materials than steel and designing accordingly.

Tawanda Mushiri and Charles Mbohwa (2011). In this paper, the finite element method was used in the development processes of the door assembly. A popular 3-D nonlinear dynamic explicit finite element code with advanced contact algorithms and material models was used to simulate several types of armors subjected to the impact of projectiles moving at various velocities

O.M. Terciu, I. Curtu, & C. Cerbu, (2012). Presented the finite element analysis of an automotive door trim panel made of lignocelluloses composites in order to determine the stresses and displacements in case of a door slam simulation. In research was investigated a new lignocelluloses composites made of polymers reinforced with woven fabrics of natural fibers and wood particles. The mechanical properties of this material were determined experimentally and used as input data in FEM simulations. The FEM results Seen that for an acceleration of the impact of $350 {}^{m}/_{s^2}$, displacements of the two points in the lignocellulose composite molded panel are lower by 43% than the plastic molded panel with classic material like polypropylene. This values displacements decrease is due to greater rigidity of lignocellulose material and smaller mass of the panel, given its reduced thickness. Since when slamming door, door panel is loaded with inertial forces due to own weight, results that it’s mass influence the load degree.

Generally Small values of displacements resulting for lignocellulosic composite component are due to the high rigidity and also low weight material layer given its lower thickness of the panel, this decreasing from 1.81kg to 1.49kg;

S.vinary, s and S.srikari, (2012). In this study was investigated how to save assembly time and cost in manufacturing by using the long fiber reinforced thermoplastic polypropylene (pp-LFT) with glass filled fiber material. The main advantage is 33% weight less than the normally using steel door. It is applied by adding 30% of glass filled on the existing steel door .It improves strength, stiffness, and manufacturability.

Summary

Generally to summarize this chapter, several experimental investigations were done to characterize the mechanical properties of the bamboo and sisal fiber reinforced composite materials. through an exhaustive literature review it has been observed that although the literature is rich in the study of mechanical behavior of sisal and bamboo fiber hybrid with other synthetic fiber , specifically hybrid bamboo and sisal fiber are not done previously ,this is the research gap.

In alkaline treatment the concentration of NaOH used varies from 3% -10%, concentration increase up to 10% improves the mechanical property.

The fiber volume fraction of hybrid natural fiber varies the mechanical property of the natural fiber composite. 100/0, 70/30, 50/50, 30/70, and 0/100 Weight fraction ratios.

Fiber and matrix volume fraction of hybrid composite the fiber from different weight percentage (20%, 30% and 40%) and the matrix weight percentage also varies from (60%, 70%, and 80%)

CHAPTER THREE

3. MATERIALS AND METHODS

This chapter details the materials used and methods followed for preparation of composite material, characterization of composite materials, modelling and analysis of door interior panel of the vehicle.

3.1. Materials for preparation of hybrid composite

3.1.1. Fiber

Fiber is the reinforcing phase of a composite material. In the present research work, bamboo and sisal hybrid fiber was taken as the reinforcement in the unsaturated polyester matrix to fabricate composites.

Sisal Fiber

Suitable quantity of sisal plant leaves were collected from Dessie town "Menbre Teshay " Ethiopia after cutting at their base from the harvest. Sisal fiber was extracted from the leaves by retting, scraping, or mechanical decortication. The sisal plant produces sword-like leaves with teeth and loses this tooth in maturity.

Bamboo Fiber

The bamboo type selected is from the highland bamboo (Yushania Alpina) species. The single bamboo timber has an average length, diameter and wall thickness of 20m, 180mm and 50mm, respectively. The bamboo, which was is used in this study was collected from the Hagre selam, which grown in farm yard. Bamboo was collected from this area because of the available of suppliers, and much amount of bamboo timber present in "ADAA Industrial Engineering, Gelan."

Sodium hydroxide

Sodium hydroxide (NaOH), also known as lye, caustic soda and sodium hydrate, is a caustic metallic base. Caustic soda forms a strong alkaline solution when dissolved in a solvent such as water. It is used in many industries, mostly as a strong chemical base in the manufacture of pulp and paper, textiles, drinking water, soaps and detergents (Greenwood, 1997).Sodium Hydroxide, in addition to Sodium Sulfide, is a key component of the white liquor solution used to separate lignin from cellulose fibers in the treatment process. It also plays a key role in several following stages of the process of bleaching the brown pulp resulting from the pulping process. These stages include oxygen delignification, oxidative extraction, and simple extraction, all of which require a strong alkaline environment with detergents and as a drain cleaner. Pure sodium hydroxide is a white solid; available in pellets, flakes, granules and as a 50%saturated solution. It is deliquescent and readily absorbs carbon dioxide from the air, so it should be stored in an airtight container. It is very soluble in water with liberation of heat. It also dissolves in ethanol and methanol, though it exhibits lower solubility in these

Although molten sodium hydroxide (as shown in fig 3.1) possesses properties similar to those of the other forms, its high temperature comparatively limits its application. In This work we used NaOH in liquid form, purchased from local suppliers with the brand name **SCILAB trading P.L.C** and performed chemical treatment of sisal fiber.

Figure 3.1: Sodium hydroxide in liquid form

3.1.2. Matrix material

Resins are of at most importance with in the composites markets as they bind the fibers together and help create the material's strength and stiffness characteristics. There are two types of resin systems: thermoset and thermoplastic. In a thermoset, the resin molecules are locked together in a irreversible way after a thermal cure; it is a one-way cure that cannot be undone. In a thermoplastic resin the chemical link which is bonding the molecules together can be broken again and again by increasing the temperature steadily which causes the matrix to go from solid to liquid. In the same way, when cooled down the thermoplastic matrix solidifies. For now concentrate on the Thermoset resins that are playing a key role in the composite industry: Polyester, Vinyl Ester, Epoxy, and Phenolic Resins…..among different thermoset resin polyester is used for this research work.

Polyester

Polyester resins are one of the most common resins used in the composite industry. The success of Polyester is mainly based on the low cost that makes this it more attractive than some higher performing resins like epoxies.

Polyester resins require a catalyzer, which functions as an initiator of the chemical reaction, to solidify. The quantity of catalyzer has an effect on the speed of the reaction and is responsible for the solidification. During the cure the polyester resins shrink significantly. The resin used for this study is polyester resin with brand name of general purpose polyester resin.

Polyester resins have numerous advantages over other resins

- The most well-known benefit of polyester is the price; the resin is relatively cheap in comparison to other types of resin.
- Polyester has the ability to accept a broad variety of fillers which makes them applicable to a wide range of projects.
- Polyester is that once de molded, the part can be sanded and finished resulting in an optically clear surface.
- Polyester is not impacted by UV radiation like other resins which is essentials for applications exposed to the sun, for instance, surfboards

Hardener (catalyst)

Polyester resin is cured by adding a catalyst, which causes a chemical reaction without changing its own composition. The catalyst initiates the chemical reaction of the polyester resin and monomer ingredient from liquid to a solid state.

3.2. Fiber extraction

3.2.1. Extraction of sisal fiber

Decortication is the most common method for extracting sisal fiber. In this process, the leaves are crushed between blunt knives and moisture and the fleshy pulp are removed from the fiber. Initially` the leaves trimmed in longitudinal direction into strips for ease of fiber extraction The peel is clamped between the wood plank and knife and hand-pulled through in longitudinal direction gently, removing the resinous material as shown in Figure 3.2 (a) and (b) then the extracted fiber washed with pure water in order to loosen, and separate the fiber until individual fibers are obtained.

a) Sisal Plant b) Longitudinally Trimmed Sisal Plant

c) Peeling of sisal plant for sisal fiber extraction

d) Extracted sisal fiber before washing and drying

Figure 3.2: Sisal fiber extraction process

The extracted fibers were sun-dried which whitens the fiber once dried, the sisal fibers are ready for fabrication of test pieces as shown in fig 3.3 and 3.4. Extracted sisal fiber is shown in Figure 3.2(d). The lustrous strands, usually creamy white, and average from 80 to 120 cm in length and 0.2 to 0.4 mm in diameter. Sisal fiber is fairly coarse and inflexible. It is valued for cordage use because of its strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in saltwater

Figure 3.3: Sun drying of extracted fibers

Figure 3.4: Dried sisal fiber

3.2.2. Extraction of bamboo fiber

Bamboo fibers can be extracted from the bamboo culm through different ways such as by mechanical means using different machines such as advanced roller & mechanical dryer; by chemicals means, applying different chemicals and or by steam explosion technique, using steam. However, in this work bamboo fiber was extracted using advanced roller machine extraction technique In general the extraction process of the bamboo fibers is concisely summarized as fig 3.5 from (a)-(d)

Nodes, most inner parts and very thin layer of exoderm of the highland bamboo have been removed and remaining parts have cleaved in longitudinal direction to thin slabs by using circular band saw.

(a) Cutting of bamboo at the node

(b) Bamboo bundle

(c) Preparing the bamboo fiber in strip

(d) Bamboo fiber

Figure 3.5: Extracted bamboo fiber before treatment

3.3. Chemical treatment of fibers

The characterization of the interface between fiber and matrix is largely important during the development of composites. Hydrophilic natural fibers and hydrophobic polymer matrixes do not bond very well to each other. To improve the interface for producing composites with better mechanical properties chemical treatment has to be done. Because of this improvement, treatments of fibers are used in order to improve the surface of reinforcement (Mohit Sooda, 2017).

Mercerization is one common treatment for bamboo and sisal fibers. It allows the surface and bulk properties of the bamboo/sisal fiber to be modified chemically. Some mercerization, or alkali treatment, consists of treating bamboo and sisal fibers with sodium hydroxide (NaOH) in order to break hydrogen bonds and then remove impurities and amorphous cellulose. Moreover, this process cleans the fiber surface, and therefore improves smoothness and promotes a chemical adhesion between the natural fiber and the polyester resin matrix.

In addition, this treatment allows removal of some lignin and hemicellulose present on the surface of the fiber resulting in an improvement of tensile strength of composites reinforced by bamboo fiber. Another contribution of this treatment is the separation of the macro fiber bundle into elementary fibers due to the removing of the lignin and hemicellulose which link the internal organization of the fibers. The alkali pretreatment causes swelling of fibers, resulting in an improvement of internal surface area and therefore separation of structural bonds which link lignin and carbohydrates, finally leading to disorganization of the lignin structure. Treatment with sodium hydroxide allows the creation of active hydroxyl groups present at the fiber surface and therefore enhances the chemical reaction between fiber and matrix, resulting in efficient stress transfer at the interface. In general, removal of these fatty like components from bamboo fiber leads the fibers to:

- Improve an adhesive properties for fiber–matrix interface
- Improve fiber's shear strength
- Improve fiber's rigidity and stiffness
- Improve moisture absorption problems
- Reduce fiber's weight etc.

However, as concentration of NaOH increased the result obtained worsened the mechanical Properties of the fibers .For this reason, after several trials, medium concentration of NaOH (i.e. 5%) is used for this work. In general, this study consumed 330ml of molten NaOH for each fiber.Eq.3.1 and 3.2 show the chemical reaction between bamboo /sisal fiber and aqueous sodium hydroxide solution.

Bamboo fiber -OH +NaOH → FIBER-O-Na+ H_2O …………………………….. eq (3.1)

Sisal fiber-OH +NaOH → FIBER-O-Na+ H_2O……………………………………eq (3.2)

3.3.1. Alkaline/ Mercerization / treatments Bamboo fibers

First Prepare bamboo fiber bundles. Then prepare 5% concentration of NaOH solution. (As shown in fig 3.6 (a). Next soaked the fibers in NaOH solution for 24 hours in distilled water in order to neutralize it, the fiber washed many times with tap water. (Fig 3.6 (b) and (b) .Finally these fibers dried in sunlight for two days. After the fiber dried, the mat prepared in 0^0 orientation as a unidirectional layers.

a) Mixing of sodium hydroxide and distilled water

b) Bamboo fiber soaked in sodium hydroxide

c) Alkaline treated bamboo fiber

d) Unidirectional (UD) bamboo fiber with zero degree fiber orientation

Figure 3.6: Alkaline Treatment & woven Preparation of Bamboo fiber

3.3.2. Alkaline/ Mercerization / treatments of sisal fibers

After extraction of sisal fiber in order to increase interfacial surface adhesion fiber are chemically treated using NaOH. NaOH solution was prepared with 5% concentration (as shown in fig 3.7 (a) .Next soaked the fibers in NaOH solution for 24 hours and then in distilled water in order to neutralize it. Fig 3.7 (a) and (b). The fiber was washed many times with tap water. Finally these fibers dried in sunlight for two days. After the fiber dried, the woven($0^0/90^0$), 0^0 fiber orientation and 90^0 a unidirectional fiber layer is prepared. (Fig 3.7 (a) and (b).


(a) Preparation of alkaline solution

(b) Soaking sisal fiber in NaOH solution


(c) Drying sisal fiber

(d) Weaving at $0^0/90^0$ fiber

Figure 3.7: Alkaline treatment & woven preparation of sisal fiber

3.4. Sample Preparation

Before hybrid reinforcement of bamboo fiber and sisal fiber fiber volume fraction and matrix volume fraction of this composite material is determined, ply stacking sequences of laminated hybrid composite structure is designed. Finally bamboo & sisal fiber with polyester resin hybrid composite is fabricated. Composite materials can be prepared by different methods. However due to many reasons such as part size and shape, cost, familiarity with the technique and availability of tools, in this work composite was fabricated using hand layup techniques.

3.4.1. Concept of Hybridization

The incorporation of several different types of fibers into a single matrix has led to the development of hybrid bio composites. The behavior of hybrid composites is a weighed sum of the individual components in which there is a more favorable balance between the inherent advantages and disadvantages. Also, using a hybrid composite that contains two or more types of fiber, the advantages of one type of fiber could complement with what are lacking in the other. As a consequence, a balance in cost and performance can be achieved through proper material design.

The properties of a hybrid composite mainly depend upon the

- Fiber selection
- Matrix selection
- fiber content/concentration/
- length of individual fibers
- orientation of fiber
- extent of intermingling of fibers
- Interfacial strength/ fiber to matrix bonding.
- Manufacturing method (K.L. Pickering,2015).

In this research work Bio fiber- Bio fiber Composite type is used by hybridizing bamboo and sisal fiber in matrix system .The composite was prepared varying fiber orientation by fixing other parameter as given in table 3.1.

Table 3.1: Work specification

Hybrid Property change factors	
Type of hybrid	Bio-fiber to bio fiber hybrid composite(sisal and bamboo)
Matrix type	Polyester (Thermoset polymer)
Fiber to fiber ratio	75% bamboo and 25% sisal
Fiber/matrix volume content	After fabrication
length of individual fibers	Long fiber in both fiber
interfacial strength/ fiber to matrix bonding/	Both are treated
Composite structure	Sandwiches
Fiber orientation	Unidirectional and bidirectional $0^0/90^0/0,90$
Method of fabrication	Hand lay

3.4.2. Rule of Hybrid Mixture

The properties of the hybrid system consisting of two components can be predicted by the rule of mixture.

$$P_H = P_1V_1 + P_2V_2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots eq\ (3.3)$$

$$where, P_H = \text{property to be investigated}$$

$$P_1 = \text{property of the first system}$$

$$P_2 = \text{property of the second system}$$

$V_1 and\ V_2$ are the relative hybrid volume fractions of the first and second system

$$\mathrm{V_1 + V_2 = 1} \qquad \ldots\ldots\ldots\ldots\ldots \text{eq (3.4)}$$

3.4.1. Fiber and matrix volume content of the composite

In design, fabrication and analysis of composite materials, the first and critical task is the determination of ingredient percentages such as fiber and matrix (resin) fraction presence in laminate .

Fiber and matrix weight fraction ($W_{F,} w_m$)

$$\text{Fiber weight fraction} = \frac{\text{weight of fiber}}{\text{Total weight}}$$

$$W_F = \frac{W_f}{W_F + W_m} \qquad \text{………………eq (3.5)}$$

$$\text{Matrix weight fraction} = \frac{\text{weight of matrix}}{\text{Total weight}}$$

$$W_m = \frac{W_m}{W_F + W_m} \qquad \text{……………..eq (3.6)}$$

$$w_F + W_m = W_C$$

Wight of fiber+ weight of matrix=1, $w_F + W_m$=1 ………………eq (3.7)

Fiber and matrix volume fraction (VF, VM)

Volume of fiber, matrix and composite is given by

$$V_f = \frac{W_f}{\rho_f} \quad , V_m = \frac{W_m}{\rho_m}$$

$$V_C = V_f + V_m \qquad \text{…………eq (3.8)}$$

$$\text{Fiber volume fraction} = \frac{\text{volume of fiber}}{\text{Total volume}}$$

$$VF = \frac{V_f}{V_f + V_m} = \frac{V_f}{V_c} \qquad \text{…………eq (3.9)}$$

Matrix volume fraction = $\frac{\text{Volume of matrix}}{\text{Total volume}}$

$$VM = \frac{V_m}{V_f + V_m} = \frac{V_m}{V_c} \quad \text{..............eq (3.10)}$$

$$V_f + V_m = 1 \quad \text{..................... eq (3.10)}$$

Let ρ_f and ρ_m are density of fiber and matrix respectively, then we have

$$V_F = \frac{W_f \times \rho_m}{W_f \times \rho_m + W_m \times \rho_f} \quad \text{.................. eq (3.11)}$$

Similarly

$$V_m = \frac{W_m \times \rho_f}{W_f \times \rho_m + W_m \times \rho_f} \quad \text{.................... eq (3.12}$$

Where:

W_F =Weight of Fiber (g)

V_F = Volume of fibers, (cm^3)

W_m = Weight of matrix (g)

V_m =Volume of matrix, (cm^3)

W_C = Weight of composite specimen (g)

V_C = Volume of composite(cm^3)

ρ_m = Density of matrix (g/cc)

VF = Fibers Volume fraction

ρ_f = Density of fiber (g/cc)

VM = Matrix Volume fraction

By using the above aforementioned equations and by measuring the weight as shown in fig 3.8 (a) and (b), these values were evaluated and presented in the following tables

Table 3.2: Fiber and matrix volume content of the composite

Sample orientation	**Composition**		**Mass fraction**			**Total**
	Polyester (%)	Hybrid (%)	Polyester (gram)	Hybrid fiber		(gram)
				Bamboo(gm)	Sisal(gm)	
Unidirectional (zero degree)	77.894	22.1053	1480	300	120	1900
Unidirectional (90 degree)	78.75	21.25	1260	220	120	1600
Bidirectional	81.66	19.33	1470	200	130	1800

(a) Weighting bamboo fiber (b) Weighting sisal fiber

Figure 3.8: Measuring of bamboo and sisal fiber before hybridization

3.4.2. Fiber orientation of fibers

The force and the rigidity of the composite depends on the fiber orientation and series of piles of their orientation series of piles .Appropriate selection of ply orientation in advanced composite materials is necessary to give required a structural strength. The structural part may need 90^0 piles to respond side loads, $\pm 45^0$ plies to respond shear loads and 0^0 piles to respond axial load.

3.4.2.1. Unidirectional fiber orientation

Unidirectional tapes have been the standard within the aerospace industry for many years, and the fiber is typically impregnated with thermosetting resins. Tape products have high strength in the fiber direction. The fibers are mixed with the resin.

3.4.2.2. Bi-directional fiber orientation

Most fabric constructions offer more flexibility for the layup of complex shapes than straight unidirectional tapes offer. Fabrics offer the option for resin mixed either by hot melt or the solution process. Generally, fabrics used for structural applications are like fibers or strands of the same weight or yield in both the warp (longitudinal) and fill (transverse) directions. For aerospace structures, tightly woven fabrics are used to save weight, minimizing size, and maintaining during the fabrication process.

Weave preparation of sisal fiber

Weaves:

Woven textiles are generally made of two sets of yarns that interlace and are oriented at 90° from each another. Weaves are the strongest and most stable structures that can be obtained from interlacing yarns. Woven textiles can be 2-D or 3-D as it can be seen in Figure 3 .9 that shows the basic procedure of making woven textiles.

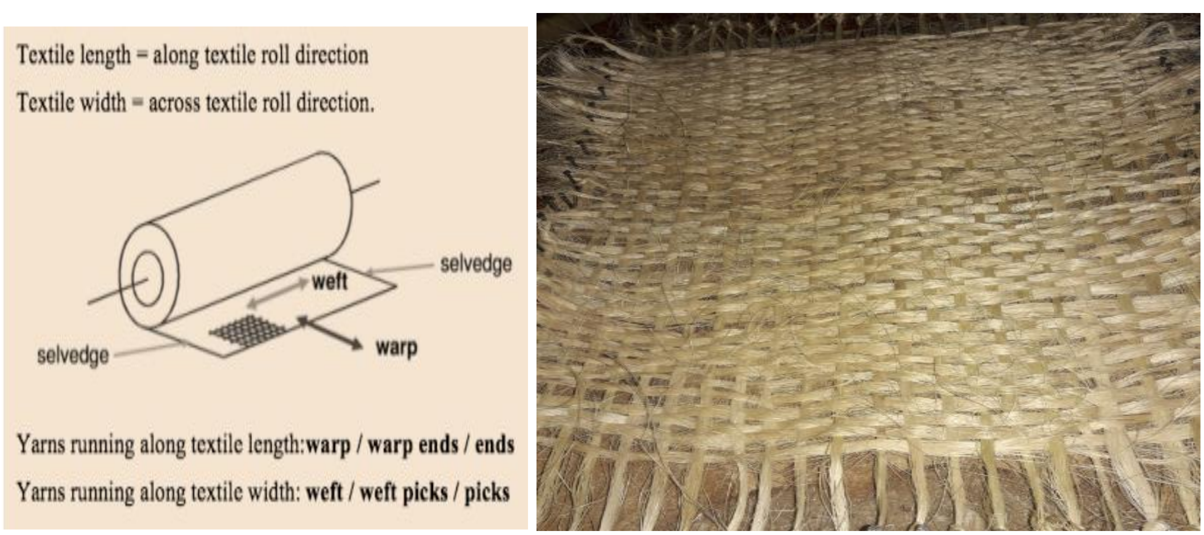


Figure 3.9: Plain woven preparation

Different structures and types of woven textiles can be produced depending on requirement In this work plain weave is used due to its mechanical properties (Figure 3.10)

Plain weave

Plain weave is the simplest weave form. It is made by interlacing yarns in an alternating over-and-under pattern. There is one warp fiber for one fill fiber with no skipping. The maximum fabric stability and firmness with minimum yarn slippage result from this weave. The pattern gives uniform strength in two directions when yarn size and count are similar in warp and fill. This weave type is the most resistant in shear and is also considered to be a rather stiff weave. Because plain weave fabrics are stable, they are used for flat laminates.

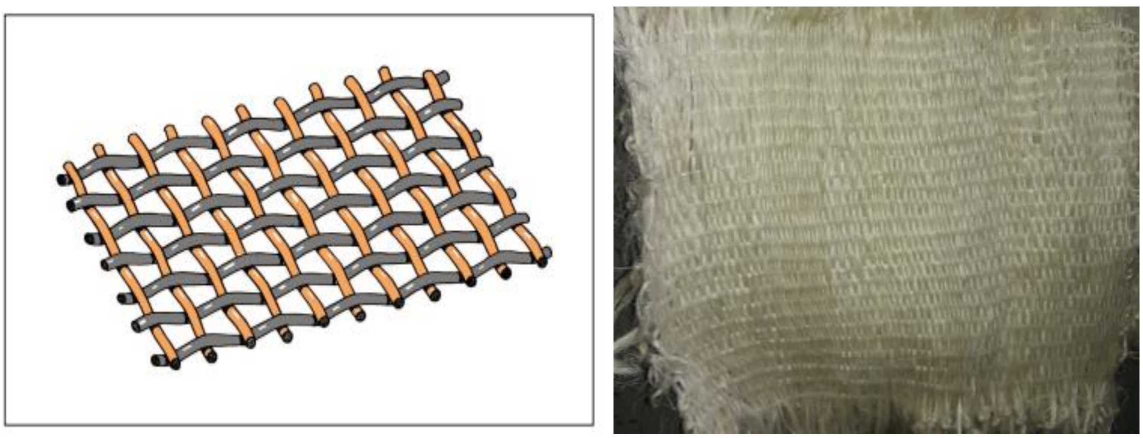


Figure 3.10: Model and prepared bidirectional plain weave

3.5. Fabrication approach

3.5.1. Composite plies and laminates design

The form of reinforcement and some preliminary conditions for this bamboo and sisal fiber reinforced hybrid composite fabrication process has been presented here. Plies in composite materials are sub structures of the composite laminate and most of the time they are considered in ‘prepreg’ (fibers pre-impregnated with partly cured resin) form. So, composite laminates are formed by stacking different plies with different orientations by forming different laminated layers.

3.5.2. Sandwich hybrids

Sandwich hybrids, also known as core-shell, in which one material is sandwiched between two layers of another. In this hybrid composite is the incorporation of two natural fibers in a matrix system. The mechanical performance of long unidirectional oriented bamboo fiber and long unidirectional horizontal/unidirectional vertical and bidirectional sisal fiber reinforced polyester hybrid composites with reference to the relative volume fraction of the two fibers at a constant total fiber loading of 0.20 volume fraction (V_f), keeping sisal fiber as the shell material and bamboo fiber as the core material.

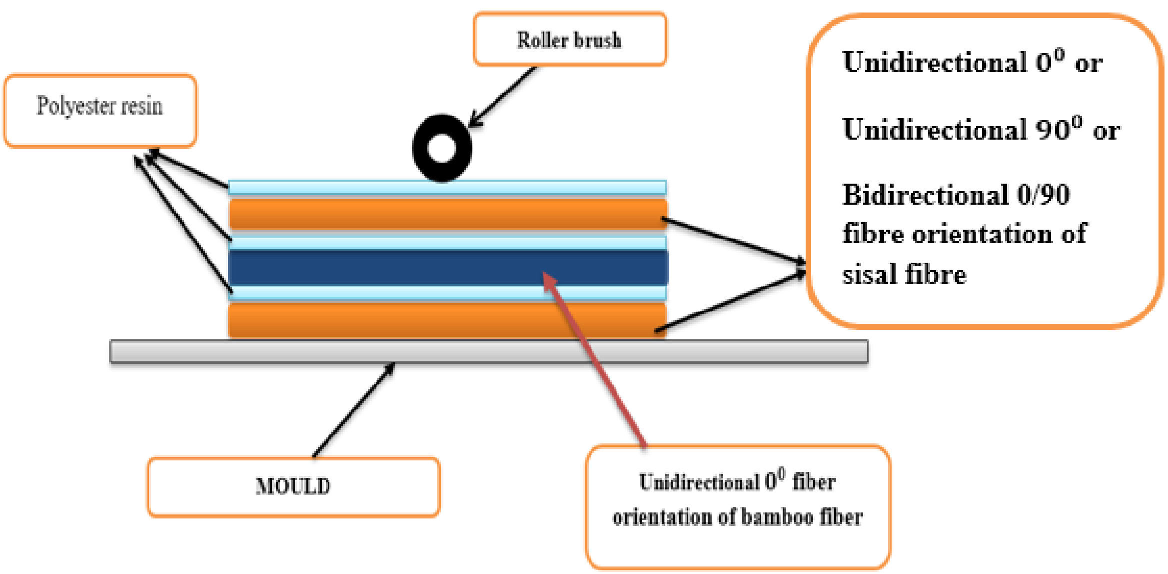


Figure 3.11: Fabrication approach of composite with different sisal fiber orentation

The figure 3.11 shows the scheme for the preparation of bamboo and Sisal fiber reinforced polyester resin hybrid composites. The composite specimens were prepared in an open mold method. Unidirectional bamboo fiber and sisal fiber in different orientation were used to prepare the samples

Polyester resin and hardener (catalyst) were taken in a plastic bottle then mixed well and made ready for layup reinforced sisal fiber. The composite samples were fabricated by hand lay-up technique. The figure 3.12 shows the fabrication approach of composite.

