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Analysis of Mechanical Properties of Ensete and Nettle Hybrid Natural Fiber Reinforced Composite for Automobile Applications

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Abstract

It is crucial to examine the mechanical characteristics of hybrid natural fiber-reinforced composites for a range of applications. Natural fiber composites have become more and more popular recently over synthetic fiber composites in a wide range of applications. It is an alternative to replace synthetic fiber for particularly automobile interior application. So improving the mechanical properties of Ensete and Nettle hybrid fiber by analysis each tested parameters' have attractive attention in this research. most conventional material used for interior and exterior of automobile like metal, plastics and synthetic fiber are not biodegradable and special metal is heavy, not cost effective and subjected to corrosion, rust, and require painting, maintenance at regular intervals. This research aims to determine how to Ensete and Nettle fibers applied for automobile application. To achieve this objective quantitative data was collected from 48 testing specimens. A fiber-reinforced epoxy composite was produced with a constant 50% fiber volume percentage. The fiber orientation angles were measured from the horizontal axis and were set at 0°, (0° and 90°), (90° and 0°), and +45°/-45°. The method of modeling and analysis, that was carried out in this research has been done in ANSYS ACP (pre) 2022R2 Workbench software, the manufacturer's material data for the test samples was compared with the findings of the static structural simulation, taking into consideration the material attributes and boundary conditions used. The study found that the changing volume ratio of the composite material adds the strength of tested parameters like tensile, compression, flexural and impact specimen. Therefore, the study had a significant influence on interior automobile and other related applications. It is clear that hybrid natural fiber reinforced composites like Ensete and Nettle have potential uses in non-structural interior automotive parts including door panels, dashboards, and inner body skins.

Keywords

Ensete, Nettle, Natural fiber, Lightweight, Fiber orientation, Interior components

1. Introduction

Elseify explained in his paper that the use of NFC is a long time ago. The use of natural fiber composites (NFC) within the automotive industry dates back to the Nineteen Thirties. Hemp-reinforced composite materials were used in body constructions to initially use natural fiber composites (NFC) in automobile applications. This continued up until the 1940s. [1]. Its use is increasing from time to time and why attention is needed as explained by Prabhu et al, Huda, and Widiastuti. The use of composite material in many applications has grown rapidly in recent years by replacing conventional materials like steel due its high strength, light weight and other favorable properties and its environmental friendliness. A matrix and fiber reinforcement are combined to create a composite material. According to a number of studies, in order to guarantee a stronger connection with the fibers, the fraction of the matrix should be greater than that of the fiber. While the matrix plays a major role in the composite's strength, the kind of fibers utilized ultimately determines the composite's final strength [2]. Exploring the properties of natural fiber reinforced polymer (NFRP) materials—such as enhanced biodegradability, the influence of fiber modification, and thermal stability—is the main focus of research [3].

Megiso written about how car designers work on reducing vehicle weight and the methods used to reduce vehicle weight as follows. One of the major concerns of automobile designers is the overall weight of the vehicle. There are several ways to reduce the weight of a vehicle; some of them include using high-strength steels (HSS) or replacing steel with lighter materials like aluminum (Al), magnesium (Mg), and other composites made of natural and synthetic fibers. Studies show that a 10% decrease in vehicle weight can result in a 4-8% increase in fuel efficiency without changing the vehicle's overall dimensions [4]. Weight has a major impact on a vehicle's performance metrics, including power, speed, and fuel economy. The car's weight may be successfully decreased by using lightweight materials as mineral wood, fiber-reinforced plastics (FRP), composite body solutions (CBS), acrylonitrile butadiene styrene (ABS), Polyvinyl chloride (ABS-PVC), High Strength Steel (HSS), and ABS [4].

Because it is a renewable resource and does not lead to environmental problems, it has been greatly accepted by researchers, according to explanation of Negawo et al. Natural fibers are becoming more and more popular in research because of their advantageous mechanical qualities, biodegradability, affordability, lightweight nature, and sustainable source. By lowering reliance on synthetic fibers, incorporating natural fibers into manufacturing processes also results in weight loss, cost savings, and renewability, all of which contribute to environmental conservation. While certain blends of natural fibers could have a lesser mechanical strength, they frequently show good impact absorption qualities. Natural fibers derived from plants are well known for being environmentally benign reinforcements in polymer composites. The addition of natural fibers to polymer composites as filler or fiber has been shown in several research published in the literature to improve the mechanical characteristics and strength of the material [5].

This is how Al-Oqla et al explained why we use NFC in vehicle interiors most of the time. Major automakers and suppliers of automobile components have been investigating the viability of using natural fibers as reinforcement for synthetic or bio-based matrices since the early 20th century. But several qualities of natural fibers are comparatively worse, especially when compared to synthetic fibers like carbon, aramid, and glass. Consequently, there have been several difficulties in completely replacing synthetic composites in automobile applications with natural fibers. As a result, interior parts like dashboards and seat backs have been the main use for natural fiber-reinforced composites [6]. However, it is possible to use natural fiber composites in automotive applications to achieve high efficiency at cheap cost, especially when utilizing them in components that need to have strong dimensional stability under moderate stresses [7].

A comparison between natural fiber and synthetic fiber is shown below from which it very clear that natural fiber is highly beneficial and environmental friendly. Unfortunately, many researches had been done in this area but could not conclusively arrive at an alternative for all parts of automobile with different types of natural fibers. However, all major automobile user use natural and synthetic fiber on many parts.

Vehicle manufacturers using NFC have been studied and listed by Akampumuza et al. A review of several research reveals that a number of well-known automakers have started to produce and develop goods made of recycled plastics or natural fiber reinforced plastics (NFRP) because of these materials' affordability, low weight, and ability to reduce exhaust emissions [8]. Mercedes Benz door trims have exceptional lateral impact fracture qualities, demonstrating the better mechanical performance of natural fibers in certain applications. Using materials that aid in suppression and damping is crucial because of the significant shock and vibrations that automobiles endure when in motion. Natural fibers can also reduce the pain caused by heat, noise, and electrostatic charges from wheels, exhaust systems, gears, and engines. As seen below, several automakers have integrated diverse natural fiber-based composites into different parts [9].

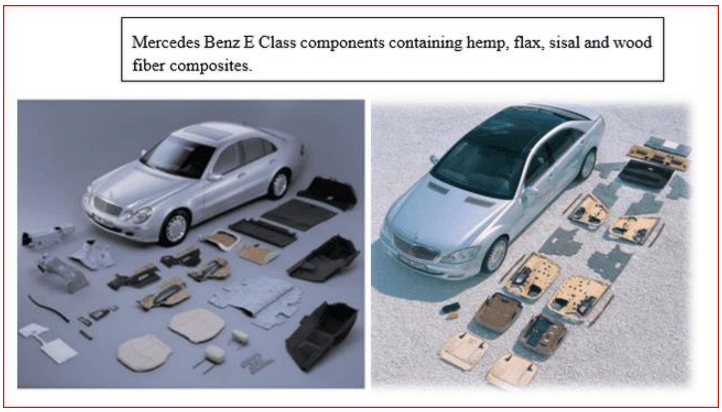

Figure 1. Mercedes Benz E Class components containing fiber composites, Obed et al. 2016