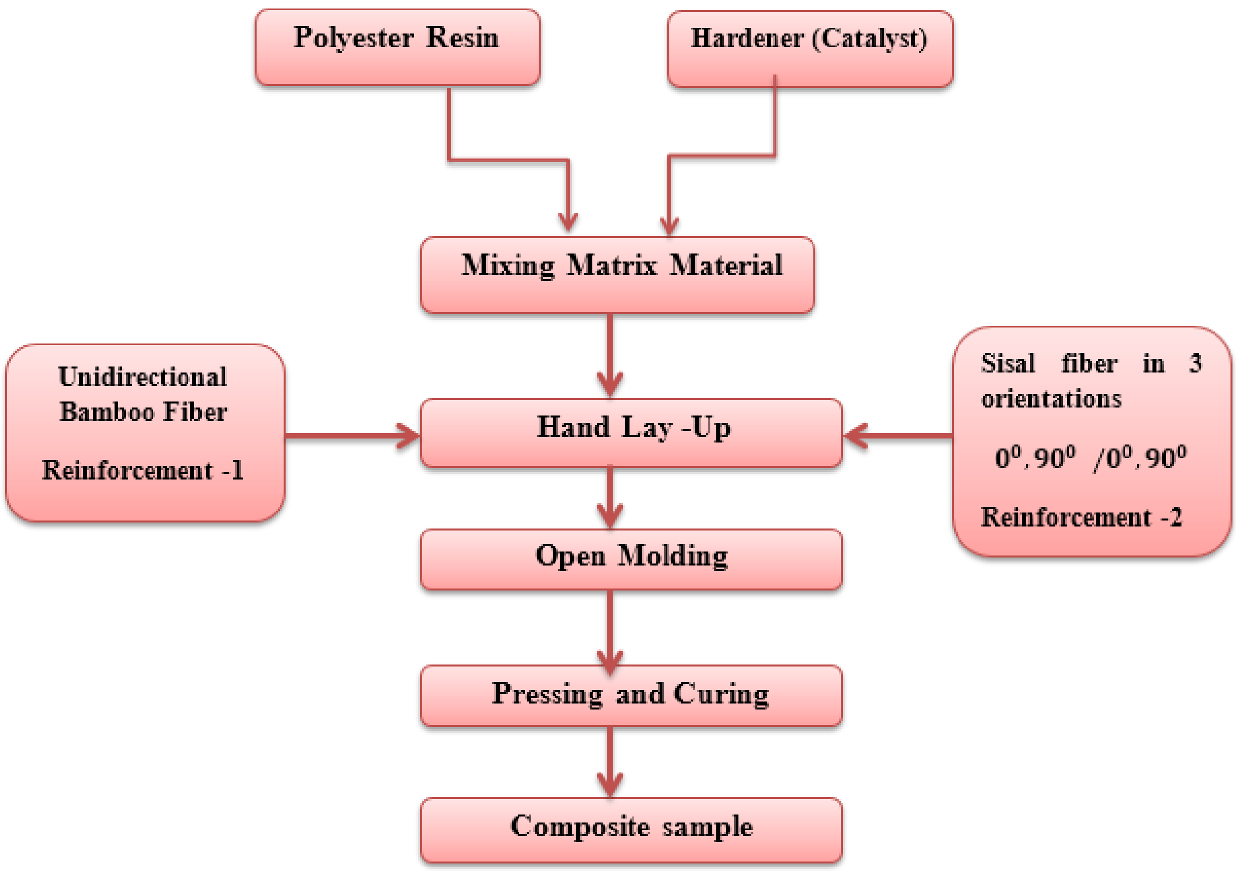


Figure 3.12: Fabrication approach of composite

3.5.3. Preparation of unsaturated polyester resin and hardener:

Unsaturated polyester mixed with hardener is used to prepare the composite plate. The weight ratio for mixing polyester and hardener is 10:1. Hardeners include anhydrides (acids), amines, polyamides, dicyandiamide etc. (as shown in fig 3.13 (a) .The mixer is strewed with stirrer for about one minute continuously (as shown fig 3.13 (b) .The mixing is performed in the mixing with in plastic bottle, during the exothermic reaction taking place with the tongue depressor the mixing is done slowly so as to not entrain any excess air bubbles in the resin.

(a) Mixing of polyester resin and catalysts according to ratio

(b) Stirring for few minutes using deep stick

Figure 3.13 : Mixing of polyester resin

3.5.4. Hand Lay-Up technique

This is an open mold method of shaping to form a structure since the layers laid are in direct contact with atmosphere; it is called an open mold. Involves manual laying of fibers with resin on mold by hands or hand tools. Thermoset resin is in liquid form at room temperature. The mold has the shape of the product and the product has the better surface finish over the side that is in contact with the mold. Hand lay-up technique is the simplest method of composite processing. The infrastructure requirement for this method is minimal.

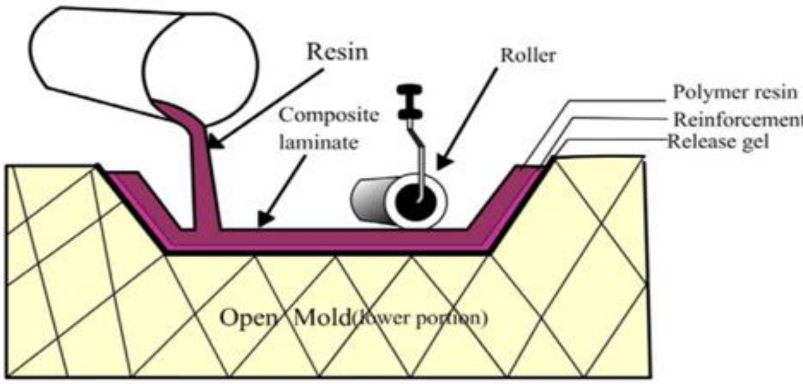


Figure 3.14: Schematic diagram of hand lay -up method

Materials requirements of Hand-lay-up method

- Mold (flat Sheet metal used as mold)
- Roller brush
- Mold release
- Glove

Mold: - The sheet metal is made up of mild steel of 2m ‘x’1m ’x’ 0.005m

Roller brush:-The roller brush is used after laying each layer to remove the air entrapping in the resin this process is repeated until the required thickness is acquired

Mold release -Mold release is essential for preventing the epoxy from sticking to the mold when laminates are apart. Even though, there are several types of mold release used depending on the mold material and desired characteristics of the finished part. The most common type and the one used for this work, is Mold Release Wax 8.2 is chosen because of its excellent release properties, easy application and exceptional mirror finish shine.

Hand lay-up process set up

3.5.4.1. Molding

The processing steps are quite simple. Bamboo and sisal fiber reinforced hybrid composite is fabricated using this method

First of all, the mold surface was polished by applying release gel/wax to avoid the sticking of polyester resin to the surface as shown in fig 3.15 (b) and (d). Polyethylene Plastic were used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of woven or unidirectional fiber were cut as per the mold size and placed at the surface of mold after Perspex sheet.

(a) Wax Release (b) Mold surface


(c) Polishing of mold surface (d) Resin poured on woven

Then polyester resin is mixed thoroughly in suitable proportion with a prescribed hardener (curing agent) and poured onto the surface of woven already placed in the mold.

(e) Spread the resin uniformly

(f) Moving roller brush in fiber resin layer

Figure 3.15: Steps for fabrication

The polyester resin was uniformly spread with the help of brush. Second layer of unidirectional bamboo fiber was then placed on the resin surface and a roller was moved with a mild pressure on the fiber-resin layer to remove any air trapped as well as the excess resin present. The process was repeated for making sandwiches structure and woven, till the required layers are stacked as shown in fig 3.15 (e) and (f).

After placing the sheet metal, the inner surface of the top mold plate was polished release gel and the it was kept on the stacked layers and the pressure is applied. After curing either at room temperature or at some specific temperature, mold was opened and the developed composite part was taken out and further processed.

3.5.4.2. Compression and Curing

Load is applied to compress the composite until the required thickness is maintained .It requires 24 hours for curing at room temperature. After curing period the sisal and bamboo fiber with polyester resin were removed from the mounds. Figure 3.16

Figure 3.16: Loading of the mold composite sample

Fabricated bamboo and sisal fiber reinforced composite Sample

Typical bamboo and sisal fiber reinforced hybrid composite samples are shown in Figure 3.17

Figure 3.17: Fabricated composite material

3.6. Experimental Procedure and Setups

3.6.1. Preparation of specimen

For testing all together 54 specimen were prepared for three fiber orientation of sisal fiber and unidirectional bamboo fiber using slitter blade as shown in figure 3.18

Figure 3.18: Cutting of sample specimen using slitter

Figure 3.19: Prepared specimen with different fiber orientation

3.6.2. Dimension of Test Pieces

ASTM was used to prepare and conduct a test of this bamboo and sisal fiber reinforced hybrid composite.

All the test pieces for tensile, compressive, and Flexural testing based on ASTM standard and their value as show below, whereas for impact test based on [ISO 9001:20001, 2010]

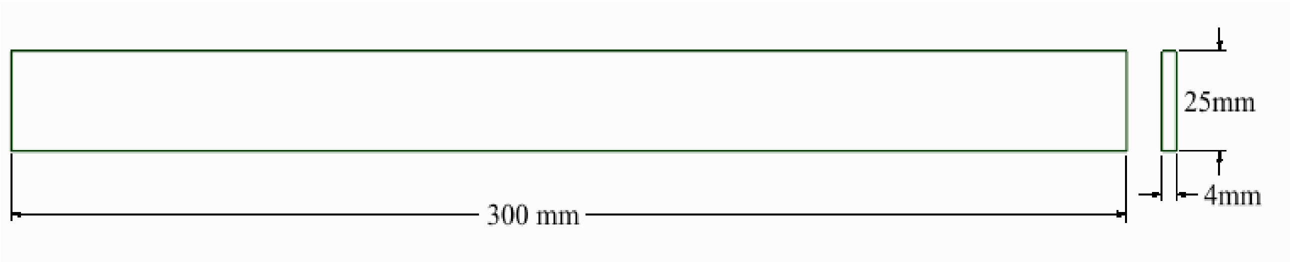


Figure 3.20: Tensile test specimen

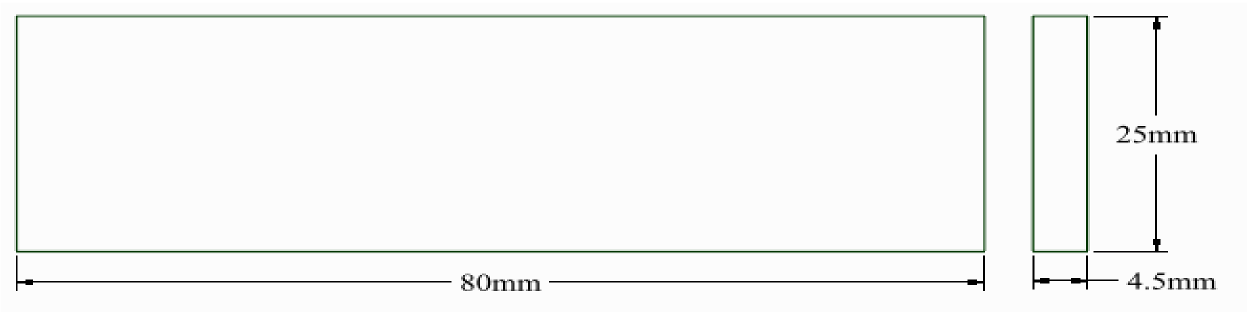


Figure 3.21: Compression test specimen dimesnsion

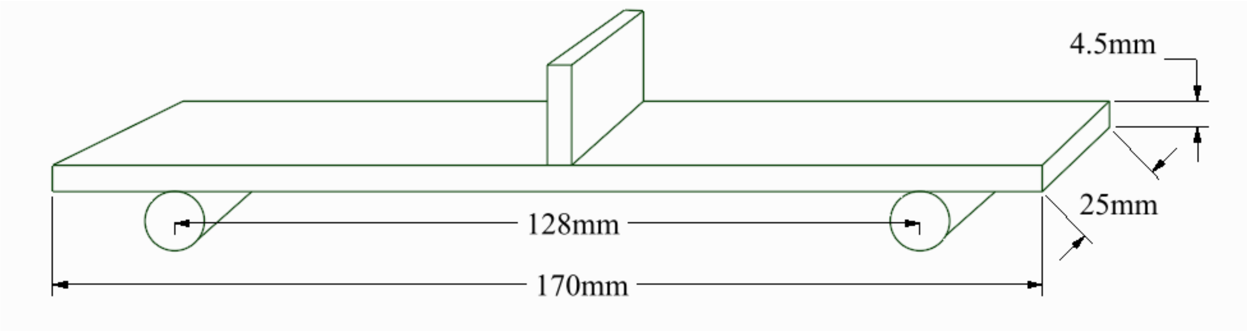


Figure 3.22: Flexural test specimen dimension

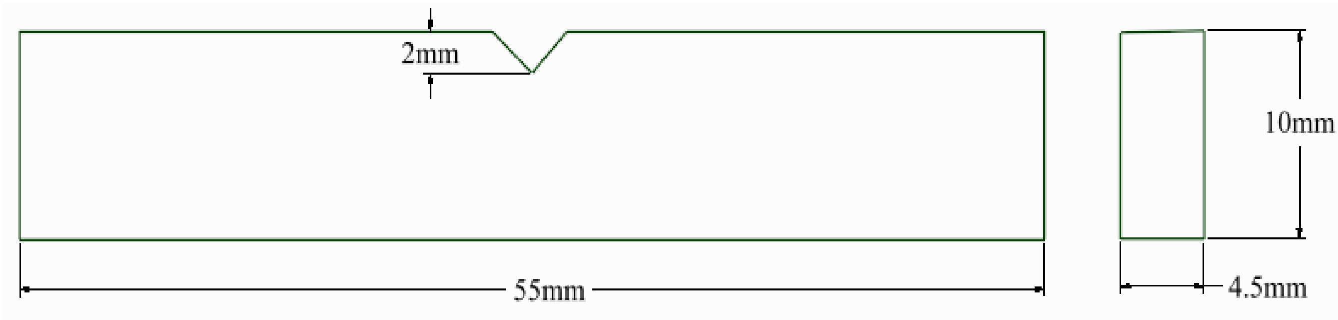


Figure 3.23: Impact test specimen dimesnsion

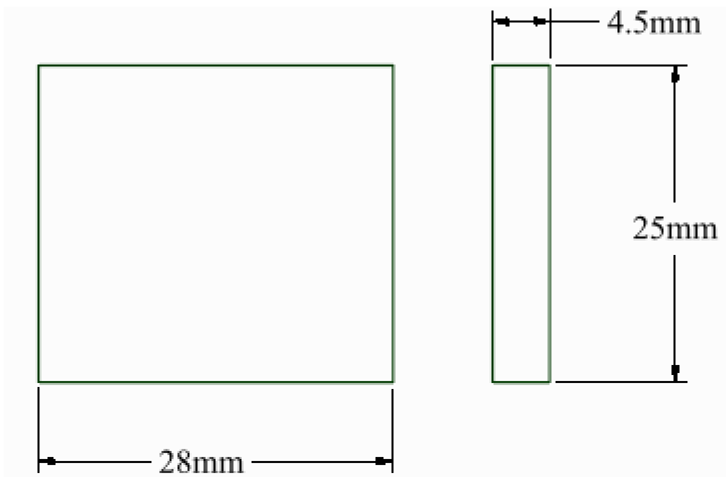


Figure 3.24: Water absorption test specimen

3.6.3. Specimen Testing

After the bamboo and Sisal fiber reinforced hybrid composite Specimen were cut in to the standard dimension they were tested for flexural ,compression, tensile strength and impact strength following standard procedure.

3.6.3.1. Universal Testing Machine (UTM)

The tester is a vertical, hydraulically operated pillar tester with direct generation of both tensile and compressive forces. The height of the lower cross member can be adjusted in steps for coarse adjustment. Cylindrical receptacles on the cross members make the different experimental set-ups easy to change, e.g. wedge grips (accessory WP 310.05, as shown in figure 2.25 and 2.26) experimental setup for tensile testing.

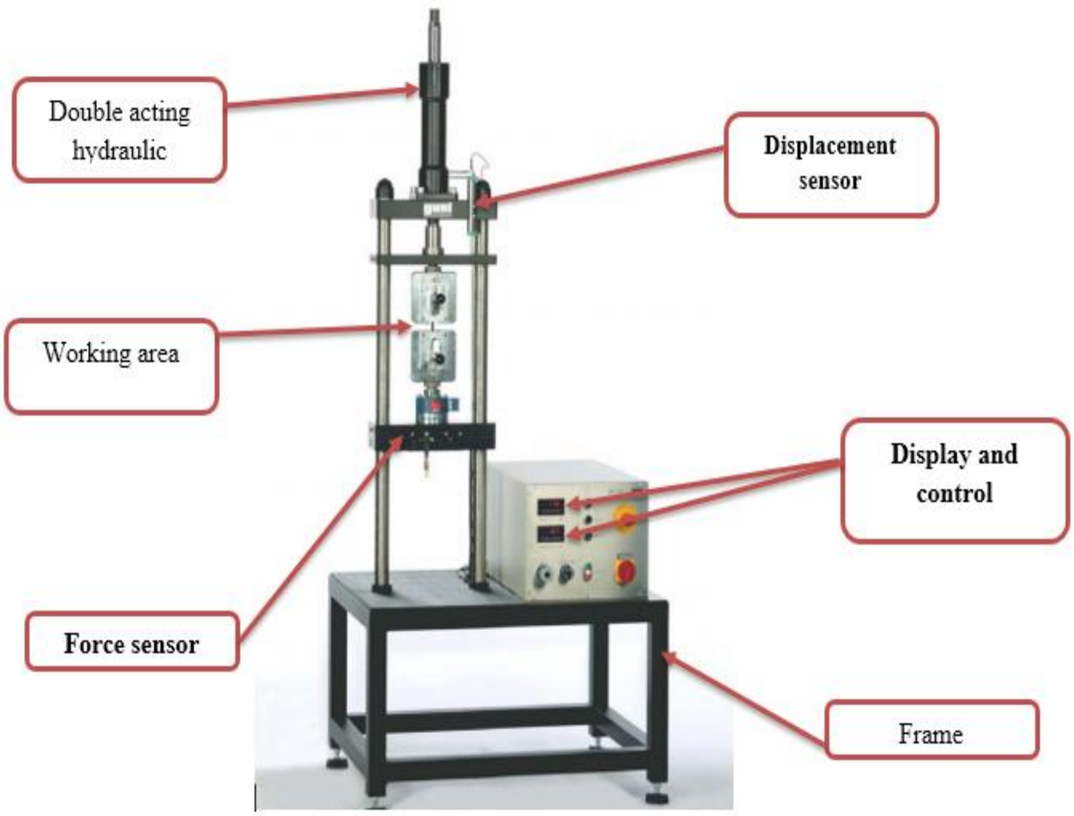


Figure 3.25: Vertical, hydraulically operated pillar tester

Figure 3.26: UTM material testing system (Defence engineering)

3.6.3.2. Pendulum impact tester **(**charpy impact test)

The charpy impact test also known as the charpy V- notch test is a standardized high strain-stress test which determines the amount of energy absorbed by a material during fracture .this absorbed energy is a measure of a given materials notch toughness and acts as a tool to study \temperature –dependent ductile-brittle transition .It is widely used applied in industry, since it is easy to prepare and conduct, results can be obtained quickly and cheaply. Fig 3.27 shown experimental setup for impact test.

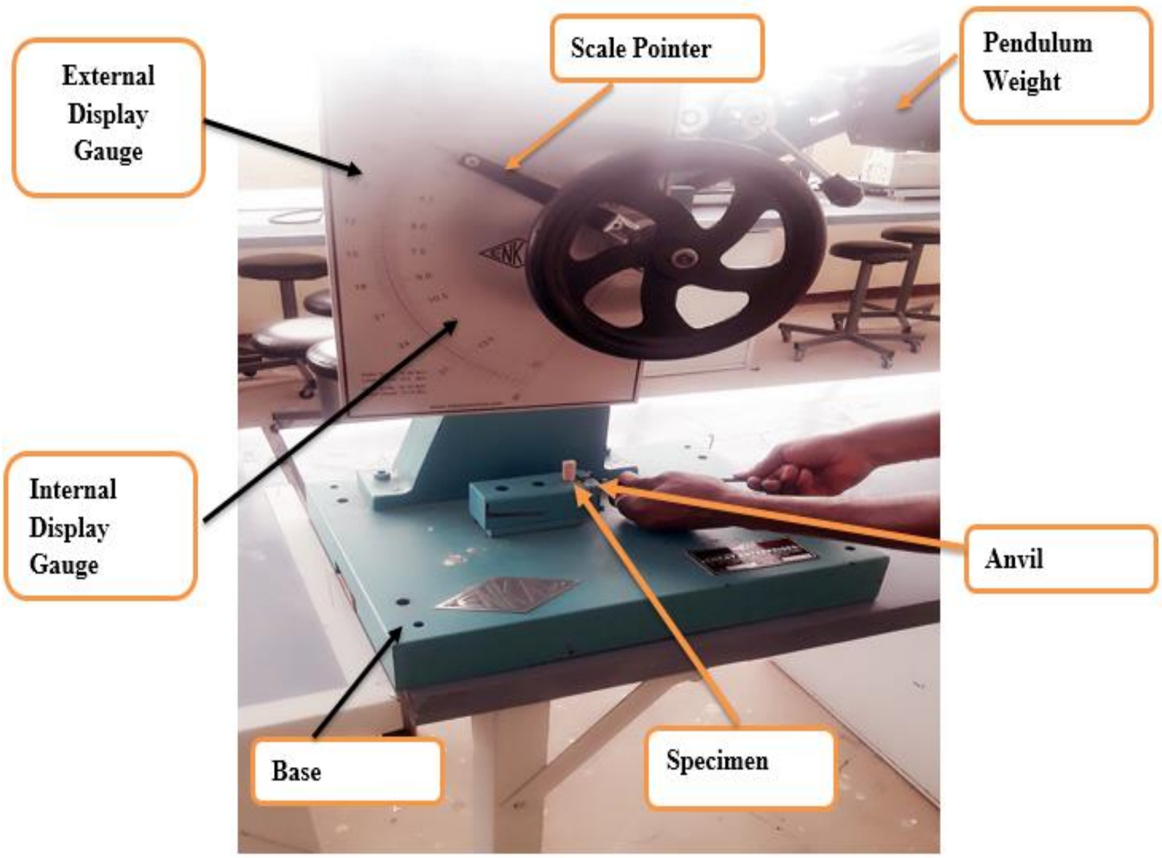


Figure 3.27: Specimen and parts of pendulum impact tester

The apparatus consists of pendulum of known mass and length that is dropped from a known height to impact a notched specimen of material .The energy transferred to the material can be inferred by comparing the difference in the height of the hammer before and after the fracture (energy absorbed by the fracture event).

3.7. Bamboo and Sisal fiber reinforced hybrid polyester Composite characterization

The composites were then characterized for tensile properties using test method ASTM D3039, compression properties ASTM D3410 and flexural properties using test method ASTM D790-2010. Three specimens of each category were tested and the results were presented as an average of tested specimens. For each composite specimen the thickness were determined the thickness measurements were performed at 3 places along the length of each specimen. Overall sample thickness was determined by averaging measurements for three specimens. The tests were conducted at a room temperature.

3.7.1. Tensile Strength Test(ASTM D3039/D3039M)

Tensile strength is the measurement of the force required to pull something such as rope, wire, or a structural beam to the point where it breaks.The tensile strength of a material is the maximum amount of tensile stress that it can take before faliure. The specimen used for tensile test is the flat type. During the test a uniaxial load is applied through both the ends of the specimen. The dimension of specimen is (300 x 25 x 5)mm.

The specime is tested in the universal testing machine (UTM) and the samples are left to break till the ultimate tensile strength occurs. The stress-strain curve is plotted for the determination of ultimate tensile strength(UTS) and elastic modulus. Graph generated directly from the machine for the tensile test with respect to load and displacement for bamboo Fiber /sisal Reinforced hybrid Composite material.Typical points of interest when testing a material include: ultimate tensile strength (UTS) or peak stress; offset yield strength (OYS) which represents a point just beyond the onset of permanent deformation; and the rupture (R) or fracture point where the specimen separates into pieces. The tensile test is performed in the universal testing machine (UTM) and results are analyzed to calculate the tensile strength of composite samples.

Figure 3.28: UTM machine Sample loaded condition for tensile testing

The testing process involves fixing the test specimen in the testing machine and slowly extending by applying load until it fractures as shown in fig 3.28. During this process, the elongation of the gauge section is recorded against the applied force. The elongation measurement is used to calculate the relations between stress and strain, stress and displacement and load and displacement.

3.7.2. Compressive Strength Test (ASTM D3410)

This section of the laboratory experiment involved in subjecting bamboo and sisal fiber reinforced hybrid composite specimen to axial compression loading using the UTM The dimension of the specimen is (80 x25 x 4.5)mm the samples the were then placed between the compression anvils to commence compression testing during testing, the maximum load attained was recorded by the UTM testing system after the specimen failed. Each specimen was documented (by pictures) before and after failure. A typical specimen failure is shown in Figure 3.29

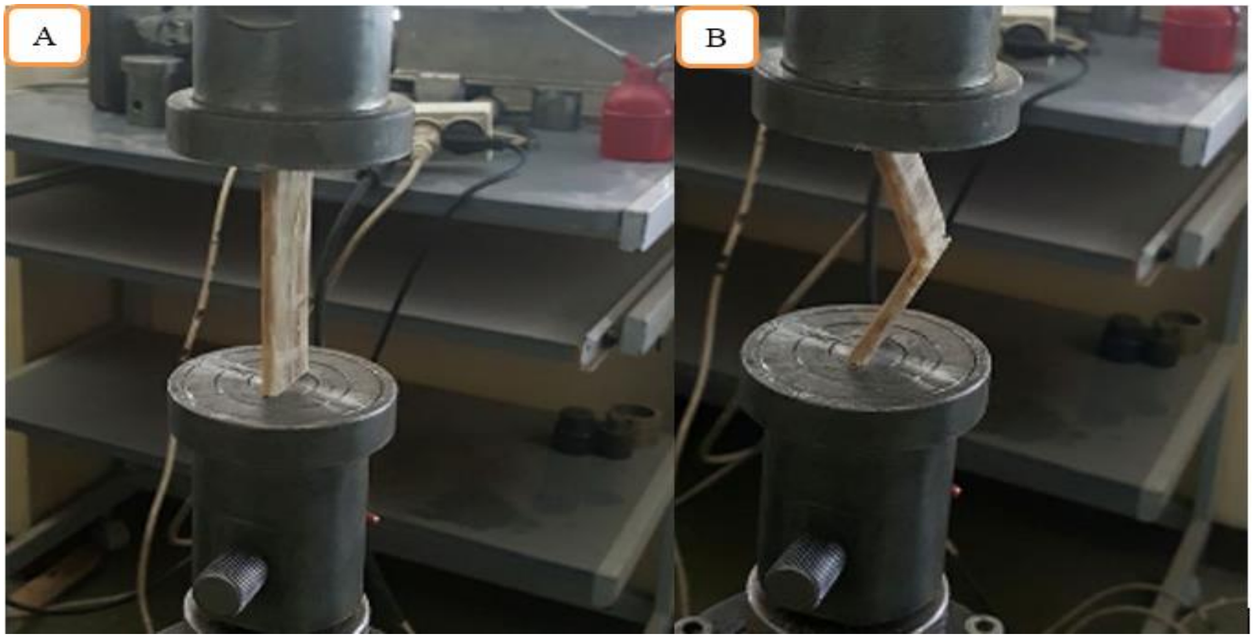


Figure 3.29: UTM machine Sample a) loaded condition for compressive testing b) fracture of compressed specimen

3.7.3. Flexural Strength Test (ASTM D790-2010)

Flexural strength is defined as a materials' ability to resist deformation under load. The short beam shear (SBS) tests are performed on the composites samples to evaluate the value flexural strength. It is a 3-point bend test, which generally promotes failure by inter-laminar shear. This test is conducted as per ASTM standard using UTM. The loading arrangement is shown in figure 3.30. The dimension of the specimen is (170 x 25 x 5) mm. It is measured by loading standard specimen (25 x 5) with a span length at least three times depth.

Figure 3.30: Specimen under flexural testing

3.7.4. Impact strength test (ISO 9001:2001)

The impact test was performed over the samples of length 55 mm, width 10 mm & thickness 5.5 mm as shown in fig 3.31 the impact speed of hammer is 3.8 meters per second having 30 kilogram weight mounted pendulum. The notch cut on the specimen shall be facing the opposite direction of the striker. The quantitative result of impact test the energy needed to fracture a material and can be used to measure the toughness of the material.

Figure 3.31: Impact test specimen

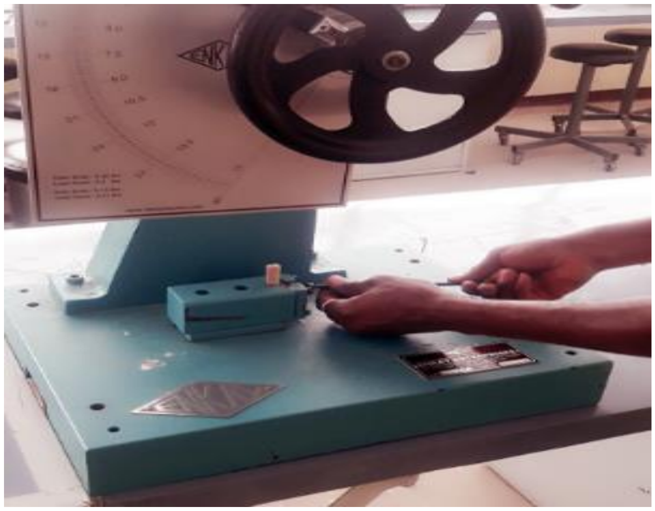


Figure 3.32: Fixing of test condition

3.7.5. Water absorption test of composites materials

Standard ASTM570 was used in this work to study the water absorption characteristics of sisal/bamboo fiber reinforced hybrid unsaturated polyester composite. Samples were removed at regular intervals and weighed immediately after wiping away water from the surface, and a precise 4-digit balance was used to find out the content of water absorbed. As shown in fig 3.34

Table 3.3:Water absorption sample data

Fiber orientation	Water absorption test (dry mass)(gram)						Average (dry) gram	Average (wet**)** gram
	Sample-1		Sample -2		Sample -3			
	dry	wet	Dry	wet	dry	wet		
Unidirectional(0^0)	3	3	3.5	3.5	3	4	3.166	3.5
bidirectional	6	6	6	6.5	6	6.5	6	6.33
Unidirectional(90^0)	3	3	3	3	3	3.5	3	3.166

Equations (1) used to determine the water absorption:

$$\text{mositure absorption} = \frac{w_2 - w_1}{w_1} \times 100 \text{ in } \% \qquad .$$

with $\mathbf{w_1}$ and $\mathbf{w_2}$ being the weight of dry and wet samples

The material is submerged in water at determined upon condition, at room temperature for 24hrs. Tendency towards moisture absorption in humid air or in water was found by natural fiber reinforced polymer composite. The effect of moisture absorption results the poor fiber-matrix interface region as a resulting in a reduction in mechanical properties along with change in dimensions of composite.

Figure 3.33: Sample specimen for water absorption test

Figure 3.34: Measuring the sample weight

3.7.6. Microstructures of composite

In this test the effect of fiber orientation on the microstructure of the composite mechanical properties such as Vickers Hardness test was examined. Both physically and mechanically were determined using standard methods and the microstructure of the samples examined using Optical microscope equipped with camera, with others such as Vickers Hardness, polishing machine, Grinding machine and others.

Sample Preparations

The first step of sample preparation is cutting composite have length of 2 cm of three different fiber orientation by using Cutter.

Mounting the sample

Mounting serve the sample for two things. One is for convenience in handling of difficult shapes of size during the subsequent steps of preparation and the other is to protect and preserve defects during preparation. Fig 3.35 shows mounting specimen on hot mounting press.

Figure 3.35: Mounting the sample in hot mounting press

Grinding and Polishing

The main object of grinding is to generate initial flat surface, removes saw marks and levels and free from excessive deformation. This several steps are; rough grinding, fine grinding, and polishing.

In the first step, saw cut specimens are rough ground on a belt surface are supplied with a sand paper or grinding paper of number 400, 800, 1200 and 2000 respectively as shown in fig.3.36 (a) and (b). Starting with 400 after finishing to use the next one clean with running water and dry by air compressor then rotate the specimen 90^0 from the first to make continuously. After grinding to removes the artifacts of little stock polishing is needed that make the surface mirror by adding diamond suspension as shown in fig 3.36 (c). When do this moderate pressure is needed at the start of each step and then gradually reduce the pressure as the step proceeds for keeping the specimen from plastic deformations

(a) Sanding o sample

(b) Different sand paper size

Figure 3.36: Polishing sample speciemen

Etching and Microscopic Examination under Optical Microscope

Etching is to reveal microstructural features through selective chemical attack to present the grain or phase will be present. The chemical used for etching is called Nital solution a mixture of 0.5ml of Nitric acid with 50ml methanol or alcohol that is commonly used for routine etching of metals The inspection is also known as Temper Etch. All samples rinsing and cleaning was performed with ethanol to avoid adverse reactions of the sample surface. This is to examine and analyze the microstructure of composite specimen.

Etching is to reveal microstructural features through selective chemical attack to present the grain or phase will be present. The chemical used for etching is called Nital solution a mixture of 0.5ml of Nitric acid with 50ml methanol or alcohol that is commonly used for routine etching as shown in fig 3.37. The inspection is also known as Temper Etch. All samples rinsing and cleaning was performed with ethanol to avoid adverse reactions of the sample surface. This is to examine and analyze the microstructure of specimen

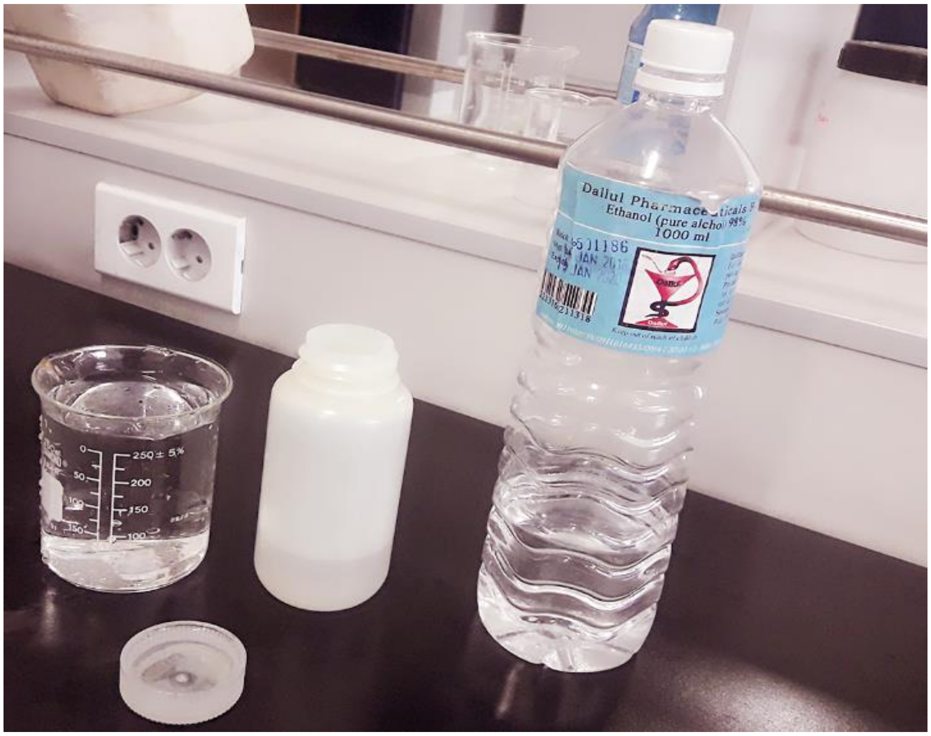


Figure 3.37: Etching of specimen in nital solution

This is to examine and analyze the microstructure of the specimen the picture took from optical microscope (fig 3.38) can be measured the grain size and volume fraction of each phase by ASTM method. This is make grid line at equal distance on the photo graph of the different samples.

(a) Examine the specimen

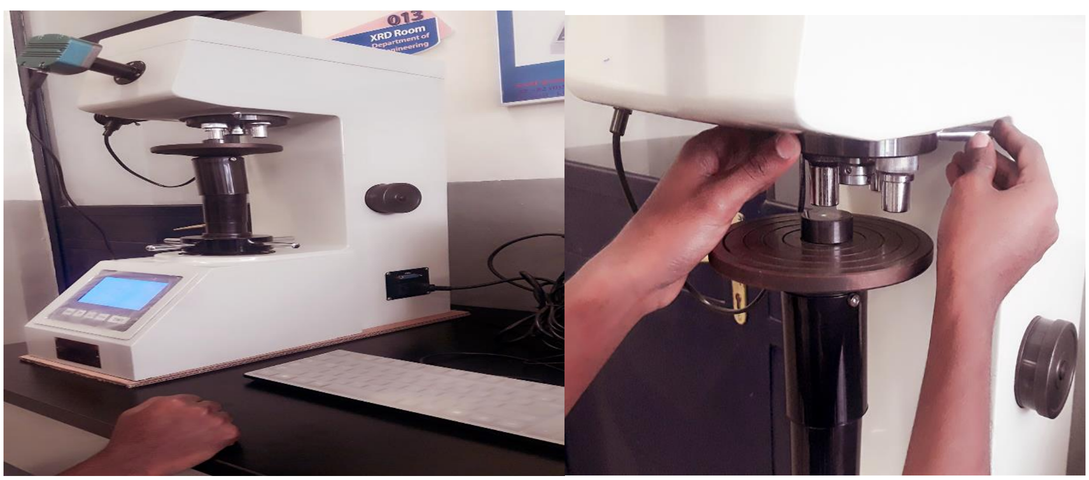
(b) Picture took from optical microscope

Figure 3.38: Microstructure of composite sample using optical microscope

3.7.7. Hardness Test

The hardness of a material is a poorly defined term which has many meanings depending upon the experience of the person involved. In general, hardness usually implies a resistance to deformation. There are three general types of hardness measurements depending upon the manner in which the test is conducted. These are (1) scratch hardness, (2) indentation hardness, and (3) rebound, or dynamic, hardness. Only indentation hardness is of major engineering interest

The Vickers hardness test uses a square-base diamond pyramid as the indenter. The included angle between opposite faces of the pyramid is 136°.Because of the shape of the indenter this is frequently called the diamond pyramid hardness test. The diamond-pyramid hardness number (DPH), or Vickers hardness number (VHN, or VPH), is defined as the load divided by the surface area of the indentation. In practice, this area is calculated from microscopic measurements of the lengths of the diagonals of the impression. Vickers hardness test is a mechanical test to know the strength of the specimen by applying load on the surface of the specimen as shown in fig 3.39 (a) and (B).



(a) Vickers hardness test

(b) Loading the specimen.

Figure 3.39: Vickers hardnes test of the specimen

CHAPTER FOUR

4. EXPERIMENTAL RESULT AND DISCUSSION

4.1. Experimental Results

4.1.1. Tensile Test

Bamboo and sisal fiber reinforced hybrid composite (BSRFHC) was fabricated with 20 % fiber volume fraction and 80 % matrix volume fraction in a $[0/90^0/0^0/90^0]$ orientation sandwich structural composite. Based on mass 75% bamboo fiber and 25 % sisal fiber used for preparation of the composite. A total of three specimens for each orientation were used for repeatability. The variation in recorded test result among the three specimens in each of the orientation is not significant. After testing of tensile test in universal testing machine, the following are the graphs obtained as the load increases.

The graphs are followed as shown below.

- Stress Vs elongation
- Force Vs elongation
- Stress Vs Strain

Typical stress–strain curves of BSRFHC under tensile loading for different fiber orientation is presented in figures 4.1, 4.2 and 4.3

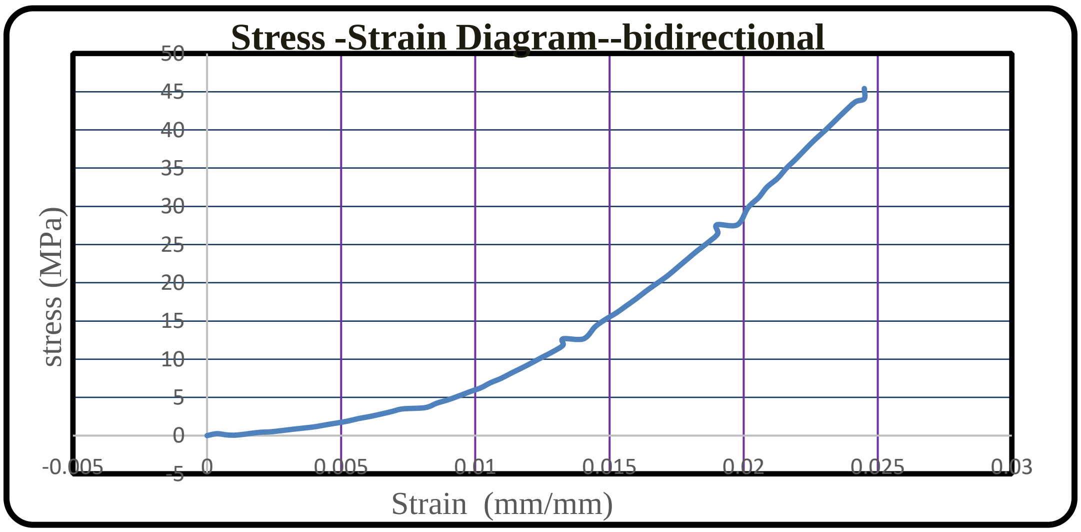


Figure 4.1: Stress vs. Strain for Bidirectional $(0^0/90^0)$ fiber orientation (tensile)

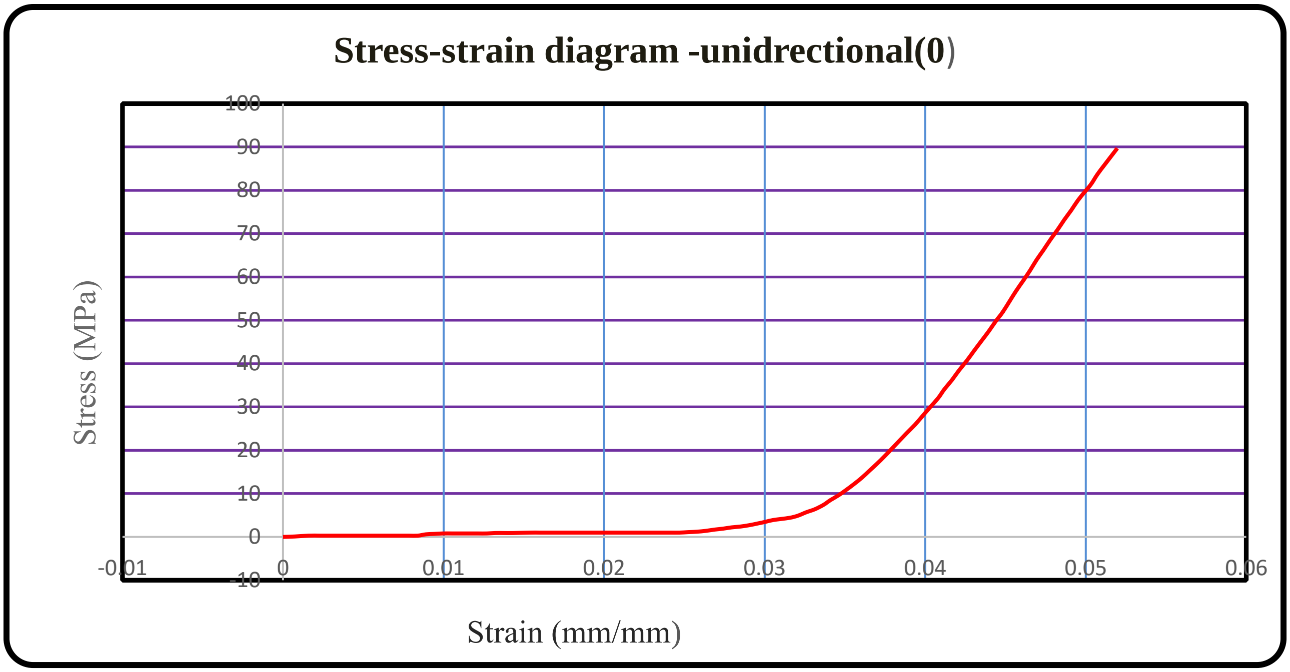


Figure 4.2: Stress vs. Strain for unidirectional 0^0 fiber orientation (tensile)

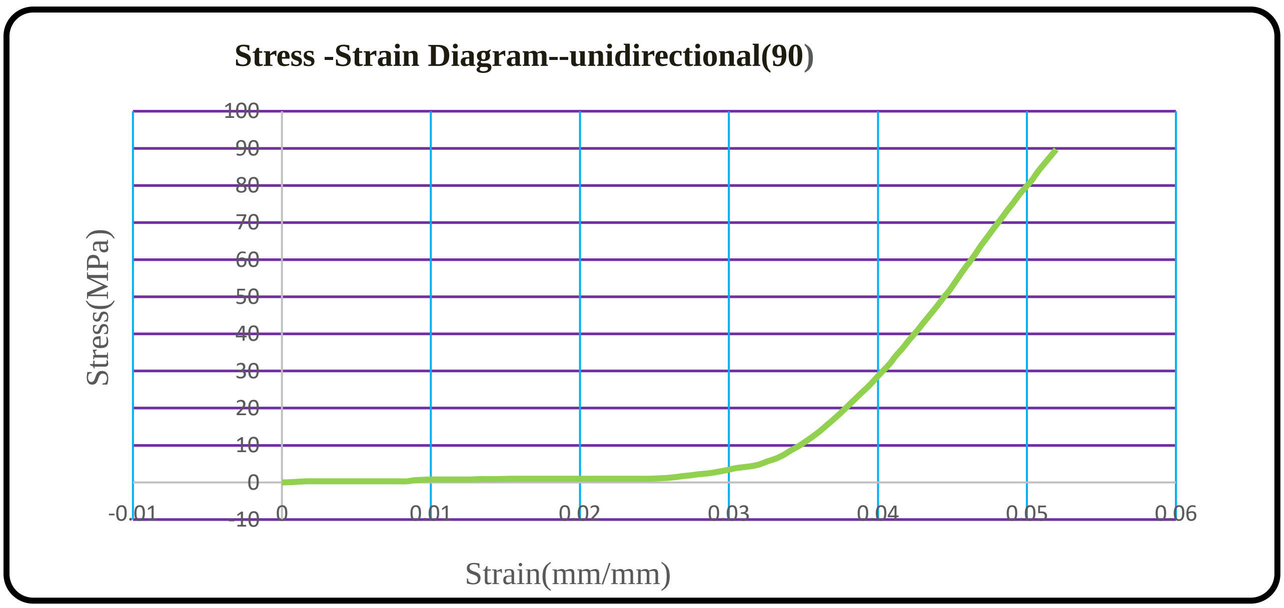


Figure 4.3: Stress vs. Strain for unidirectional 90^0 fiber orientation (tensile)

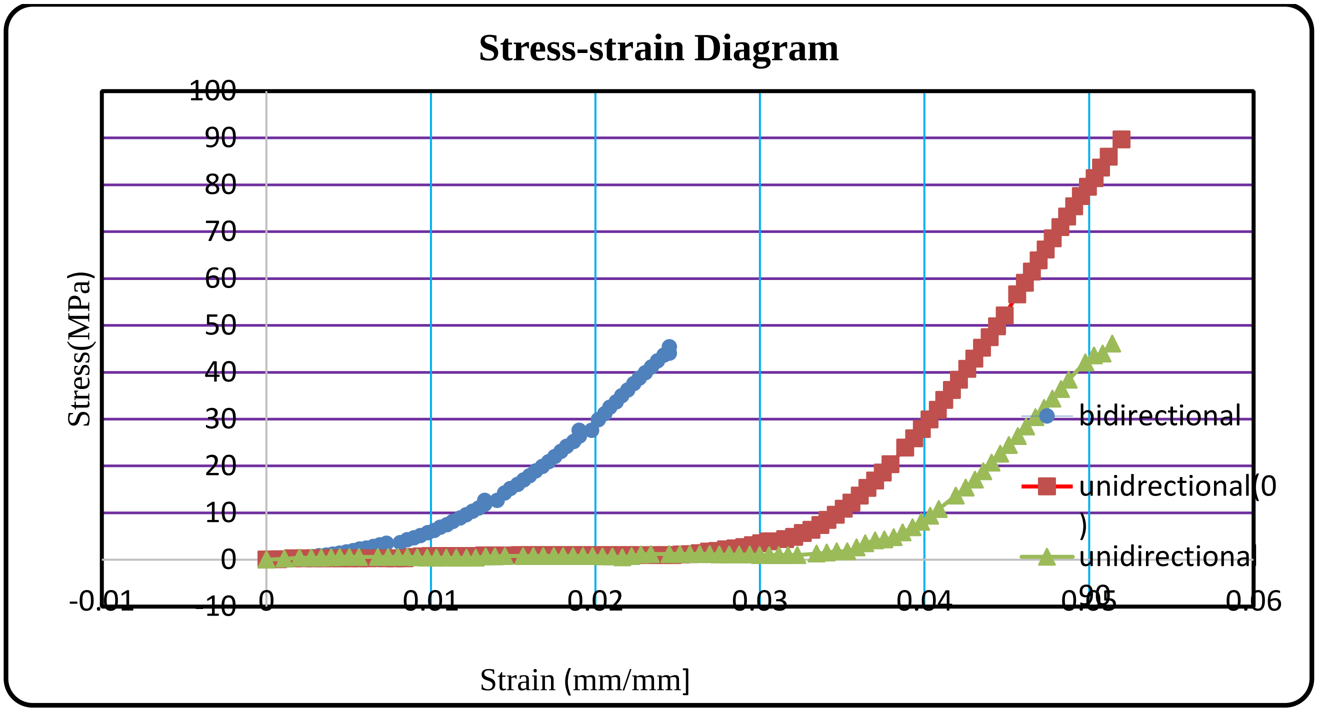


Figure 4.4: Stress vs. Strain for each fiber orientation (tensile test)

Stress-strain are laboratory stress/strain that obtained by taking load & elongation of a given specimen as primary output from the experiment that defined the curve of stress-strain.

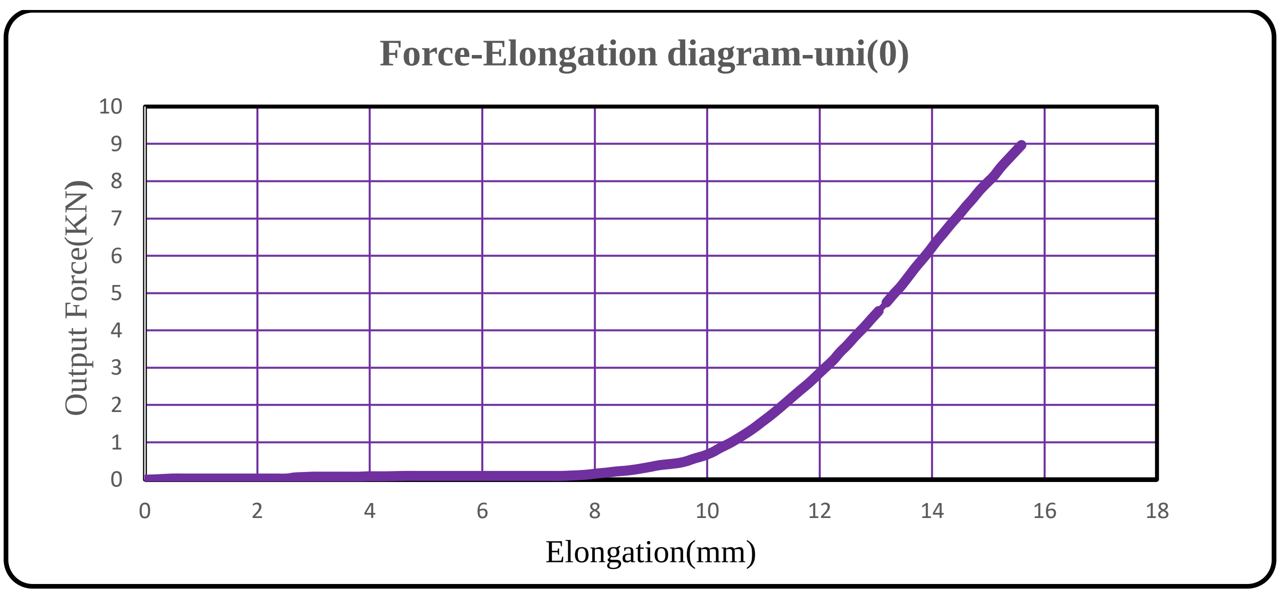


Figure 4.5: Force Vs Elongation for 0^0 fiber orientation tensile test result

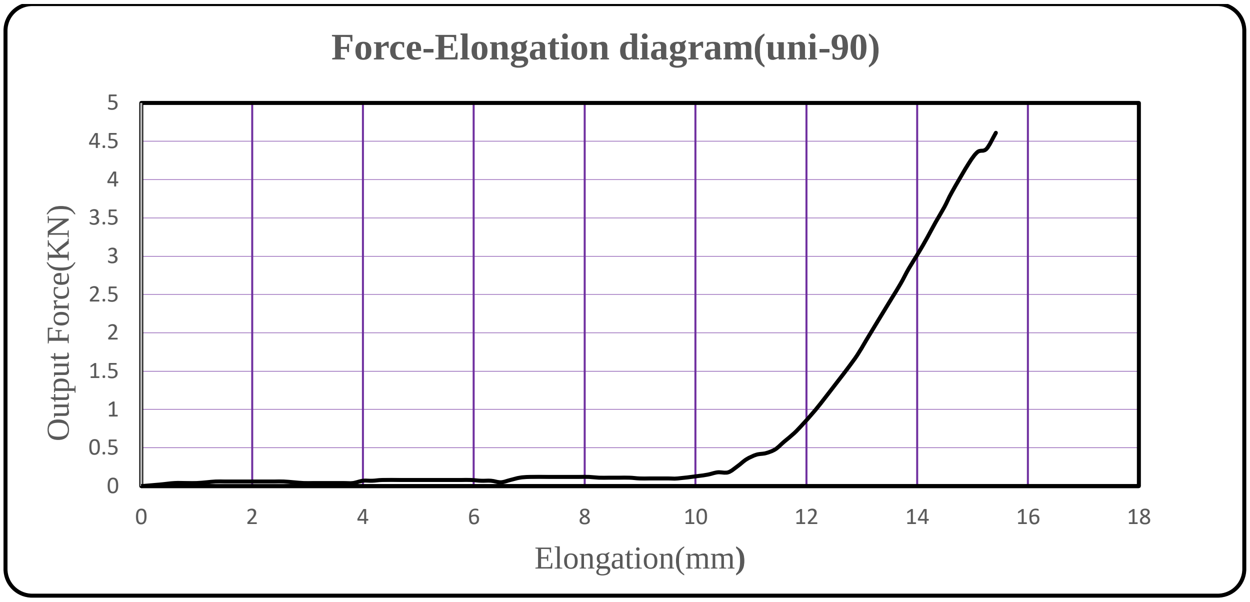


Figure 4.6: Force Vs Elongation for 90^0 fiber orientation tensile test result

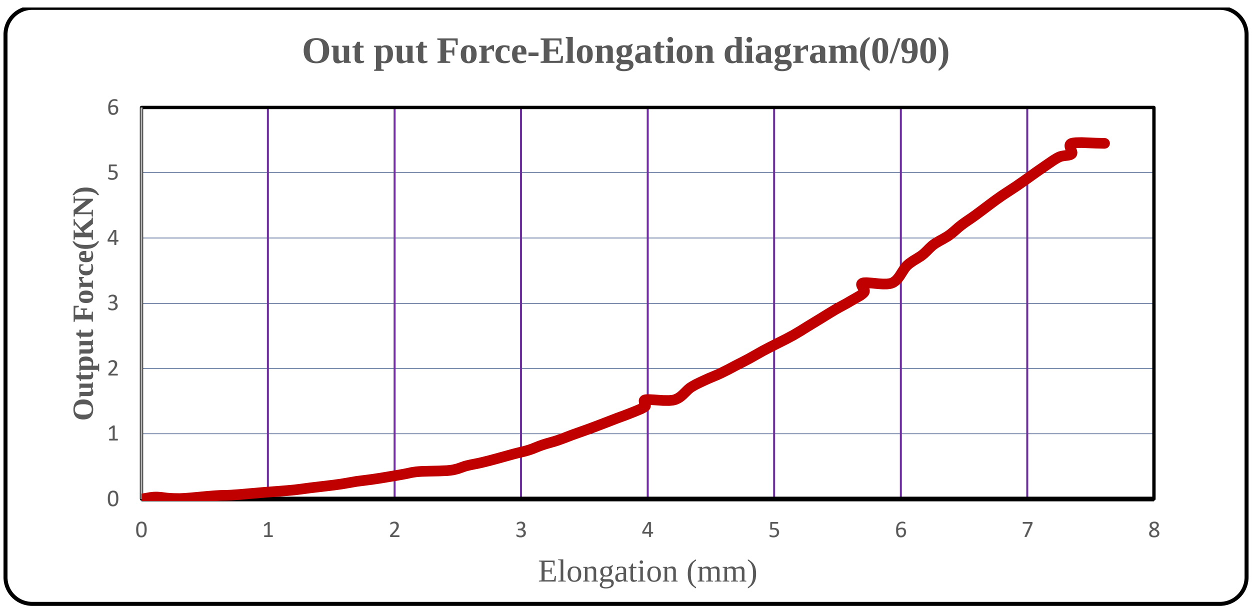


Figure 4.7: Force Vs Elongation for (0/90) fiber orientation (tensile)

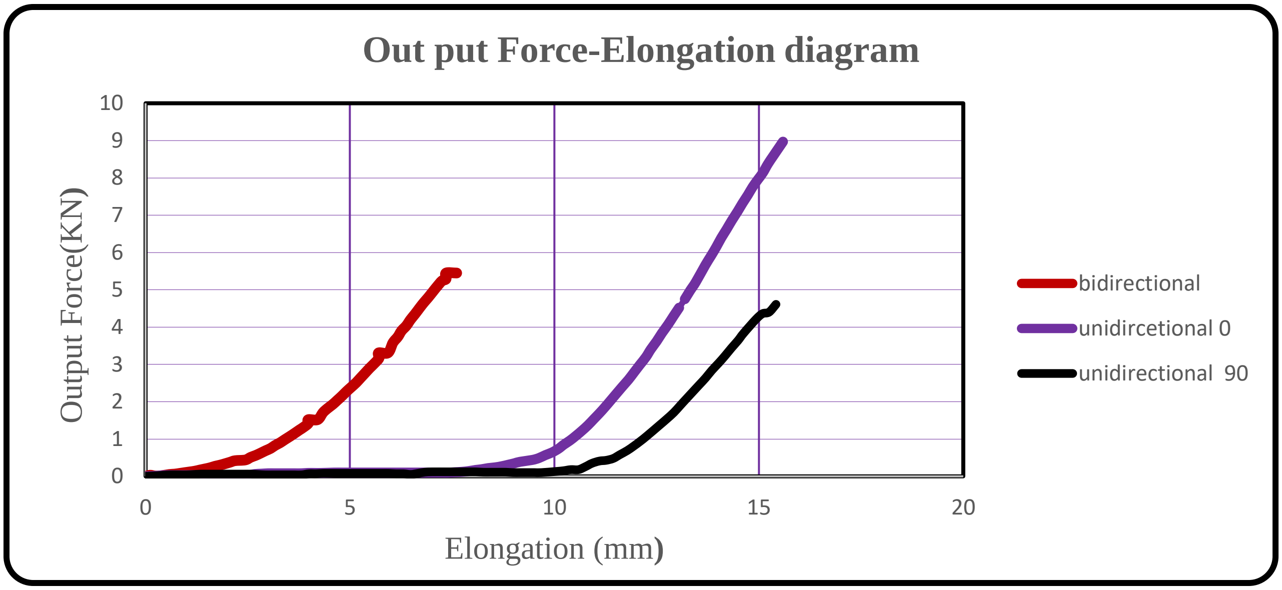


Figure 4.8: Force Vs Elongation for three fiber orientation tensile test

From 4.5, 4.6.4.7 and 4.8 depict the force Vs elongation with different fiber orientation. From the figure 4.8 it is observed that the output force for zero degree fiber orientation is higher than other fiber orientation.

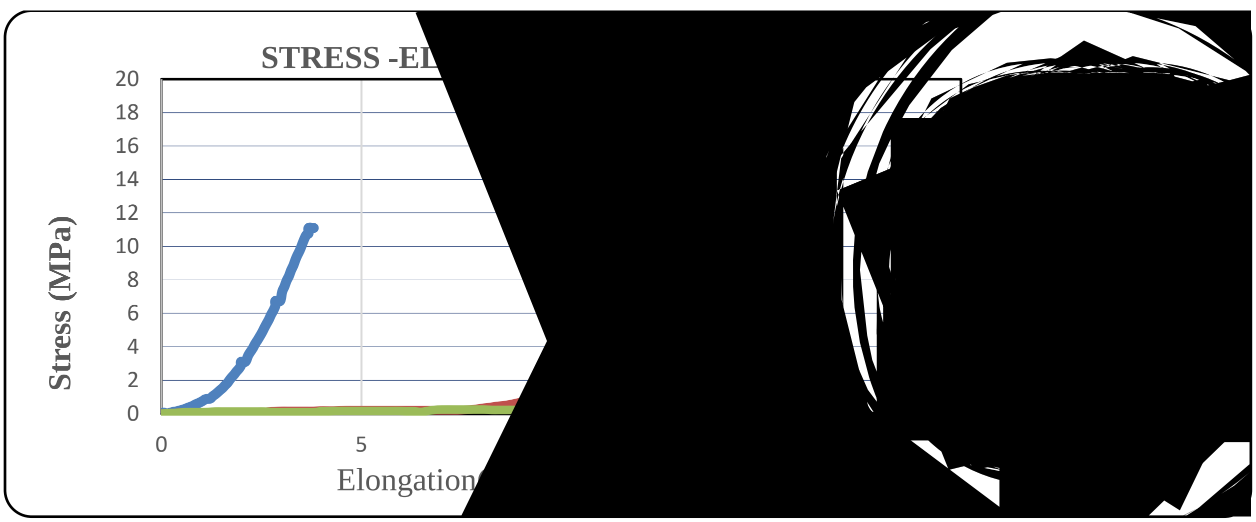


Figure 4.9: Stress Vs Elongation for three fiber orientation tensile test

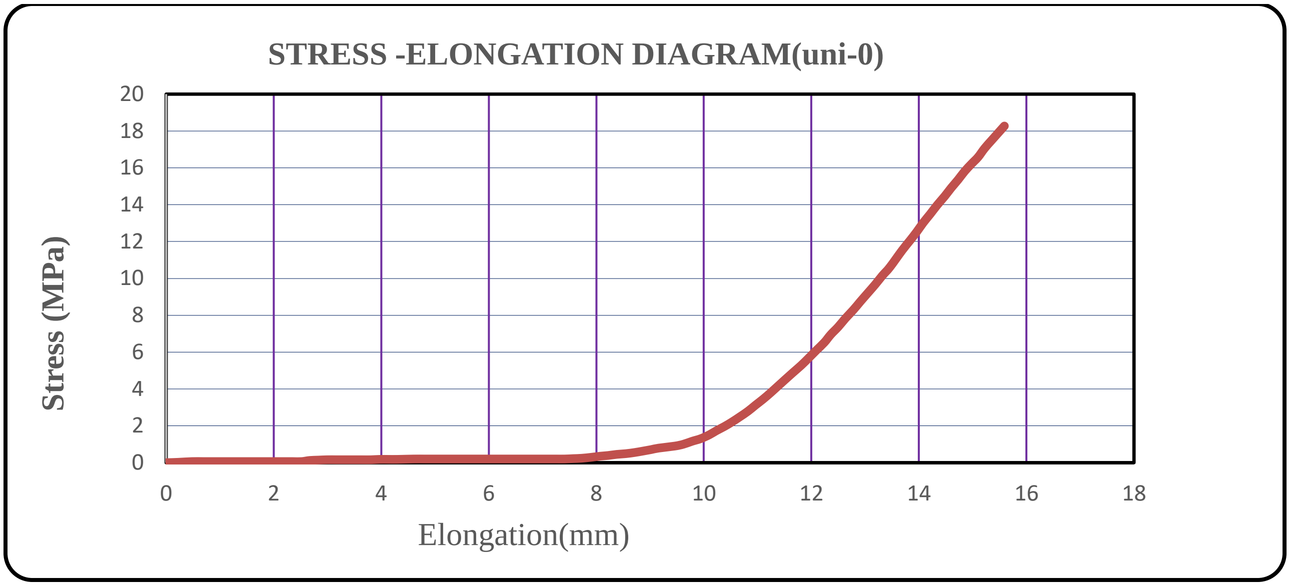


Figure 4.10: Stress Vs Elongation for 0^0 dergee fiber orientation (tensile test)

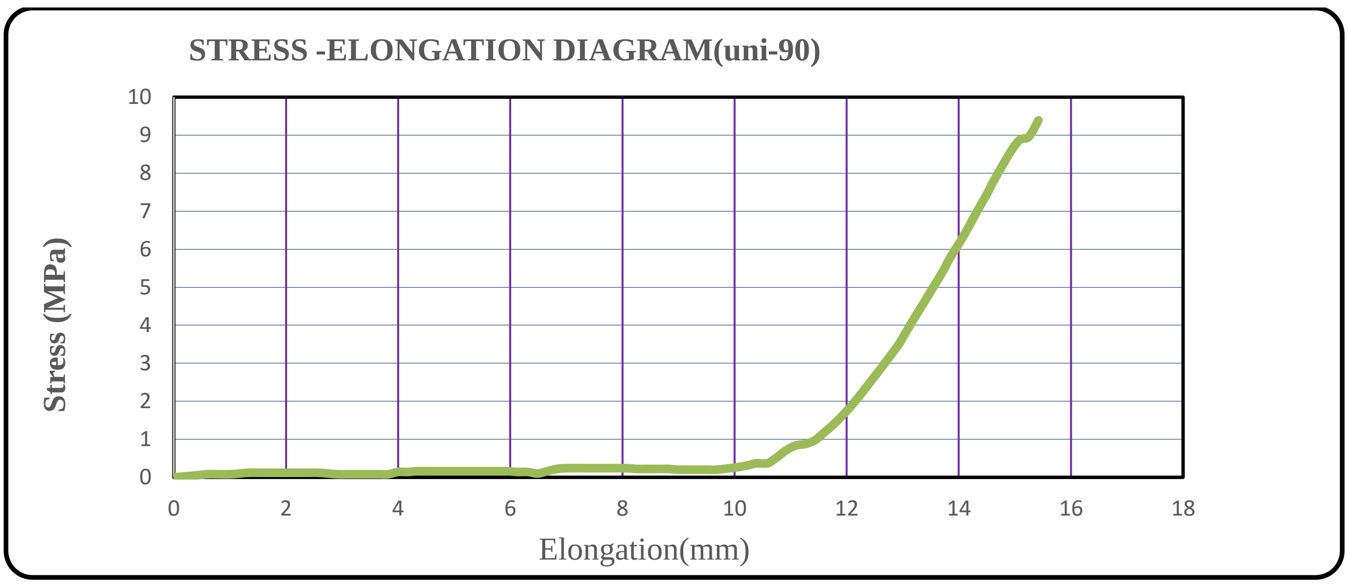


Figure 4.11: Stress Vs Elongation for 90 dergee fiber orientation (tensile test)

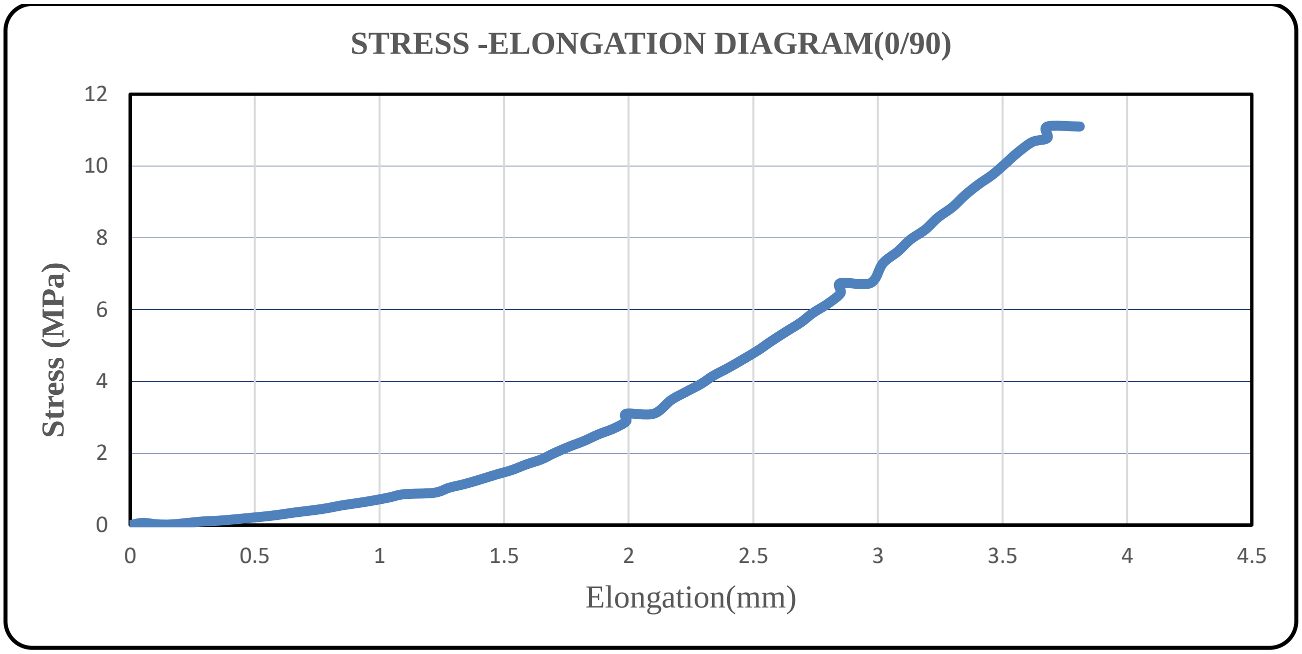


Figure 4.12: Stress Vs Elongation for 0/90 dergee fiber orientation (tensile test)

Tensile strength of hybrid composites determined its ability to resist breaking under tensile stress. The tensile properties of bamboo –sisal hybrid composites with various fiber orientation. Fig. 4.4. Shows the tensile stress-strain curves of the tested samples in each orientation. The curves show the brittleness and ductile natures of the composites. For UD 0 and UD 90, the samples elongated with the increased stress level up to the certain values where the specimen failure occurred. The curves, continuous until total failure of the samples occurred as the outer layers of sample break. No such observation reported in the woven /bidirectional fiber orientation .Based on the curves, it was observed that the elongation at break of bidirectional fiber orientation is lesser than the other fiber orientations

4.1.2. Compression test

Compressive strength is the capacity of a material to withstand loads tending to reduce the size, as opposed to tensile strength, which withstands loads tending to elongate. Compressive strength resists compression whereas tensile strength resists tension. Compressive strength is so important in deriving the compressive load limit since, at times there might be a fracture in structure at this limit. Compressive test specimens were prepared with three fiber orientation. For each fiber orientation, there specimens were prepared for repeatability. After testing of compression test in universal testing machine, the following are the graphs obtained as the load increases.

The graphs are followed as shown below.

- Stress Vs elongation
- Force Vs elongation
- Stress Vs Strain

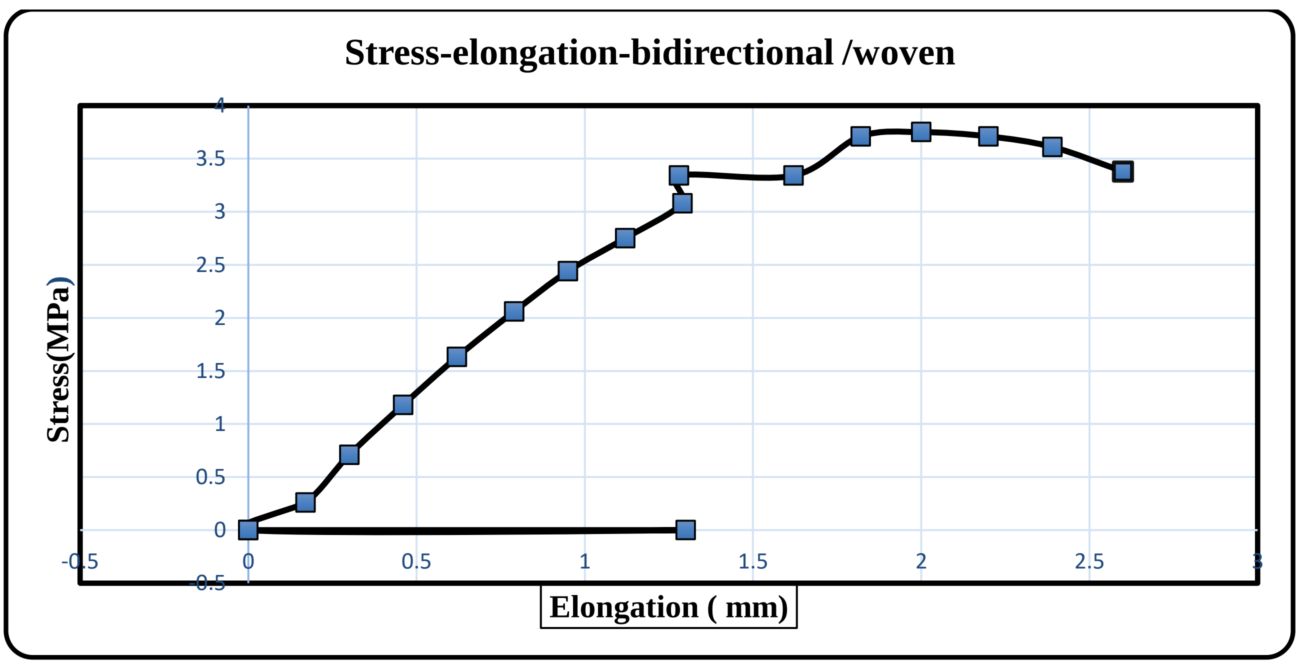


Figure 4.13: Stress vs. Elongation for bidirectional ($0/90^0$) fiber orientation compression t

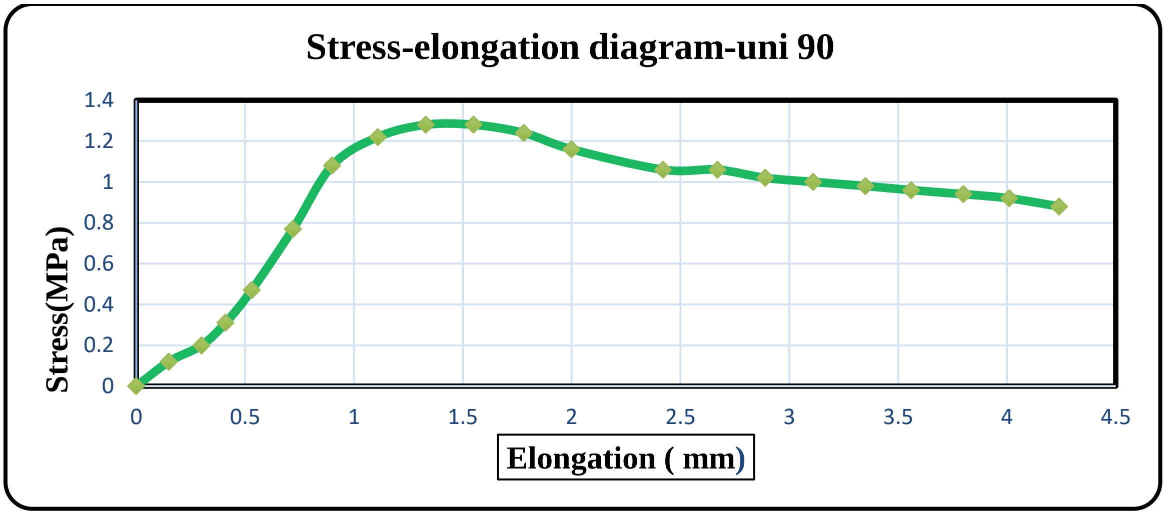


Figure 4.14: Stress vs. Elongation for unidirectional 90^0 fiber orientation compression test

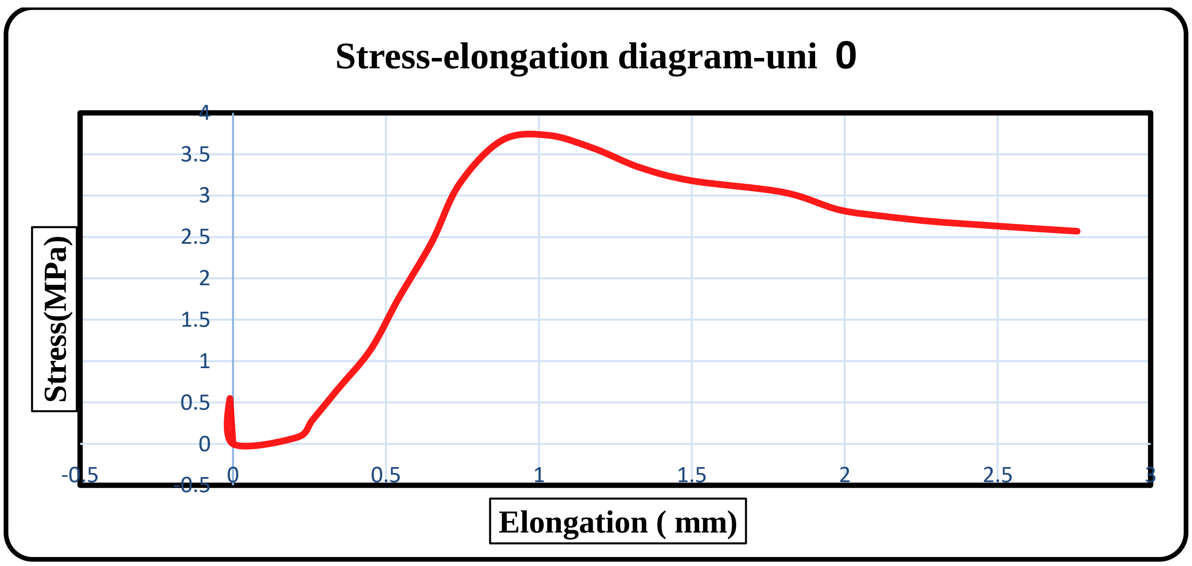


Figure 4.15: Stress vs. Elongation for unidirectional 0^0 fiber orientation compression test

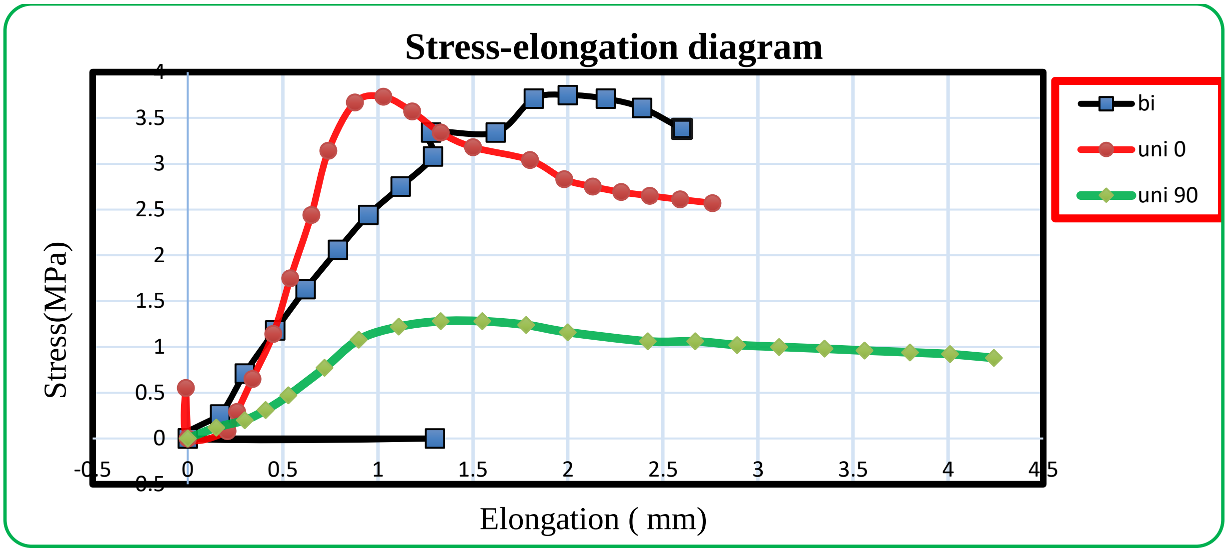


Figure 4.16: Stress vs. Elongation for each fiber orientation compression test

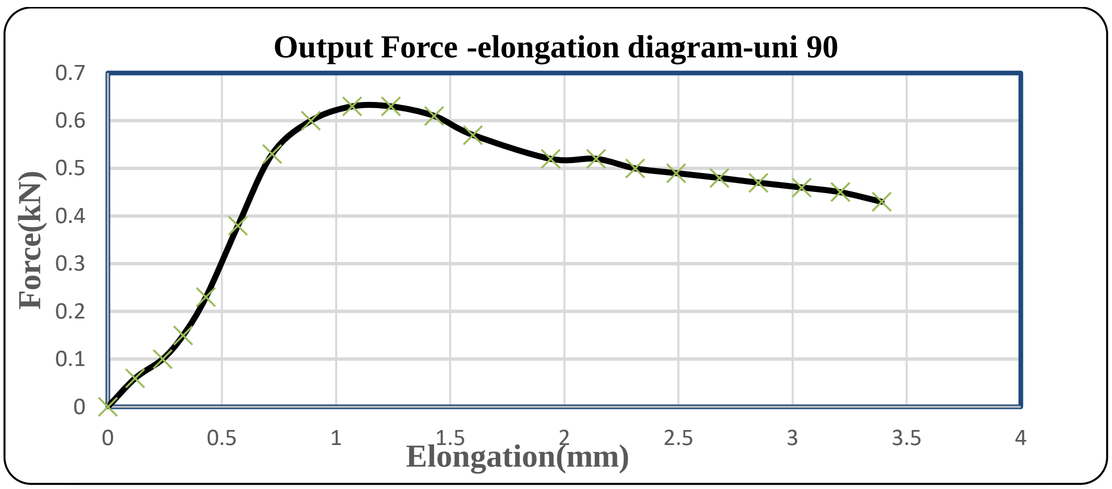


Figure 4.17: Force vs. Elongation for unidirectional 90^0 fiber orientation compression test

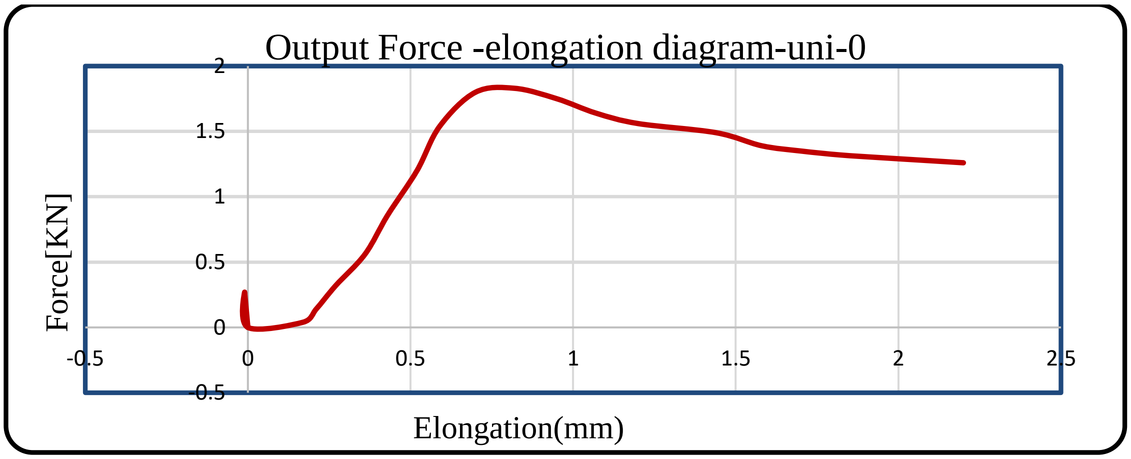


Figure 4.18: Force vs. Elongation for unidirectional 0^0 fiber orientation compression test

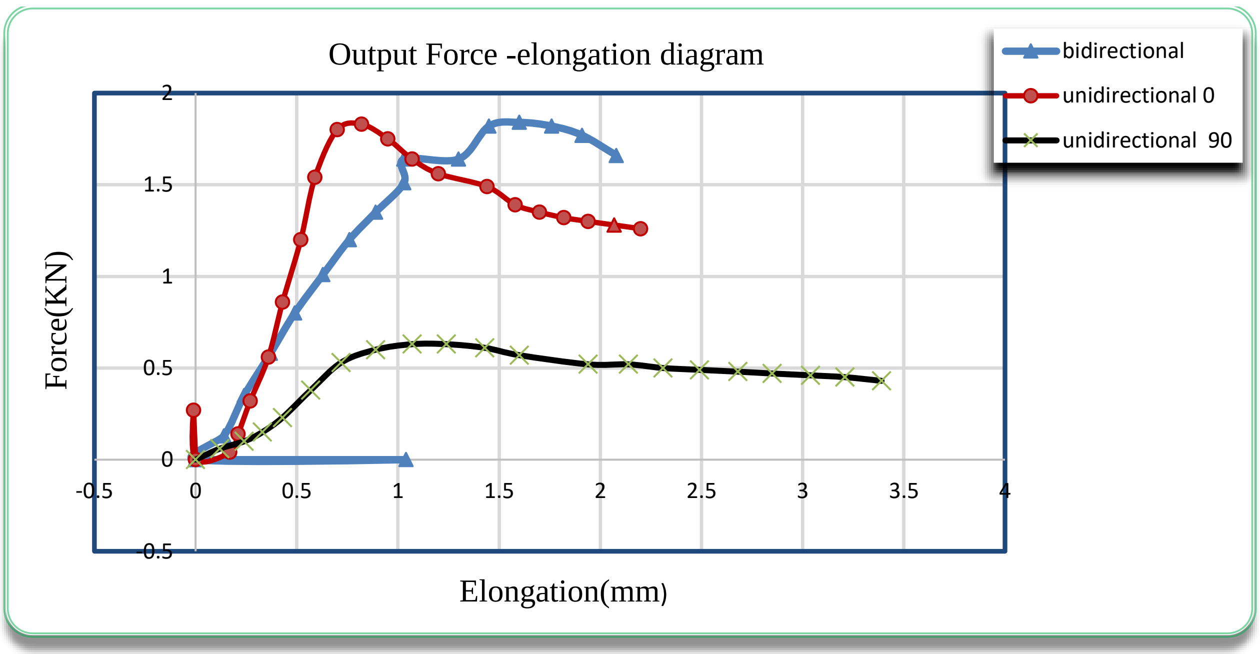


Figure 4.19: Force vs. Elongation for each fiber orientation (compression)

From the above figure 4.19 it is observed that the force for 0^0 is slightly greater than $0^0/90^0$ fiber orientation .The lowest output force observed in 90^0fiber orientation.

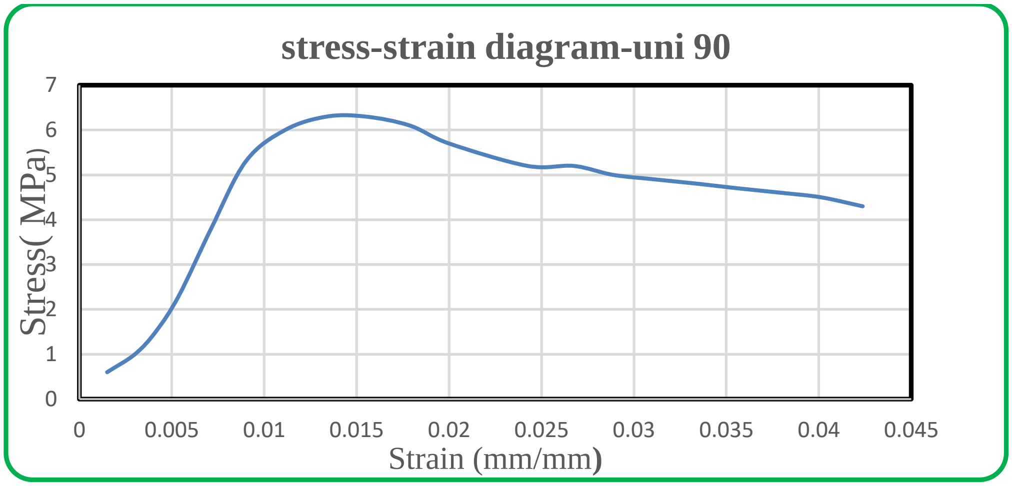


Figure 4.20: Stress-strain for unidirectional 90^0 fiber orientation compression test

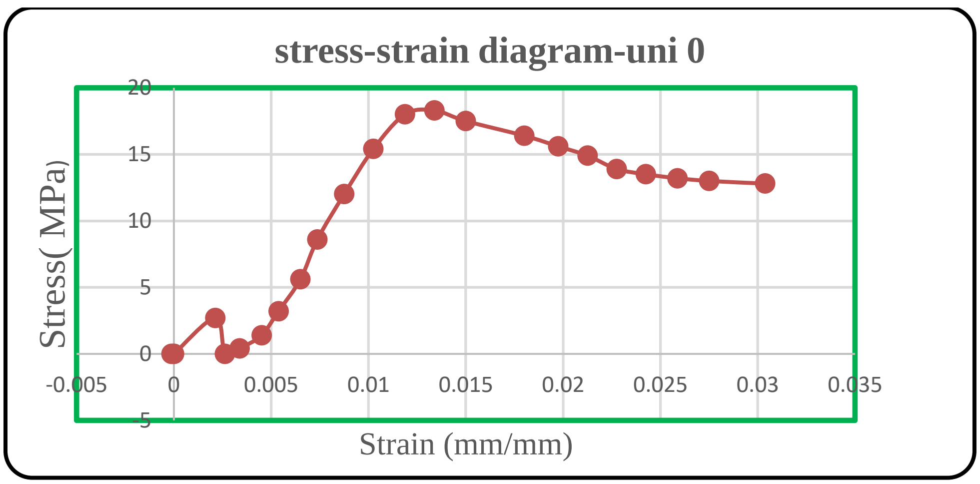


Figure 4.21: Stress-strain for unidirectional 0^0 fiber orientation compression test

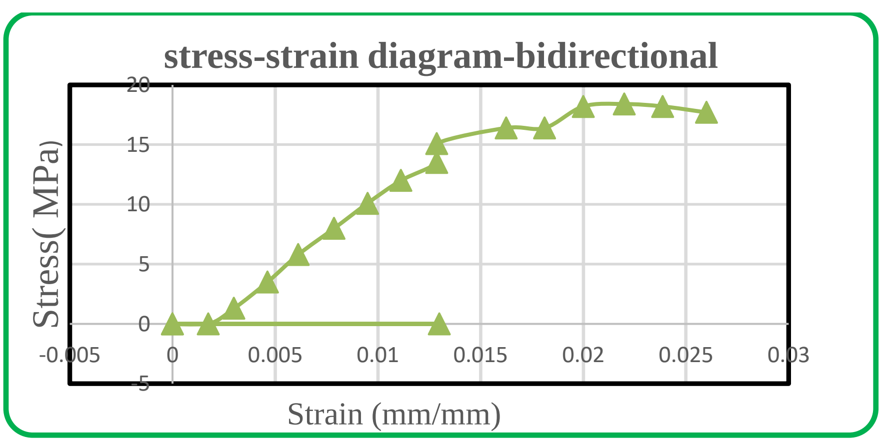


Figure 4.22: Stress-strain for unidirectional$(90^0/0^0)$ fiber orientation compression test

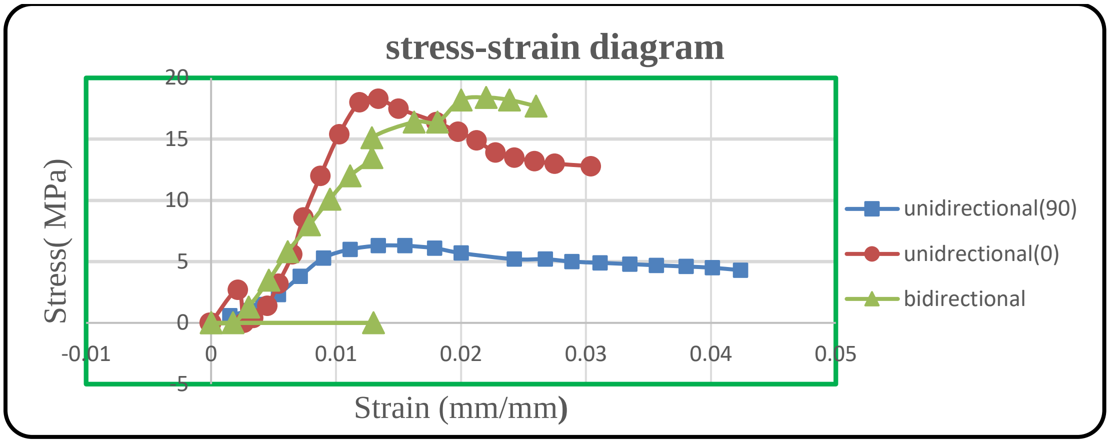


Figure 4.23: Stress vs. strain for each fiber orientation (compression)

4.1.3. Flexural Test

The flexural test measures the force required to bend a beam under three point loading situations. The data is often used to select elements for parts that will support loads without deflection.

Flexural modulus is used as an indication of a material's stiffness when deflection. Three point bend test was carried out using UTM machine in accordance with ASTM standard to Measure the flexural strength of the composites .The load was applied in the middle span of the specimen. The span length was 128 mm, 25 mm width, and 170 mm overall length as shown in figure 4.24 as shown and data were collected from the computer which is integrated with the standard UTM test machine as shown in fig.4.25.

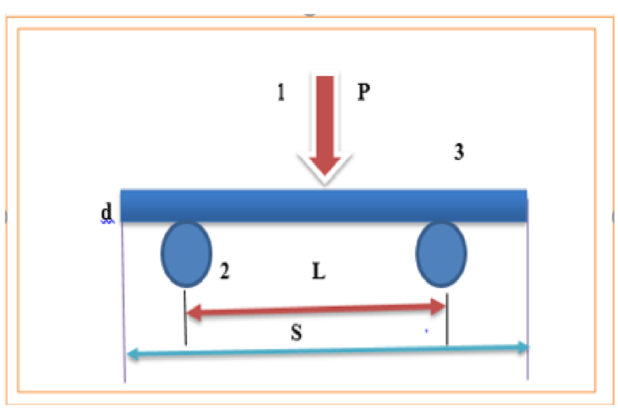


Figure 4.24: Three point bending

1: load probe, 2: support, 3: specimen, d: depth of specimen, L: support distance (span) and S: overall length of specimen.

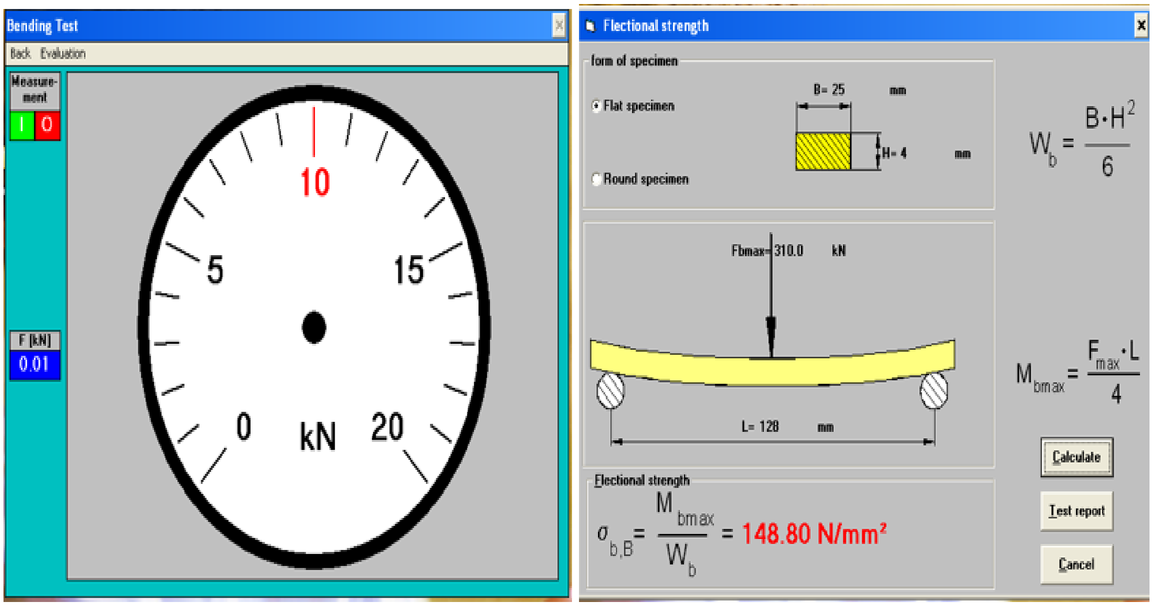


Figure 4.25: Loading in control system

Section modulus (w_b) $\mathbf{w_b = \frac{(w \times H^2)}{6}}$ ....…………..eq (4.1)

Maximum bending moment $M_{bmax} = \frac{F_{max} \times L}{4}$ ………….. eq (4.2)

Under three point bending in figure 4.25 when the load P is applied at mid span of a rectangular Specimen of span L between two rollers, the maximum bending stress is determined by:

Maximum bending stress ………………... $\delta_{bmax} = \frac{\boldsymbol{M_{bmax}}}{\boldsymbol{w_b}}$………….. ………… ……eq (4.3)

The test results are tabulated and presented in the table 4.1 based on the maximum values of the three specimens for each test condition

Table 4.1: Flexural test results

No	Orientation	Designation	Width (mm)	Thickness (mm)	Initial measurement (mm)	Maximum test force (N)	Flexural Strength MPa
1	Unidirectional 90^0	BSFHC-FS-1	25		128	170	81.60
		BSFHC-FS-2	25	4	128	166	80.27
		BSFHC-FS-3	25	4	128	160	76.80 M
		Average					79.556
2	Bidirectional /plain woven	BSFHC-FS-1	25	4.8	128	378	118.12
		BSFHC-FS-2	25	4.8	128	380	118.75
		BSFHC-FS-3	25	4.8	128	384	120
		Average					118.9
3	Unidirectional 0^0	BSFHC-FS-1	25	4	128	308	147.83
		BSFHC-FS-2	25	4	128	310	148.80
		BSFHC-FS-3	25	4	128	314	150.71
		Average					149.1 MPa

4.1.4. Impact test

Table 4.2 shows the results of impact test of three fiber orientation of bamboo /sisal fiber hybrid composite.

Table 4.2: Impact test result

Orientation	Designation	Impact energy(joule)
Unidirectional 90^0	BSFHC-IS-1	4.5
	BSFHC-IS-2	4.8
	BSFHC-IS-3	4.8
	Average	**4.7**
Bidirectional /plain woven	BSFHC-IS-1	4.2
	BSFHC-IS-2	4.2
	BSFHC-IS-3	4.5
	Average	**4.3**
Unidirectional 0^0	BSFHC-IS-1	5.1
	BSFHC-IS-2	6
	BSFHC-IS-3	4.2
	Average	**5.1**

4.1.5. Water absorption test

Table 4.3 shows the results of water absorption test of three fiber orientation of bamboo /sisal fiber hybrid composite

Table 4.3: Water absorption test result

Samples	Average (dry) w_d	Average (wet) w_w	$\frac{w_w - w_d}{w_w} \times 100\ in\ \%$
Unidirectional $\mathbf{0^0}$	3.166	3.5	0.0954
bidirectional	6	6.33	0.0521
Unidirectional $\mathbf{90^0}$	3	3.166	0.05243

4.1.6. Hardness test

The results obtained during hardness test on composite specimen of different fiber orientation are summarized in table 4.4

Table 4.4: Hardness test result

Fiber orientation	**Designation**	**Values (MPa)**	**Average (MPa)**
Unidirectional zero	BSFHC-HS 1	**3.2**	2.733/1kgf
	BSFHC-HS 2	**2.7**	
	BSFHC-HS 3	**2.3**	
Unidirectional 90	BSFHC-HS 1	**2.7**	2.866/1kgf
	BSFHC-HS 2	**3.1**	
	BSFHC-HS 3	**2.8**	
Bidirectional	BSFHC-HC 1	**6.5**	6.533/3kgf
	BSFHC-HC 2	**6.5**	
	BSFHC-HC 3	**6.6**	

4.1.7. Failure Modes

The intact and damaged specimens of tensile, flexural tests, impact test, and compressive re depicted in figure 4-26, 4-27, 4-28 and 4.29 respectively.

Unidirectional zero degree fiber orientation

Figure 4.26: Test Specimens before Testing

(a) Fractured Specimen under Bending (b). Fractured Specimen under Tensile Load

Figure 4.27: Test Specimens after Testing

(a) $0/90^0$ fiber orientation (b). 90^0fiber orientation (c) 0^0 fiber orientation

Figure 4.28: Test Specimens after impact Testing

The qualitative results of the impact test can be used to determine the ductility of the material. If the material breaks on a flat plane, the fracture was brittle and if the materials breaks with jagged edges or shear lips, then the fracture was ductile .Usually a material does not break in just one way or the other .and thus comparing the jagged to flat surface areas of the fracture will give an estimate of percentage of ductile and brittle fracture.

Figure 4.29: Fractured specimen after compression test

The qualitative results of the impact test can be used to determine the ductility of the material. If the material breaks on a flat plane, the fracture was brittle and if the materials breaks with jagged edges or shear lips, then the fracture was ductile .Usually a material does not break in just one way or the other .and thus comparing the jagged to flat surface areas of the fracture will give an estimate of percentage of ductile and brittle fracture.

4.2. Discussion

4.2.1. Tensile Test

The test results are tabulated (see appendix) and presented in the fig.4.30 based on the maximum values of the three specimens for each test condition.

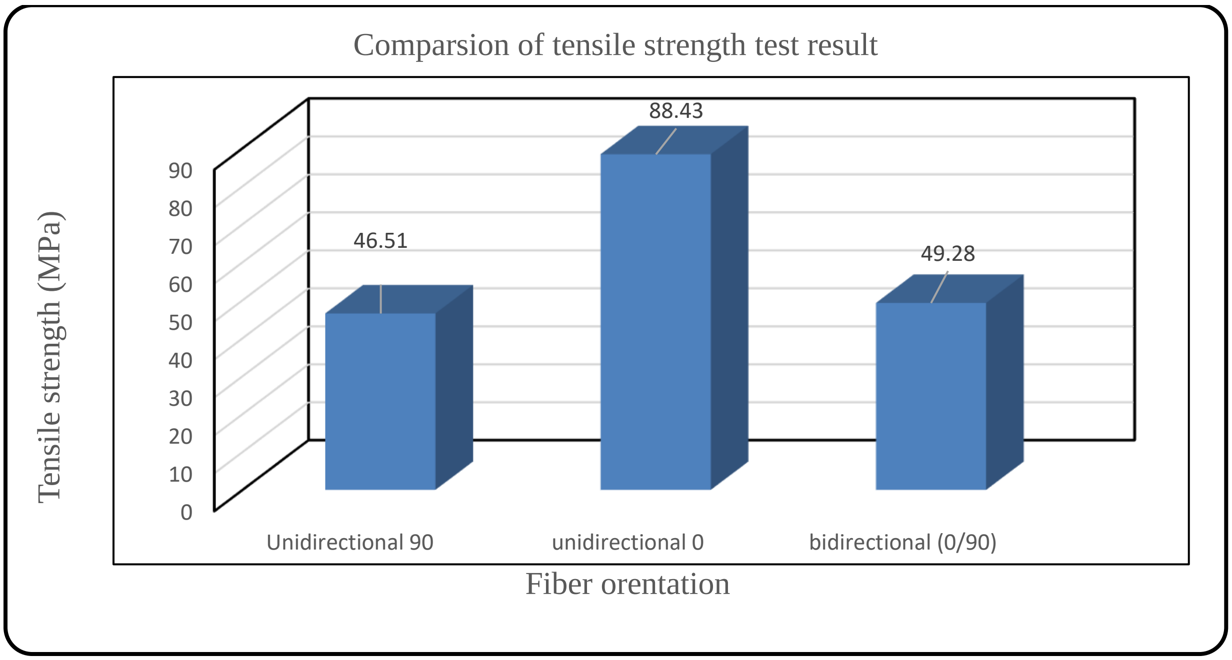


Figure 4.30: Comparsion of tensile strength for three fiber orentation

Discussion

The tensile strength of bamboo/sisal fiber reinforced hybrid composites is presented in fig.4.30. It is observed that the 0^0 fiber orientation composite is exhibiting higher tensile strength than 90^0 fiber orientation composite and bidirectional (0^0 /90^0) fiber orientation composite

The increase in tensile strength of hybrid composite is because of by varying sisal fiber orientation. As bamboo fiber orientation is fixed at 0^0. the variation tensile strength with fiber orientation is shown in figure 4.30.

From Figure 4.8,Force Vs Elongation diagram for three fiber orientation ,the percent elongation as well as force varies in different fiber orientation the maximum 8.97 kN force is with 15.39 % E for 0^0 Fiber orientation of bamboo/sisal fiber reinforced hybrid composite is observed. Whereas 5.45 kN with 3.8% E and 4.61kN with 15.42 for 90^0 fiber orientation composite and bidirectional (0^0 /90^0) fiber orientation composite respectively.

The tensile strength, output force and elongation at break is clearly illustrated in figure 4.4. The maximum tensile strength is 88.43 MPa for 0^0 Fiber orientation composite and the maximum percent elongation is 15.39 with 8.97 kN

In general, it is observed that as varying fiber orientation, the tensile strength varies. The higher tensile strength is observed 0^0 Fiber orientation of bamboo/sisal fiber reinforced hybrid composite.

4.2.2. Compression test

The test results are tabulated (see appendix) and presented in fig 4.31 based on the maximum values of the three specimens for each test condition

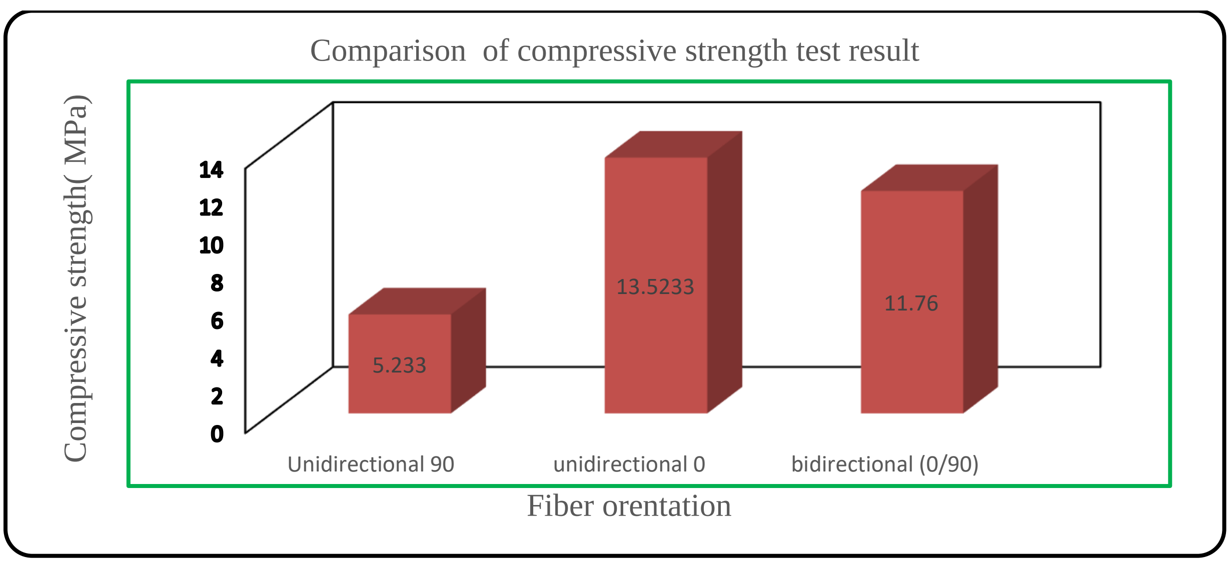


Figure 4.31: Comparsion of compressive strength for three fiber orentation

Discussion

The compressive strength of bamboo/sisal fiber reinforced hybrid composites is presented in fig 4.31.It is observed that the 0^0 fiber orientation composite is exhibiting higher compressive strength than 90^0 fiber orientation composite and bidirectional (0^0 /90^0) fiber orientation composite.

From Figure 4.19, Force Vs Elongation diagram for three fiber orientation, the percent elongation as well as force varies in different fiber orientation. The maximum 1.26 kN force is with 2.76 % E for 0^0 Fiber orientation of bamboo/sisal fiber reinforced hybrid composite is observed. Whereas 0.43 kN with 4.24% E and 1.6 kN with 2.6 % elongation for 90^0 fiber orientation composite and bidirectional (0^0 /90^0) fiber orientation composite respectively.

4.2.3. Flexural Test

The results obtained during flexural test on composite specimen of different fiber orientation are summarized in fig. 4.32

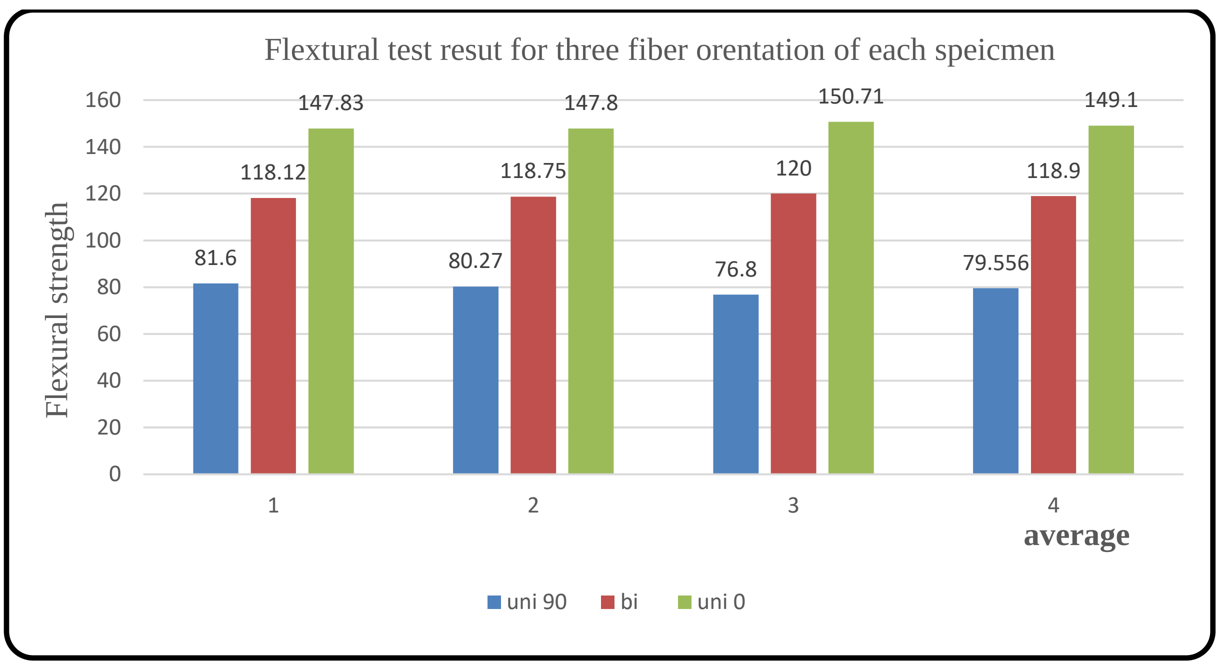


Figure 4.32: Flexural test result comparsion

Discussion

From figure 4.32 comparing three different fiber orientation of bamboo\sisal fiber reinforced hybrid composite the highest flexural strength is observed for 0^0 fiber orientation (149.1 MPa) and lowest in the case of 90^0 fiber orientation (79.55 MPa)

The maximum tensile force applied on the specimen is highest for bidirectional fiber orientation (as shown in fig 4.33) even its flexural strength is less than 0^0 fiber orientation due to its sample thickness of bidirectional fiber orientation. Maximum bending moment is observed on bidirectional fiber orientation and maximum bending stress observed in unidirectional 0^0 fiber orientation (see appendix).

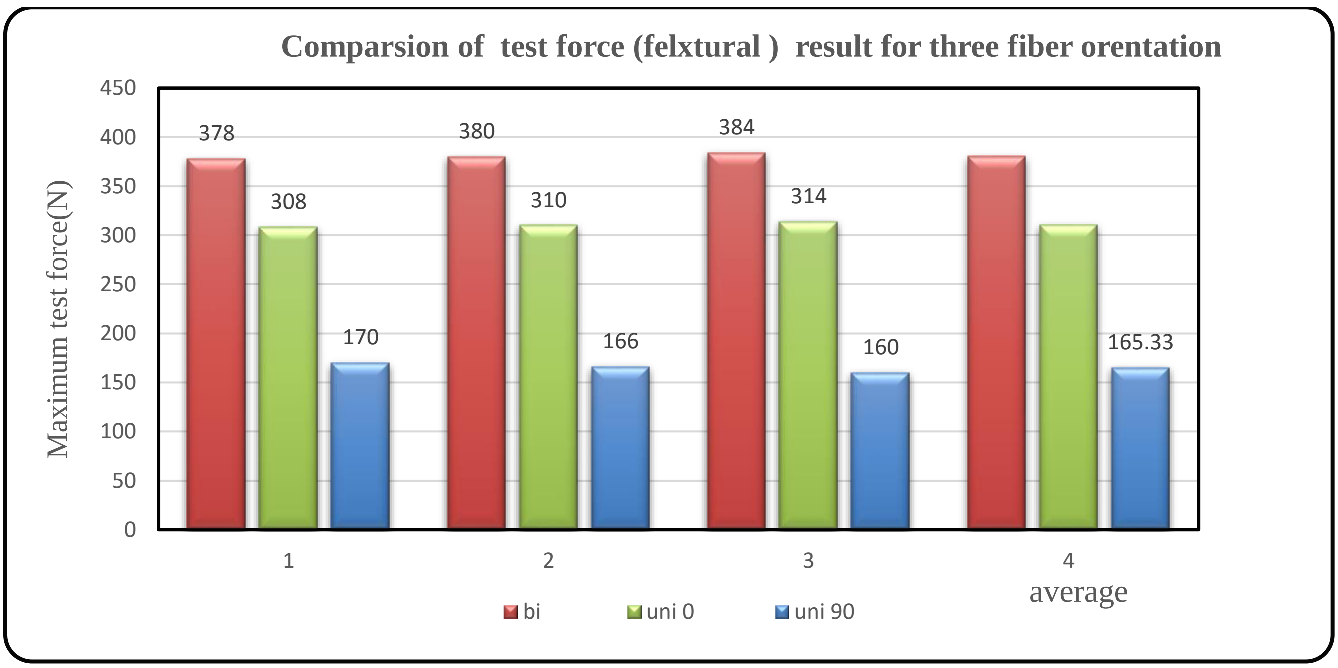


Figure 4.33: Comparsion of Maximum test force

4.2.4. Impact test

The impact test was carried out with charpy machine, results are presented in table 4.2 and the corresponding graphs have been plotted. In the graphs(as shown in fig 4.34) plotted for energy absorbed in Joules, It has been observed that unidirectional 0^0 fiber orientation of bamboo/sisal fiber reinforced composite have higher impact strength 5.1 J when compared to other types of orientation. Since it contains three unidirectional fiber layer alone.

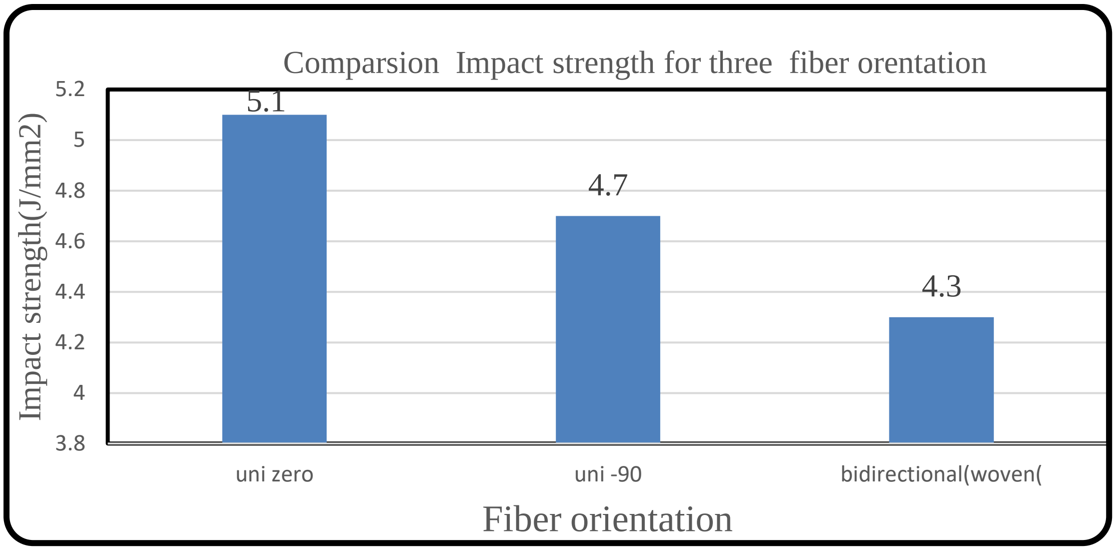


Figure 4.34: Comparsion of impact strength

4.2.5. Water absorption

From water absorption test result as shown in fig 4.35. BSFRHC shows high water absorption percentage in unidirectional zero degree fiber orientation (9.54%) and bidirectional (woven) absorbs minimum percentage of water (5.21%).

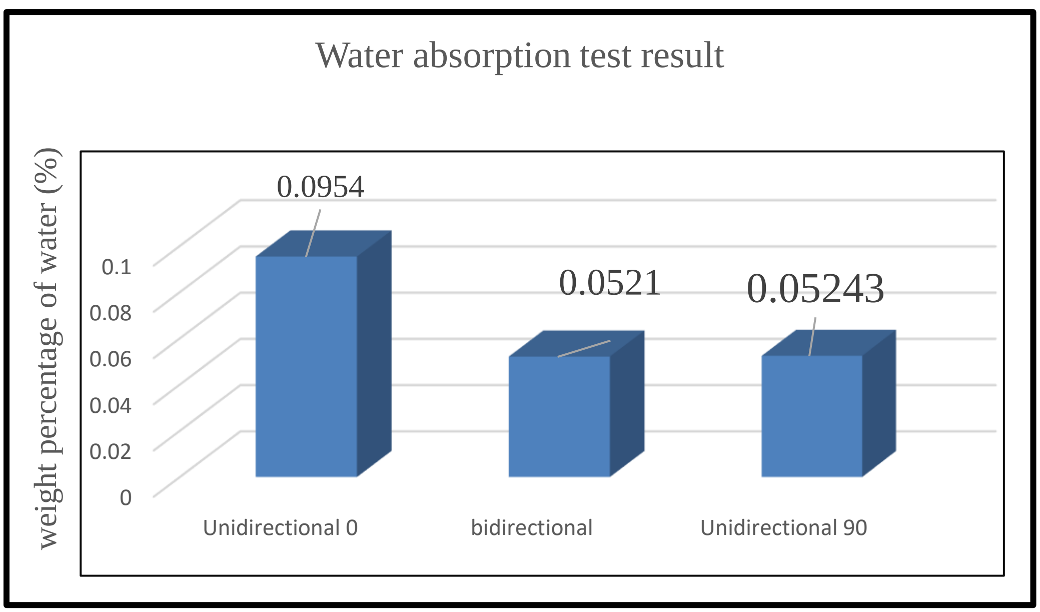


Figure 4.35: Comparsion of water absorption behavior for three fiber orentation

From the data given in fig 4.35 it is observed that the water absorption is more for unidirectional fiber 0^0 orentation compared to other fiber orientation .where water molecules got interlocked in composite material ,the weight of it increases ,thus evidenced that with immersion time the absorption behavior of BSFHRC varies in different orientation.

4.2.6. Hardness test result

From the data given in fig.4.36.It is observed that the hardness of the material is more for bidirectional fiber orientation compared to other fiber orientation

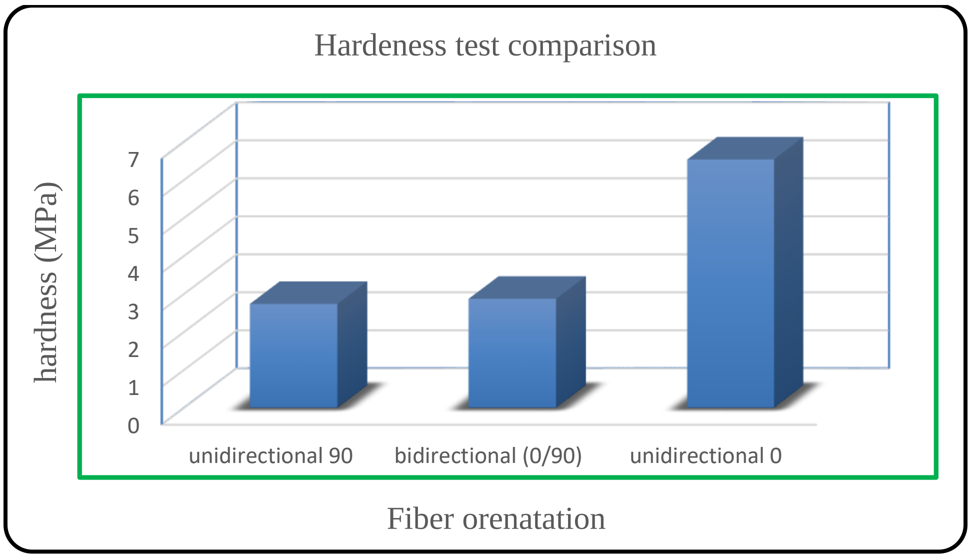


Figure 4.36: Comparsion of harndess test for three fiber orenataion

4.2.7. Comparison with the Previous works

Tensile strength

The tensile properties of samples are compared and given in table 4.5.The tensile strength are found to be higher 88.4 MPa for composites with unidirectional fiber orientation of composite. The tensile strength woven /bidirectional recorded in intermediate with the values of 88.4 MPa and 46.4 MPa. The lowest tensile properties are observed in non-woven unidirectional 90 degree fiber orientation 46.4 MPa. Some of other researchers working regarding tensile properties of natural fiber composites are compared with the Current work. From table 4.5The tensile strength which is found in the current work is more similar sisal/jute with bidirectional fiber orientation

Table 4.5: Comparison with previous works on tensile properties of hybrid composites

Matrix Material	Fiber	F/F	Fiber orientation	Fiber/matrix ratio	Method of fabrication	Tensile Strength(Mpa)	References
polyester	Bamboo/sisal	75/25	Chopped	50/50	Hand lay	23.5	Current work
Epoxy resin	Sisal /Coir	20/20	random	40/60	Hand lay	30.00	(G.Velmurugan, 20)
epoxy resin	Banana/Pineapple	25/15	__________	40/60	Hand lay up	60	(Madhukiran,2013)
Polyester	Glass fiber/ Rice husk	_______	chopped	35/65	Hand lay up	10	(G Gupta, 2018)
Polyester	Glass fiber/ Banana	_______	chopped	35/65	Hand lay up	45	(G.Gupta. 2016)
Epoxy resin	SISAL/Jute	Woven		--------	Hand lay	97.5	(Madhu Van ,2016)

Flexural strength

Flexural Properties of the current work compared with that of some of other researchers work.

From table 4.6

Table 4.6: Comparison with previous works on Flexural properties hybrid composites

Matrix Material	Fiber	Fiber / Fiber	Fiber orientation	Fiber/matrix ratio(w/w)	Method of fabrication	Flexural Strength (Mpa)	References
polyester	Bamboo/sisal	75/25	chopped	50/50	Hand lay	57.8	Current work
Epoxy resin	Sisal /Coir	20/20	random	40/60	Hand lay	36.26	(G.Velmurugan, 2014)
Polyester	Glass fiber/ Rice husk	_____	chopped	35/65	Hand lay up	83	(G.Gupta. 2016)
Polyester	Glass fiber/banana	_____	chopped	35/65	Hand lay up	89	(G.Gupta. 2016)
Epoxy resin	SISAL/Jute	…..	Woven	…….	Hand lay	46	(Madhu Van ,2016)

Impact strength

The impact strength of the current work compared with that of some of other researchers work.

From table 4.7

Table 4.7:Comparison with previous works on impact properties of sisal fiber composites

Matrix Material	Fiber	Fiber /fiber	Fiber orientation	Fiber/matrix ratio	Method of fabrication	Impact Strength $KJ/_{cm^2}$	References
polyester	Bamboo/sisal	75/25	Chopped	50/50	Hand lay up	19.7	Current work
Polyester	fiber/Rice husk	---	chopped	35/65	Hand lay up	8.3	(G.Gupta. 2016)

Polyester	Glass /banana	-----	chopped	35/65	Hand lay up	8.3	(G.Gupta. 2016)
Epoxy resin	Sisal /Coir	20/20	Random	40/60	Hand lay	4.42	(G.Velmurugagan, 2014)

4.3. Finite Element Analysis of Internal Door Panel

Geometrical modelling of the internal door panel

The 3D Modeling is a geometrical representation of a real object without losing information the real object would have it has volume .mass and density of the material. In this this research, the 3D modelling of the front internal door panel is done by using space claim software. This is done by taking the actual data from a selected type of vehicle

The Toyota hiace 2y model vehicle is selected for this purpose. This vehicle is selected due to some reasons; such as,

- Toyota hacek 2y model vehicle are old enough to need spare parts for the replacement of their parts; such as internal door panel. Thus it will be feasible to implement the findings of this research on the selected vehicle
- Large number of this car available in transport sector and easy to take data.

Figure 4.37: Selected Toyota hiace 2y model vehicle

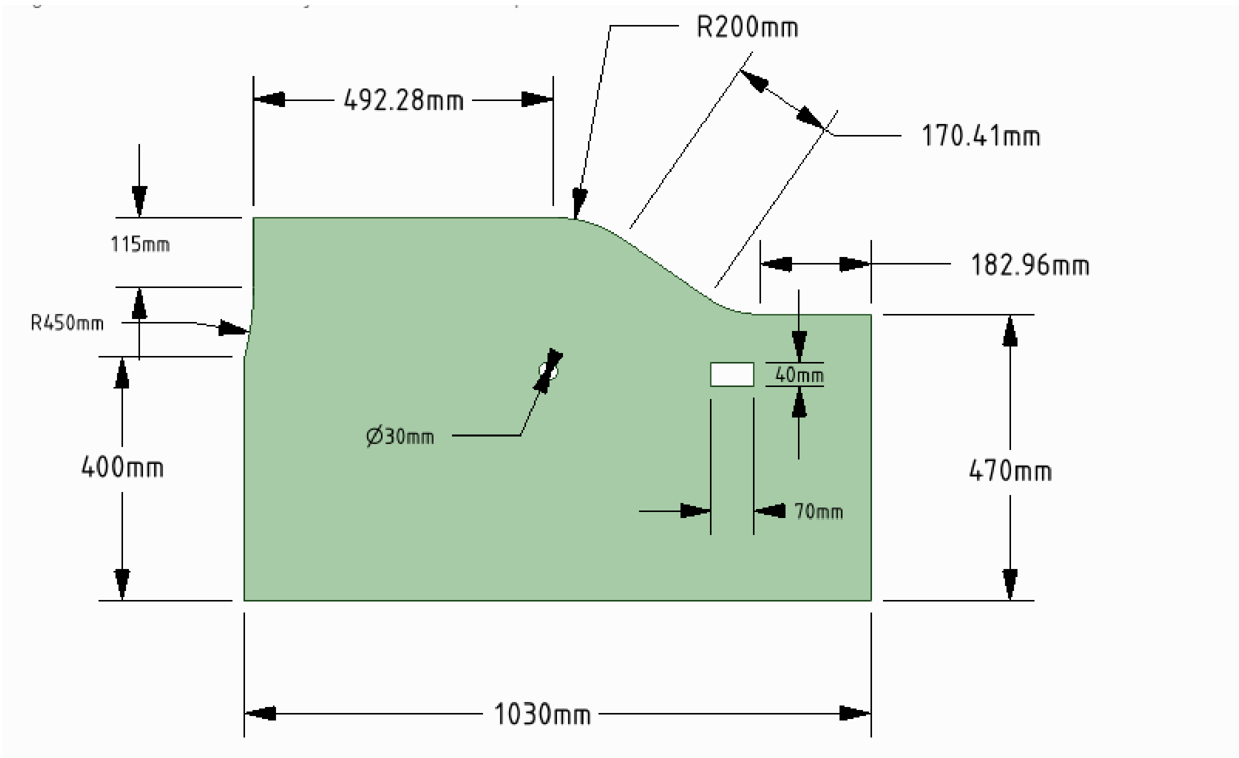


Figure 4.38: Drawing of the internal door panel (all dimensions are in mm)

Finite Element Modeling and analysis

For many engineering problems analytical solutions are not suitable because of the complexity of the material properties, the boundary conditions and the structure itself. The basis of the finite Element method is the representation of a body or a structure by an assemblage of subdivisions called finite elements.

Numerical simulation gives an efficient tool for the analysis of deformation behavior of structural components in different industries, which could provide clear results of different alternative models at the initial designing stage in order to get the best structure. Due to high cost of prototypes when developing new vehicle models, computer simulations of vehicle dynamics become more and more important in the product development process.

Mechanical components are a continuous elastic structures. FEA divides the structure into small but finite, well-defined, elastic substructures called elements. By using polynomial functions, together with matrix operations, the continuous elastic behavior of each element is developed in terms of the element's material and geometric properties. Loads can be applied within the element, on the surface of the element, or at the nodes of the element. The element's nodes are the

Fundamental governing entities of the element, as it is the node where the element connects to other elements, where elastic properties of the element are eventually established, where boundary conditions are assigned, and where forces are ultimately applied. A node possesses degrees of freedom. Degrees of freedom are the independent translational and rotational motions that can exist at a node. At most, a node can possess three translational and three rotational degrees of freedom. Once each element within a structure is defined locally in a matrix form, the elements are then globally assembled through their common nodes into an overall system matrix. (Barbero, 2014)

Applied loads and boundary conditions are then specified and through matrix operations the values of all unknown displacement degrees of freedom are determined. (As shown in 4.39). Once this is done, it is a simple matter to use these displacements to determine strains and stresses through the constitutive equations of elasticity.

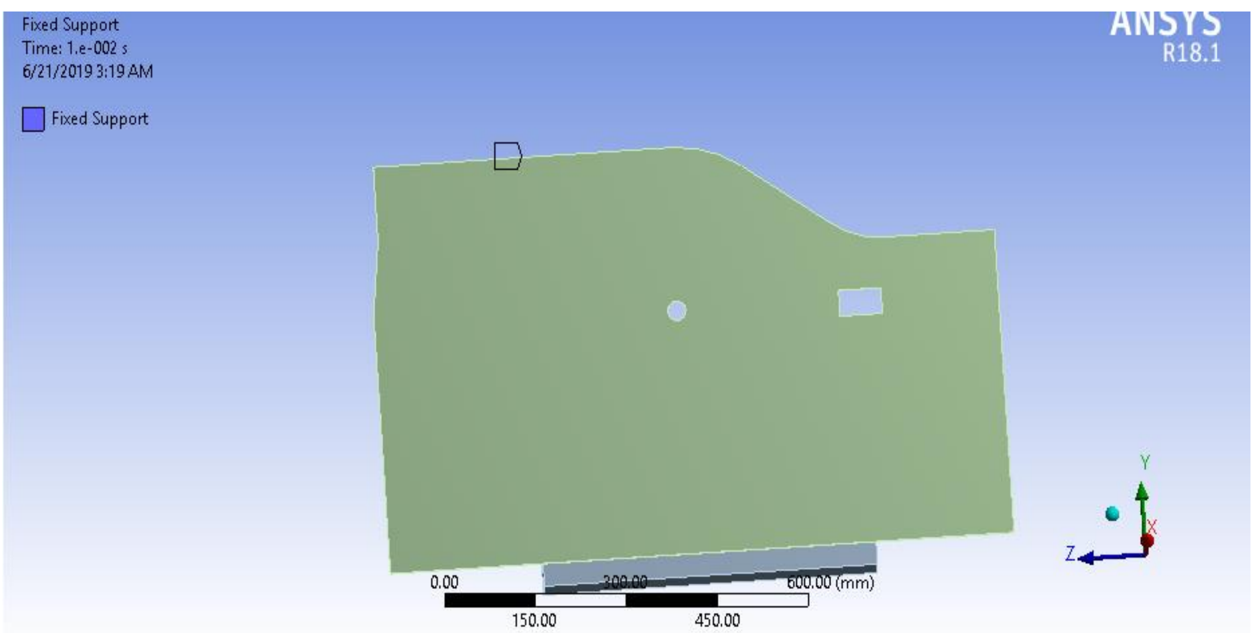


Figure 4.39: Applying boundary conditions on ANSYS Workbench

An establishment of appropriate finite element model for an actual practical problem depends to a large degree on the understanding of the physical problem including a qualitative knowledge of the structural response to be predicted, the knowledge of the basic principles of mechanics and the good understanding of the finite element procedures available for analysis. (Barbero, 2014)

Discretization of the domain into finite elements is the first step in the finite element method. This is equivalent to replacing the domain having an infinite number of degrees of freedom by a system having finite number of degrees of freedom. The shape, size, number and configuration of elements have to be chosen carefully so that the original body or domain is simulated as closely as possible without increasing the computational effort needed for the solution. (Barbero, 2014)

Before meshing of the body it is necessary to add the material properties, external loads, and apply the boundary conditions. In order to start of the problem, only parameters of the calculation regime should be added to the input file.

Assumptions

It is known that automotive components are geometrically complex; consequently, some assumptions and approximations need to be made in order to make the simulation more practical. Thus; we can consider the following assumptions for the entire FEM analysis.

- ❖ The stress and strain character of the door panel by applying a load on the surface, but not consider the full scale, Vehicle geometry and the passage damage.
- ❖ the materials properties of the door panels were made of steel (outer part) and composite materials (interior part), but the project would consider the simulation of composite materials(interior door)

Methods of Finite Element Analysis

The establishment of the finite element model and the finite element analysis of this thesis work were conducted through the software package, ANSYS. ANSYS is a combined interactive/batch type computer –aided design software package, which contains many mechanical analysis programs developed, commercialized and marked by ANSYS.inc. ANSYS is the name commonly used for ANSYS mechanical, general-purpose finite element analysis

(FEA) computer aided engineering software tools. ANSYS mechanical is a self-contained analysis tool incorporating pre-processing such as creation of geometry and meshing, solver and post processing modules in a unified graphical user interface. ANSYS is a general-purpose FEM package for numerically solving a wide variety of engineering problems.

In general, a finite element solution may be broken into the following three stages. This is a general guideline that can be used for setting up any finite element analysis.

Preprocessing: it is about defining the problem which will be analyzed by FEM. The element type, material/geometric properties and Meshing are also defined under this section.

Solution: in this section assigning loads, constraints and solving the resulting set of equations the given problem are performed.

Post processing: further processing and viewing of the results; in this stage one may wish to see nodal displacements, equivalent stress, equivalent elastic strain and normal stress

The following steps are used in the solution procedure using ANSYS Workbench software for ANSYS Explicit Dynamics finite element analysis

1. The geometry of the panel to be analyzed is imported from modeling software to the ANSYS Workbench in an acceptable format.
2. The material type and its properties are specified.
3. Meshing the imported panel model.
4. The boundary conditions and external loads are applied.
5. The solution is generated based on these input parameters.
6. Finally, the solution can be displayed

Importing the model geometry

The mechanical geometry model of the panel is done by space claim software. For The finite element analysis, it should be imported to the ANSYS Workbench

Input the material type and properties

The material type and its properties such as density, strength, Young's modulus shear modulus and Poisson's ratio are specified under the project model geometry system. The engineering data helps to input the mechanical properties of the bamboo/sisal fiber reinforced hybrid composite in unidirectional zero degree fiber orientation .The important material properties are taken from the experimental test result of composite in table 4.8.

Table 4.8: Mechanical properes of BSFRHC for unidirection 0^0 fiber orentation

Property	Bamboo/sisal fiber reinforced composite
Density (ρ)	1.09 g/cm^3
Tensile Strength	88.4 MPa
Flexural Strength	148.5 MPa
Compressive Strength	13.5 MPa
Young's Modulus	1726MPa
Poisson's ratio	0.251

In the finite element analysis the basic concept is to analyze the structure which is an assembly of discrete pieces called elements which are connected together at a finite number of points called nodes. A network between these elements is known as meshing. This is the step that divides the complex geometry model into small elements that become solvable in an otherwise too complex situation. The meshing of the geometry under consideration may be generate directly, i.e., generation of nodes and elements, one at a time. Solid Modeling constitutes a part of the finite element analysis. Thus, the sole purpose of Solid Modeling is to create the mesh of the geometry, as conveniently and efficiently as possible. The meshing process can be performed only after the specification of element type. ANSYS offers several convenient options to assist in meshing. These include Automatic Meshing, Smart Sizing, and Mapped Meshing. One of the most powerful features of ANSYS is automatic mesh generation. ANSYS meshes the solid model entities up on execution of an "appropriate" single command. With automatic meshing, the user can still provide specific preferences for mesh density and shape. If no preferences are specified by the user, ANSYS uses the default preferences.

In this specific research work, Meshing is done by using this automatic meshing generation method and the refinement is done, specifically for areas at which high stress concentrations will occur.

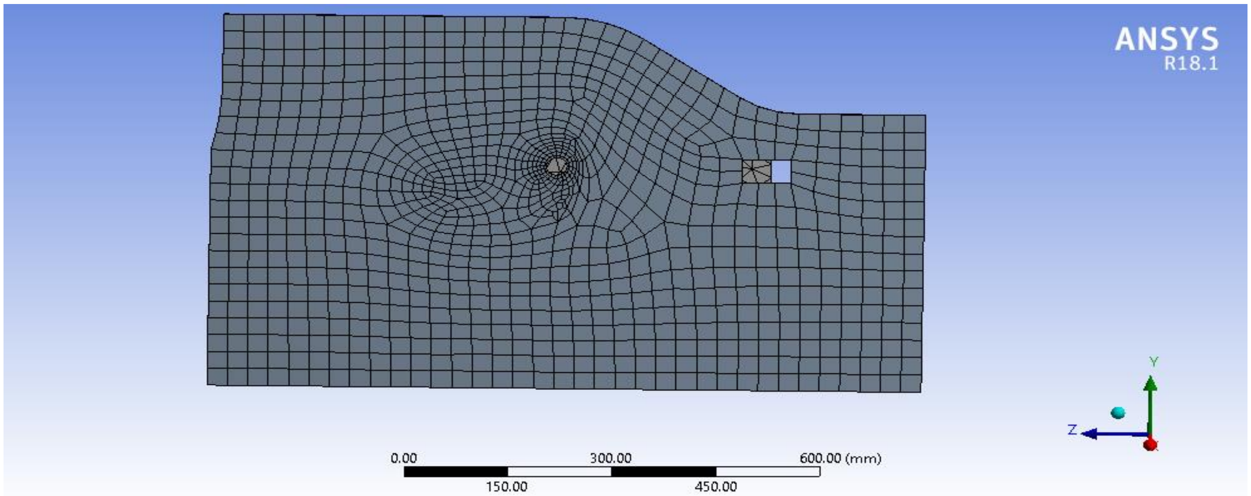


Figure 4.40: Geometric meshing of the model on ANSYS Workbench

Application of boundary conditions and external loads

The next step of finite element analysis involves applying appropriate boundary conditions and the proper loading mechanism. There are two ways to apply the boundary conditions and loading to the model in ANSYS; either apply the conditions to the solid model (key point, lines and areas),

Or the conditions can be directly imposed on the nodes and elements. In this research work, the first approach is preferable; because if it is decided to change the meshing, there will not need to reapply the boundary conditions and the loads to the new finite element model. (Moaveni, 2007)

The internal door panel has several areas where constraints are applied as follows:

- Upper part rests on a metal door structure, thus blocking shifting on the y direction (U2)
- In screw mounting areas shifting are blocked on all three directions (U1, U2 and U3)
- On clips systems panel mounting metal structure areas, shifting are blocked on all the three directions (U1, U2 and U3);

  Where, U1, U2 and U3 are the displacements in x, y and z directions, respectively.

The main goal of a finite element analysis is to examine how a structure or component responds to certain loading conditions. Specifying the proper loading conditions is, therefore, a key step in the analysis. Loads can be applied on the model in a variety of ways in the ANSYS program. Also, with the help of load step options, one can control how the loads are actually used during solution.

For this research the load to be applied for the analysis purpose is velocity of the impactor when impactor moves with 60km/hr. is used for the analysis purpose.

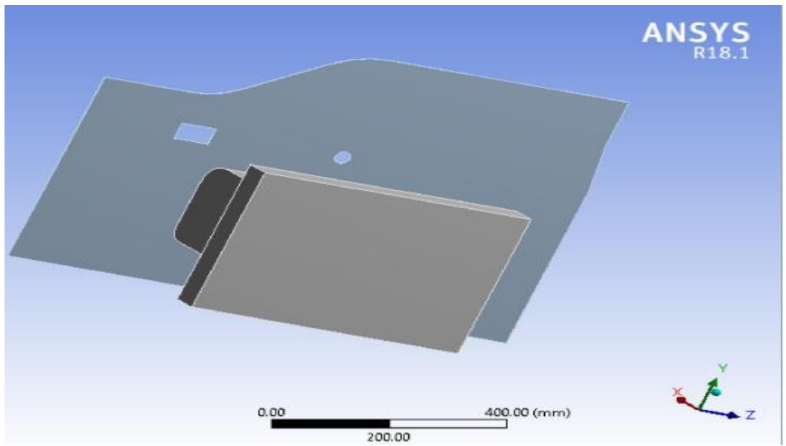


Figure 4.41: Impactor and door panel in ansysys workbench

Generate solutions

The solution is generated based on the above input parameters. The total deformation, normal stress, equivalent elastic strain and the equivalent (Von Mises) stress are the basic variables to be solved by this software analysis

Results and discussion

Equivalent (Von-Mises) stress

The equivalent (Von Mises) stress values of front internal door panel of presented in fig 4.41.

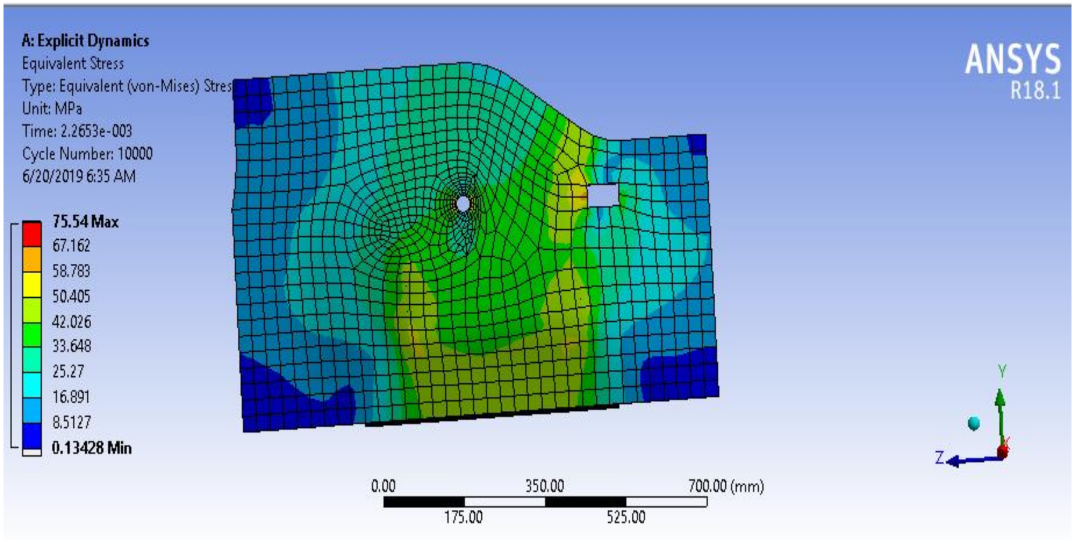
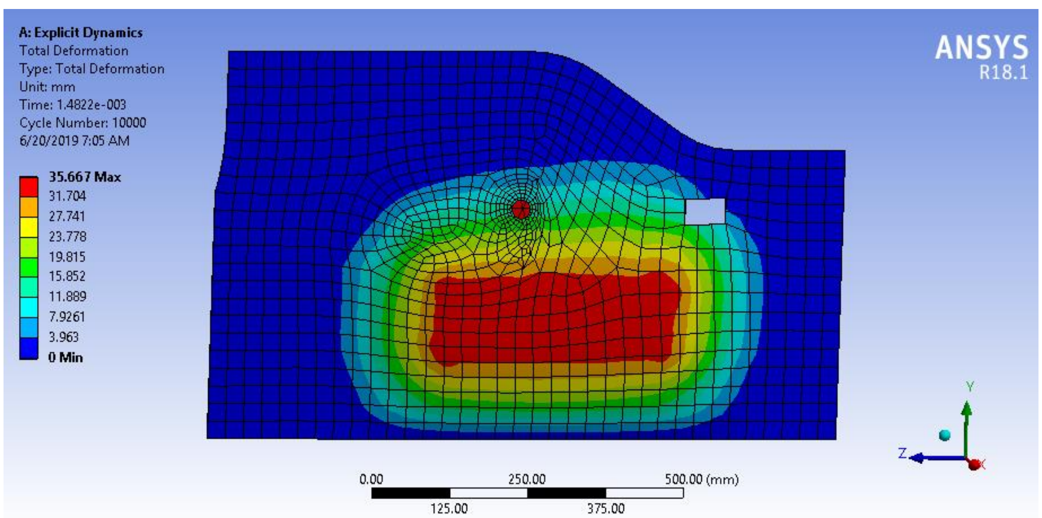


Figure 4.42: Equivalent (Von Mises) stress for interanl door panel

Displacement

Figure 4.43: Total deformation



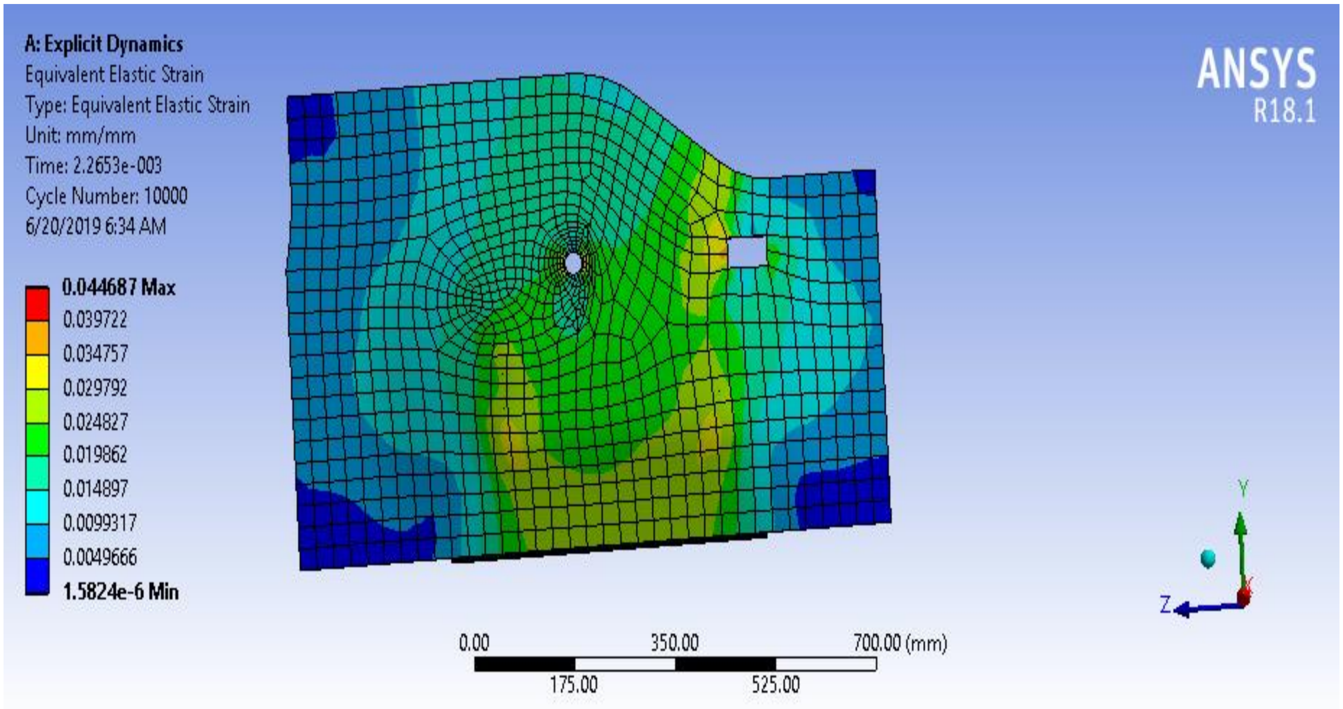


Figure 4.44: Equivalent elastic strain for interanl door panel

Normarl stress

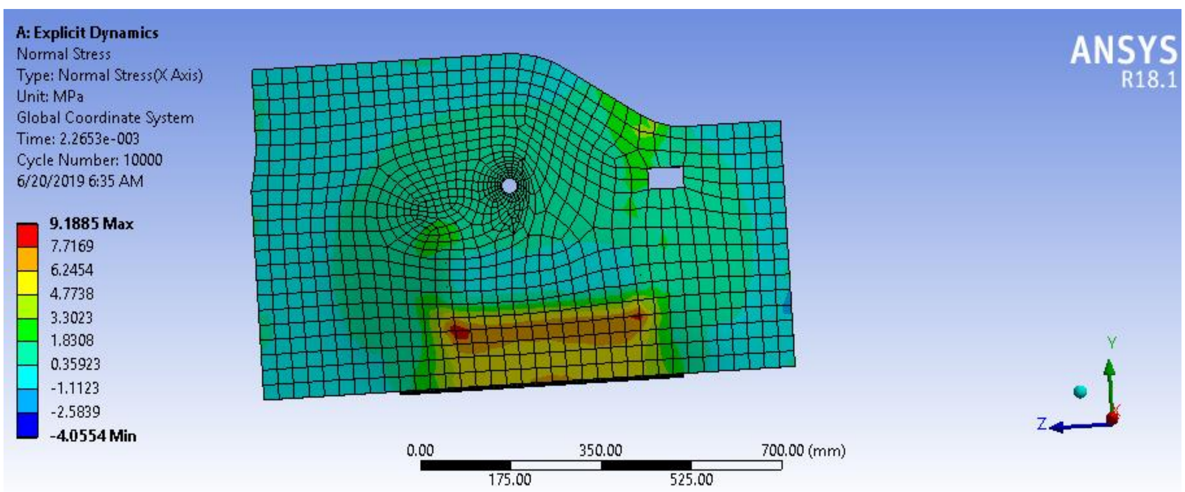


Figure 4.45: Normal stress on internal door panel

Discussions

This explicit dynamic analysis of the internal door panel of a vehicle using BSFRHC was performed for side impact analysis of internal door panel the impact produced while the the impactor moves 60km/hr.

Comparing the results obtained by FEA of the bamboo /sisal fiber reinforced hybrid composite panel with the panels of other previously recommended materials (lignocellulosic composite and polypropylene plastic composite materials) is important to see the improved achievement.

In this research the comparison between the results of the FEA of these materials is carried out by making everything the same, except the material properties; i.e. at the same impactor velocity, in the same model and the same method of FEM analysis. The results of the FEM analysis for the lignocellulosic composite and polypropylene materials are displayed in the appendix part.

Stress

External loads applied to a structural model in equilibrium is reacted by internal forces set up within the material. Stress is defined as the average force per unit area that some particle of a body exerts on an adjacent particle, across an imaginary surface that separates them

Equivalent (Von-Mises) stress

Equivalent (Von Mises) stress, which arises from distortion energy failure theory, is widely used by designers to check whether their design will withstand a given load condition.

Using the ANSYS Workbench 18.1 software, along with the given boundary conditions and applied loads we got a value for this load, the values equivalent (von-Mises) stress. Then the maximum equivalent (Von-Mises) stress values are noted

The results of this analysis shows that the equivalent (Von-Mises) stress of the BSFRHC panel is the smallest one as compared to that of the lignocellulosic composite and polypropylene panels under the same applied load and boundary conditions. This implies that BFREC material is less stressed.

Table 4.9: Comparing the FEA results of the panel of different materials

Internal door panel	Equivalent Stress (MPa)	Maximum Displacement (mm)	Mass(kg)
BSFRHC door panel	75.54	35.66	0.95
Lignocellulosic composite	79.613	54.385	1.0481
Polypropylene panel	82.4	56.78	1.0657

This analysis shows that, the maximum displacements of the bamboo/sisal fiber reinforced hybrid composite panel has the lowest value. It is lower than the lignocellulosic composite panel and of the polypropylene panel. This values displacements decrease is due to the greater rigidity of bamboo/sisal fiber reinforced hybrid composite material.

Moreover, the mass of bamboo/sisal fiber reinforced hybrid composite panel is reduced from 1.0657 kg to 0.95 kg polypropylene materials and 1.0481kg to 0.95kg than that of lignocellulosic composite and respectively.as shown in fig 4.46.

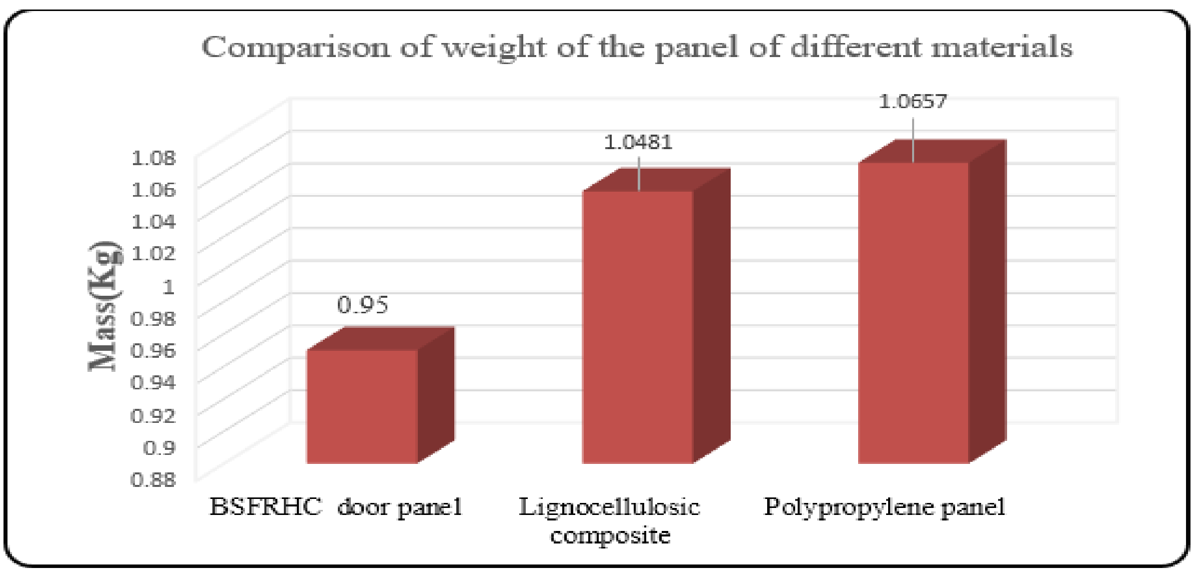


Figure 4.46: Comparison of weight of the panel of different materials

The charts plotted in fig 4.47, 4.48 and 4.49 show the comparisons of these values for different materials of door panel.

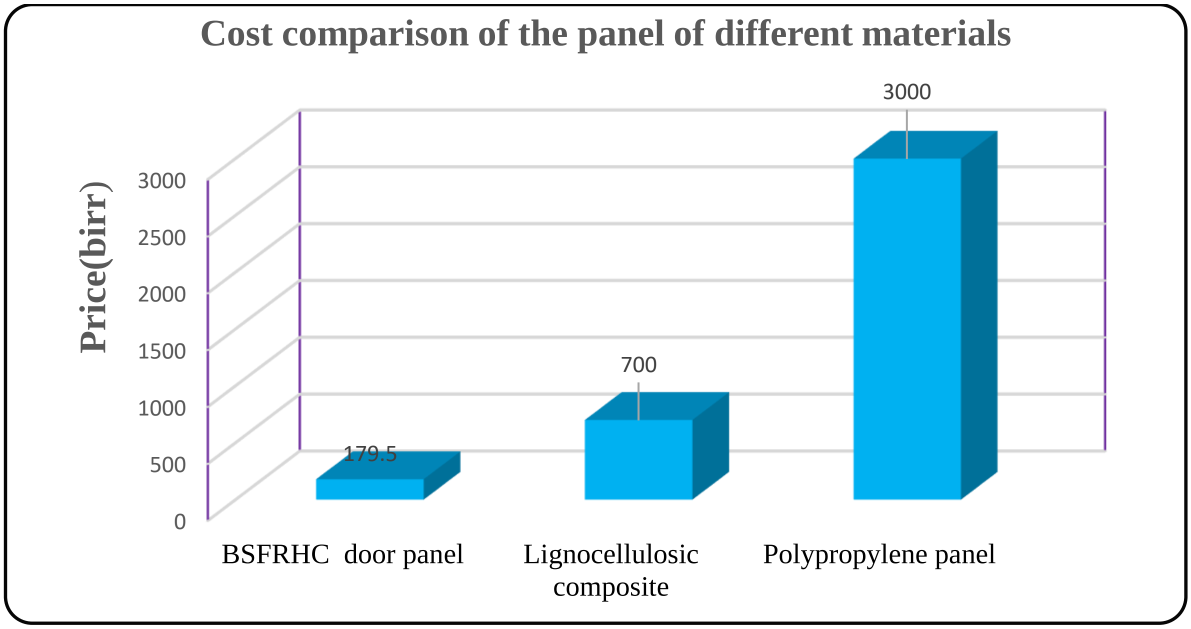


Figure 4.47: Comparison of cost of the panel of different materials

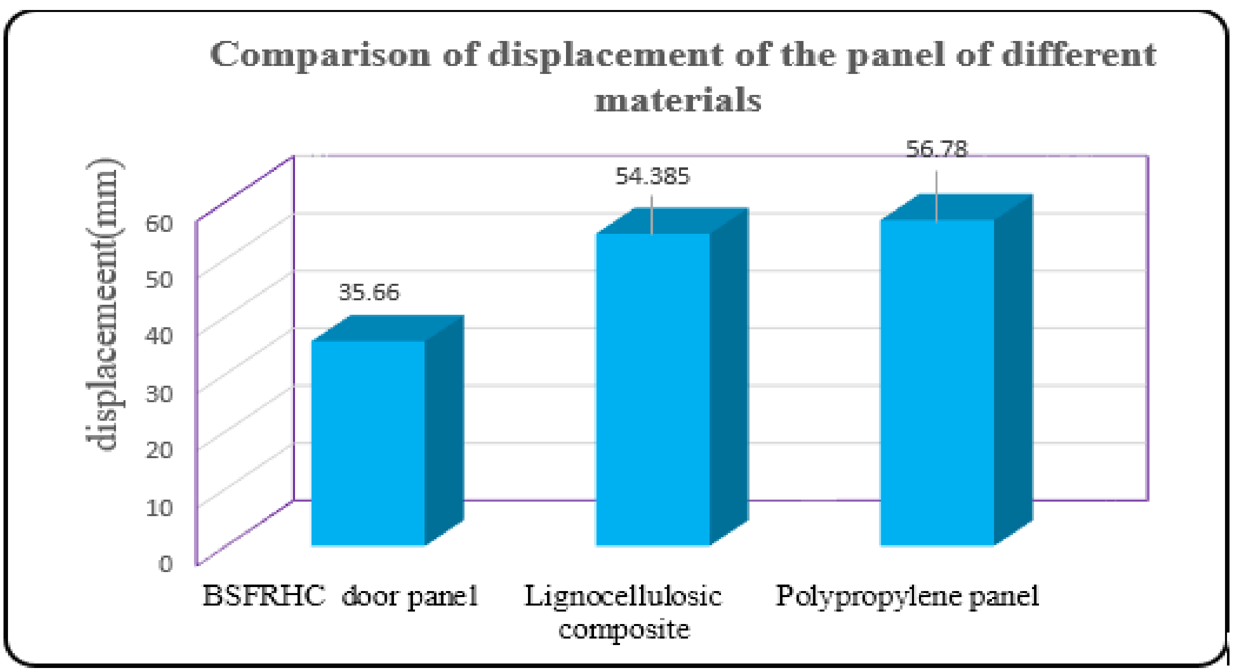


Figure 4.48: Comparison of weight of the panel of different materials

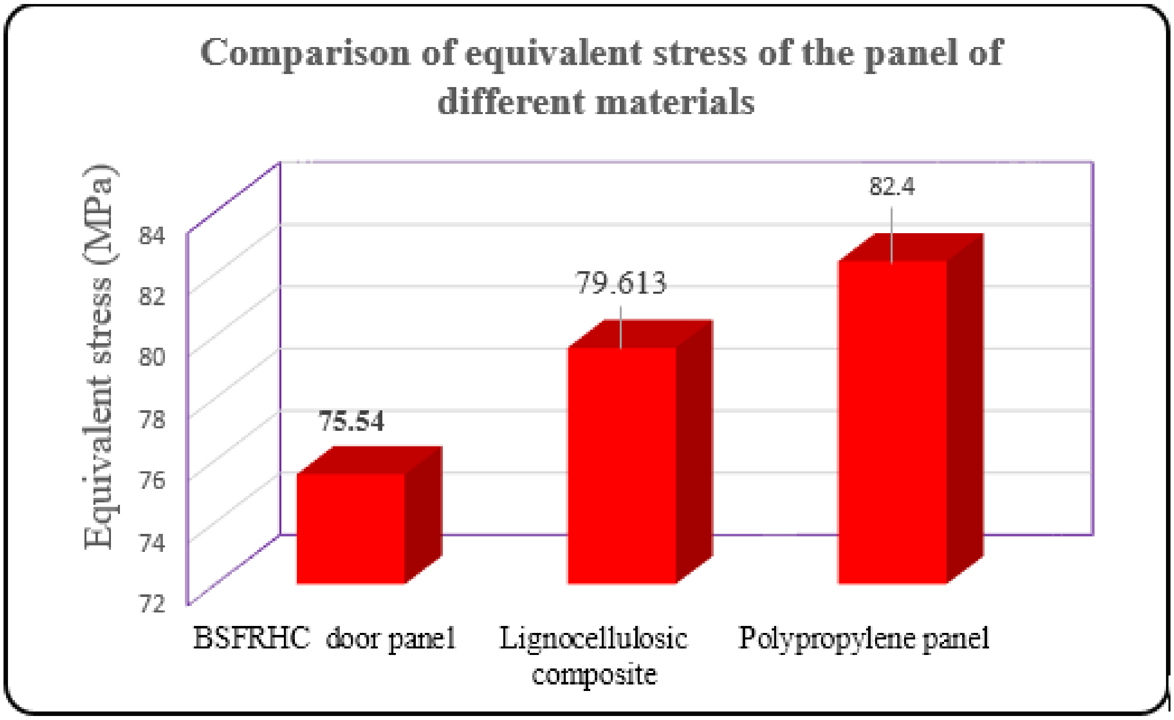


Figure 4.49: Comparsion of equivalent stress of pnael of different materials

Generally the fabricated bamboo/sisal fiber reinforced composite has a potential to be used for automotive interior part application.

CHAPTER FIVE

5. CONCLUSSION AND RECOMMENDATION

4.4. Conclusion

The three years old bamboo fiber was extracted from Ethiopian high land bamboo ‘Yushania Alpina’ species, and then alkaline treatment was carried out. And also sisal fiber was extracted manually from Ethiopian Highland sisal plant, and then the alkaline treatment was carried out.

Next to that bamboo and sisal fiber reinforced hybrid composite was manufactured and its mechanical performance such as the tensile, compression flexural and impact properties were determined using laboratory experiments.

All the important information related to composite material was gathered with experimentation. Moreover such tests constitute fundamental confirmation of the reliability of the material and of its usage in automotive interior body application .

After determining the material properties of bamboo/sisal fiber reinforced hybrid composites with three different fiber orientation of the composite material the following conclusions can be drawn

1. Successful fabrication of the hybrid composite using bamboo/sisal fiber reinforced polyester has been done by the hand layup technique.
2. Different mechanical properties of BSFRHC were determined from different fiber orientation
3. 0^0 fiber orientation of bamboo /sisal hybrid composite samples possess good tensile strength and can with stand the strength up to 84.4 MPa
4. The 0^0 fiber orientation of bamboo /sisal hybrid composite hybrid composite samples maximum flexural strength of 149.1MPa.
5. From the impact Experimental test results it is found that impact energy of unidirectional 0^0 fiber composite higher compared to others which is about 5.1 Joules.
6. Now a day’s most of automobile manufacture company’s try to replace synthetic fibers with natural fibers but it is not comparable in properties. While fabricating hybrid

composite by the combination of two natural fibers given them advantage to replace synthetic fibers.

7. This work also demonstrates the potential of the hybrid natural fiber composites can be regarded as a useful material in light weight applications.
8. From all the results and comparisons we can conclude that the fabricated BSFRHC can be used in automobile parts which does not need a very high mechanical performance, but need light weight and recyclability such as interior panel.

4.5. Recommendation

The way of fiber extraction of bamboo and sisal fiber has the impact on the mechanical property (tensile) of hybrid composite ,so it is recommended that the fiber is to be extracted with better way ,so that fiber with uniform diameter and length ,which has good strength.

It is also recommended to use bamboo and sisal fiber hybrid composite to fabricate the non-structural body parts of the vehicle to reduce the weight of the vehicle.

4.6. Future work

From different aspects, working on natural materials as composite have several advantages. From this point of view, regarding BSFRHC's several things can be made and improved in the future in which this study couldn't address.

So the following research areas are recommended for future studies.

- ❖ Characterization of the fibers can be done by using different fabrication techniques (such as vacuum bagging) on BSFRHC.
- ❖ Design of natural fibers extraction processing machine.
- ❖ Applying of BSFRHC for production of other internal parts of the vehicle such as, dashboards. Roof, floor etc.

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Appendix

Appendix A Tensile test result on UTM machine

In this appendix, all the data have been collected during the laboratory specimens testing were Provided. Data collected during the laboratory tensile specimens testing

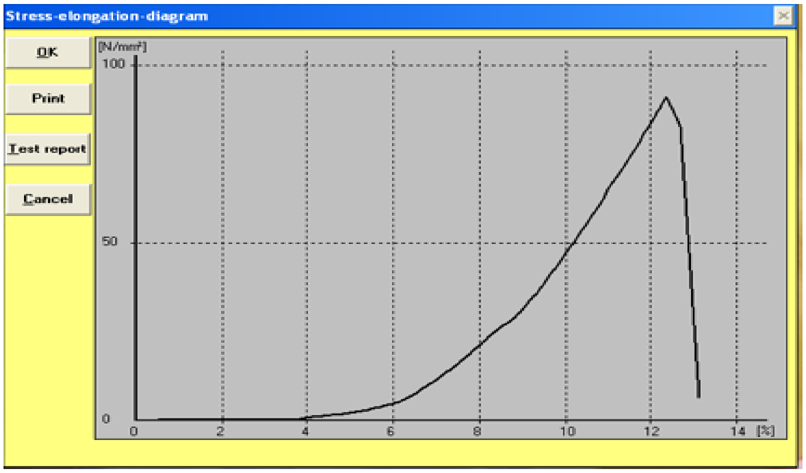


Figure A.1: stress elongation diagram for unidirectional 0^0 fiber orentation

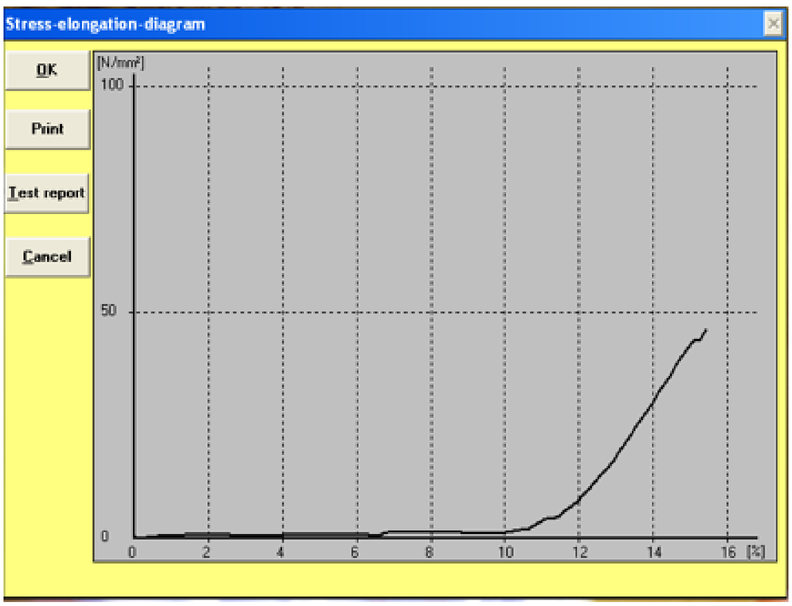


Figure A.2 stress elongation diagram for unidirectional 90^0 fiber orentation

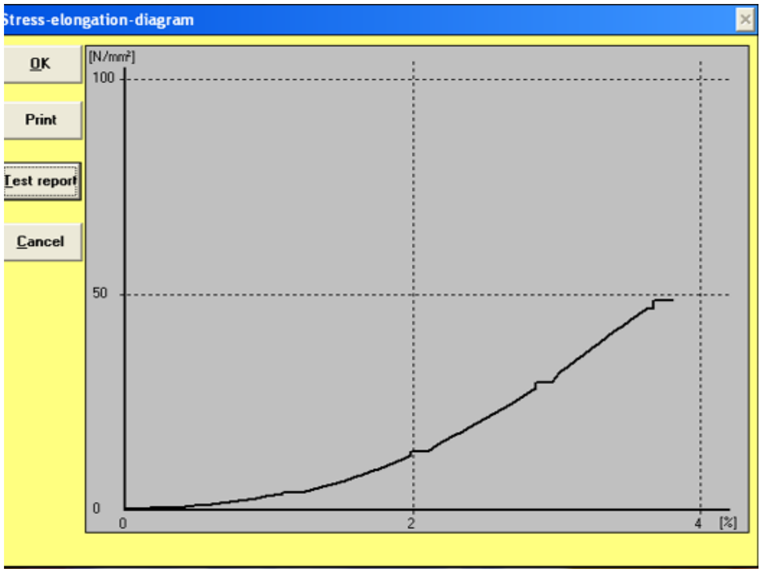
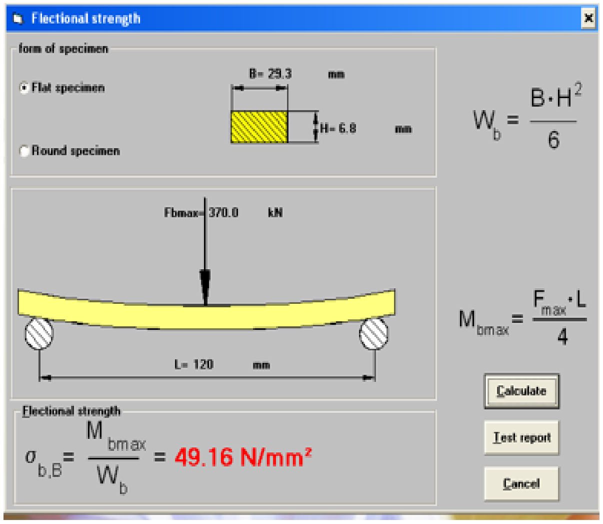


Figure A.3: stress elongation diagram for unidirectional 0/90 fiber orentation

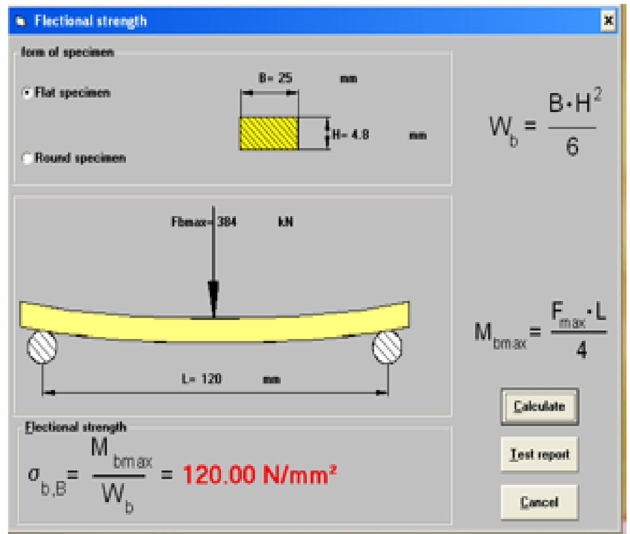
Table A.1: Summrized tensile test result

	Orientation	Designation	Height Mm	Width mm	Thickness mm	Tensile strength mm
1	Unidirectional 0^0	BSFHC-TS 1	300	25	4	90
		BSFHC-TS 2	300	25	4	89.70
		BSFHC-TS 3	300	25	4	85.6
					Average	88.43
2	Unidirectional 90^0	BSFHC-TS 1	300	25		47.30
		BSFHC-TS 2	300	25		46.10
		BSFHC-TS 3	300	25		46.13
					Average	46.51
3	Bidirectional /plain woven/	BSFHC-TS 1	300	25	.4.8	48.44
		BSFHC-TS 2	300	25	4.8	48.80
		BSFHC-TS 3	3000	25	4.8	50.60
					Average	49.28

Appendix B Flexural test result on UTM machine



(a).Unidirectional 90^0 fiber

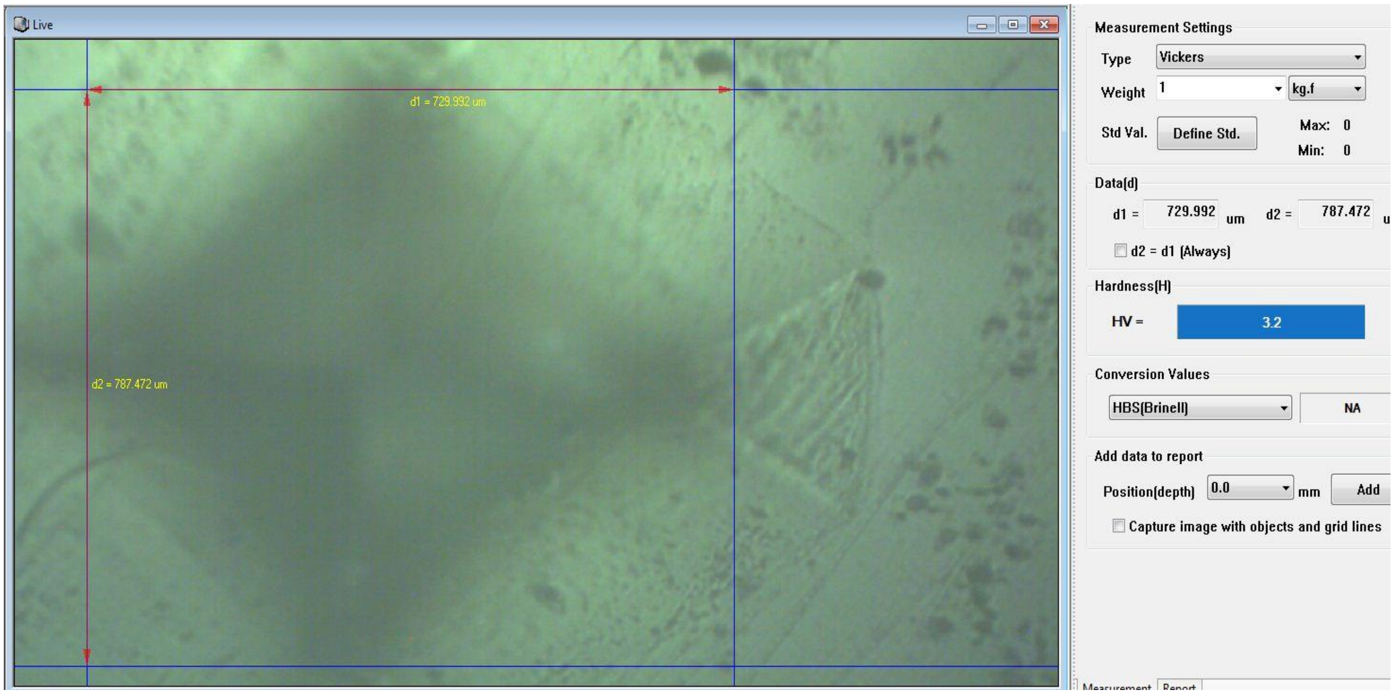


(b). Bidirectional fiber orientation

Table A.0.2: Summrized flextural test result

No	**Orientation**	**Designation**	$w_b(mm^{3)}$	M_{bmax} $N.mm$	**Maximum test force N**	δ_{bmax} $N/_{mm^2}$	**Flexural Strength**
1	Unidirectional 90^0	BSFHC-FS-1	66.666	5440	170	81.608	81.60
		BSFHC-FS-2	66.66	5312	166	79.68	80.27
		BSFHC-FS-3	66.66	5312	160	76.87	76.80
		Average					79.55 MPa
2	Bidirectional /plain woven	BSFHC-FS-1	96	12,096	378N	126	118.12
		BSFHC-FS-2	96	12,160	380N	126.6	118.75
		BSFHC-FS-3	96	12,288	384N	128	120
		Average					118.9 MPa
3	Unidirectional 0^0	BSFHC-FS-1	66.66	9856	308	147.85	147.83
		BSFHC-FS-2	66.66	9920	310	148.94	148.80
		BSFHC-FS-3	66.66	10,048	314	150.87	150.71
		Average					149.1 MPa

Appdix C Vikers hardness test result



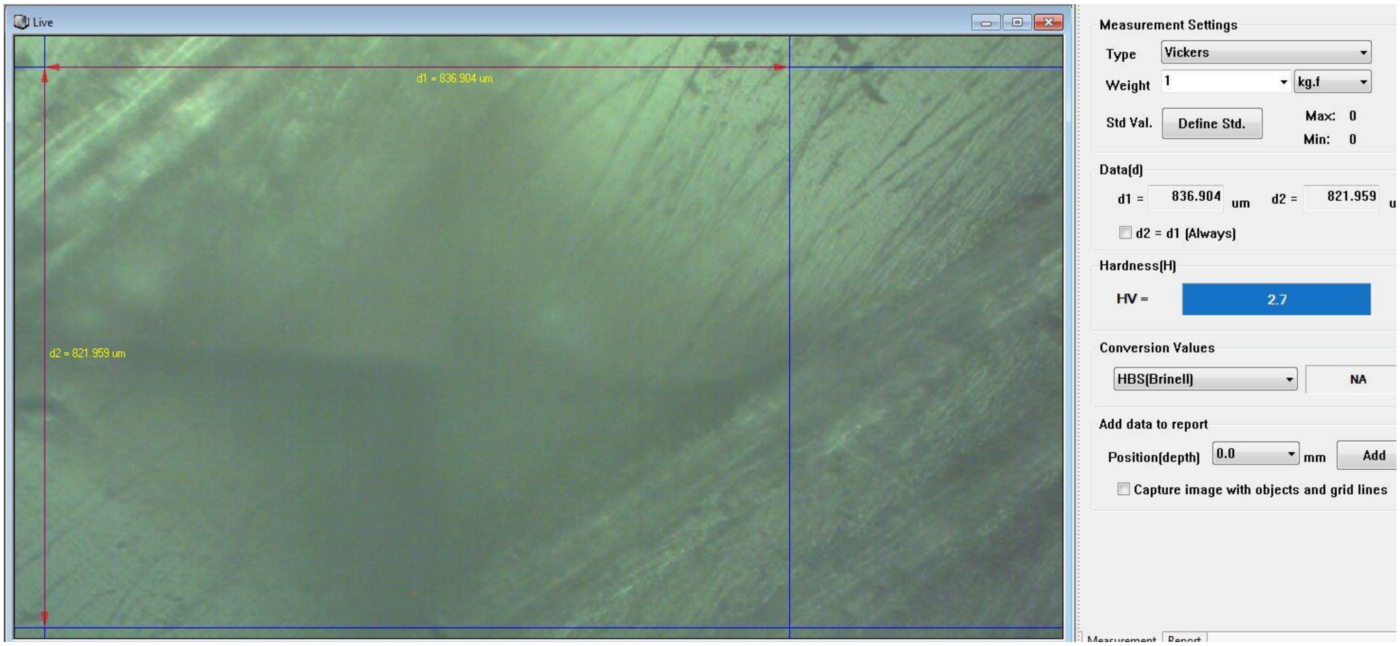


Figure B.1 hardness test result for unidirectional zero degree

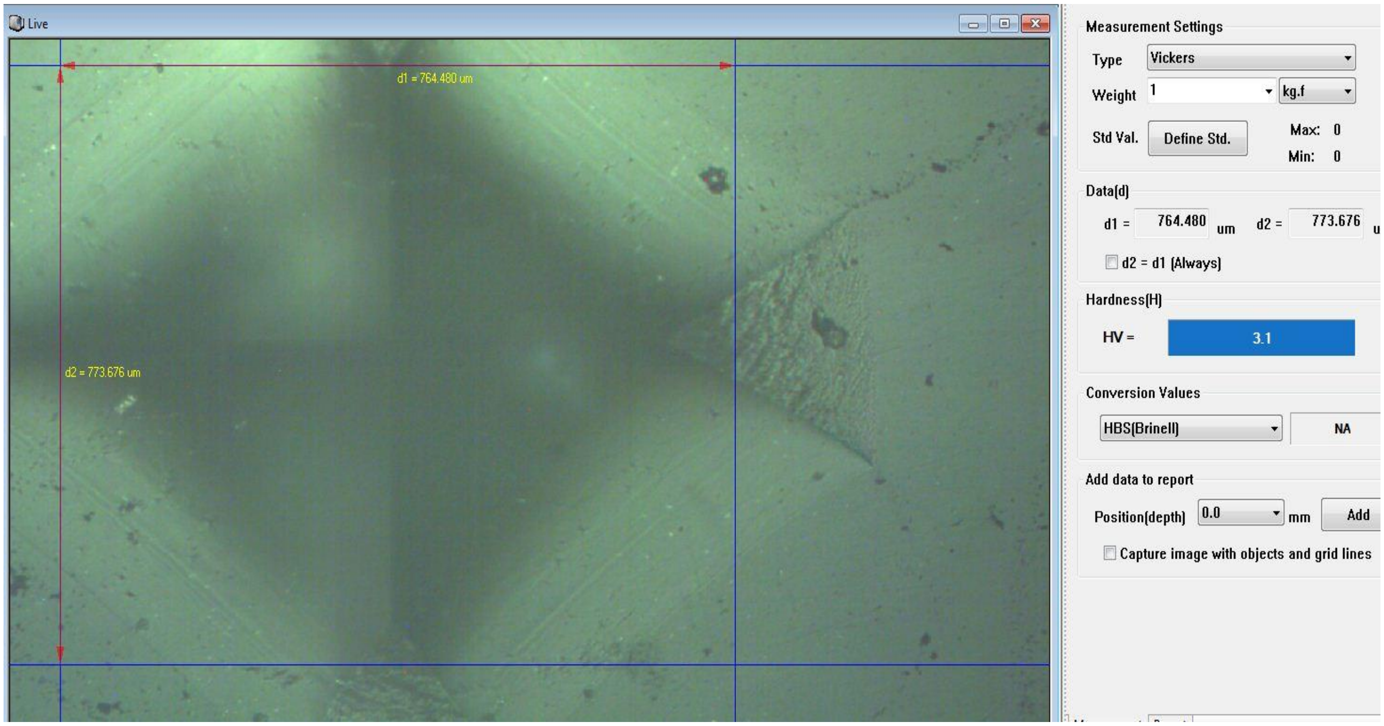


Figure B.2 hardness test result for unidirectional 90 degree

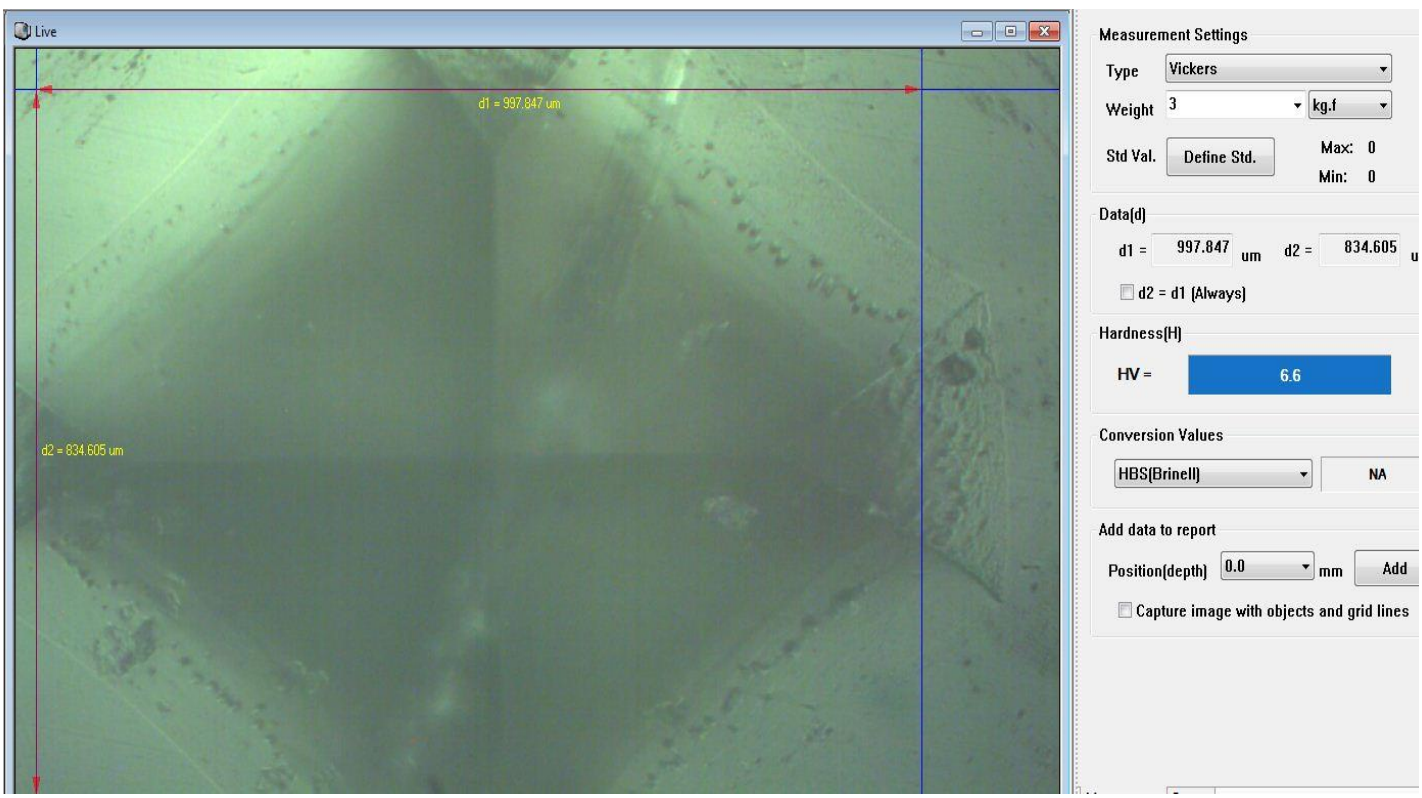


Figure B .3 Hardness test result for bidirectional/woven

Appdix D 1 Material cost

No	Item	Unit	Quantity	Price (birr)
1	Bamboo fiber	gram	300	15
2	Sisal fiber	gram	200	10
3	Hardener	Kg	10ml	4.60
4	Sodium hydroxide	ml	330ml	9.9
5	Polyester Resin	Litter	1	135
6	Wax	gram	10	4.60
Total cost of internal door panel				179.5birr

Table D .3 Material properties of Lignocellulosic composite and polypropylene material (O.M. Terciu, 2012)

Materials	Density (ρ) [g/cm3]	Young's Modulus (E) [MPa]	Poison's ratio (ν)
Lignocellulosic composite	1.19	3041	0.37
Polypropylene material	1.21	1300	0.35

TYPICAL PROPERTIES of POLYPROPYLENE

ASTM or UL test	Property	Homopolymer	Co-Polymer	Flame Retardant
PHYSICAL				
D792	Density (lb/in^3) (g/cm^3)	0.033 0.905	0.033 0.897	0.035 0.988
D570	Water Absorption, 24 hrs (%)	<0.01	0.01	0.02
MECHANICAL				
D638	Tensile Strength (psi)	4,800	4,800	4,300
D638	Tensile Modulus (psi)	195,000	-	-
D638	Tensile Elongation at Yield (%)	12	23	28
D790	Flexural Strength (psi)	7,000	5,400	-
D790	Flexural Modulus (psi)	180,000	160,000	145,000
D695	Compressive Strength (psi)	7,000	6,000	-
D695	Compressive Modulus (psi)	-	-	-
D785	Hardness, Rockwell R	92	80	-
D256	IZOD Notched Impact (ft-lb/in)	1.9	7.5	0.65
THERMAL				
D696	Coefficient of Linear Thermal Expansion ($x\ 10^{-5}$ in./in./°F)	6.2	6.6	-
D648	Heat Deflection Temp (°F / °C) at 66 psi at 264 psi	 210 / 99 125 / 52	 173 / 78 110 / 43	 106 / 41 57 / 14
D3418	Melting Temperature (°F / °C)	327 / 164	327 / 164	327 / 164
-	Max Operating Temp (°F / °C)	180 / 82	170 / 77	180 / 82
C177	Thermal Conductivity ($BTU\text{-}in/ft^2\text{-}hr\text{-}°F$) ($x\ 10^{-4}$ cal/cm-sec-°C)	 0.76-0.81 2.6-2.8	 - -	 - -
UL94	Flammability Rating	HB	n.r.	V-O
ELECTRICAL				
D149	Dielectric Strength (V/mil) short time, 1/8" thick	500-660	475	500-650
D150	Dielectric Constant at 1 kHz	2.25	2.2-2.36	2.3
D150	Dissipation Factor at 1 kHz	0.0005-0.0018	0.0017	-
D257	Volume Resistivity (ohm-cm) at 50% RH	8.5×10^{14}	2×10^{16}	10^{15}
D495	Arc Resistance (sec)	160	100	-

NOTE: The information contained herein are typical values intended for reference and comparison purposes only. They should NOT be used as a basis for design specifications or quality control. Contact us for manufacturers' complete material property datasheets. All values at 73°F (23°C) unless otherwise noted.

Figure D.4 Properties polypropylene material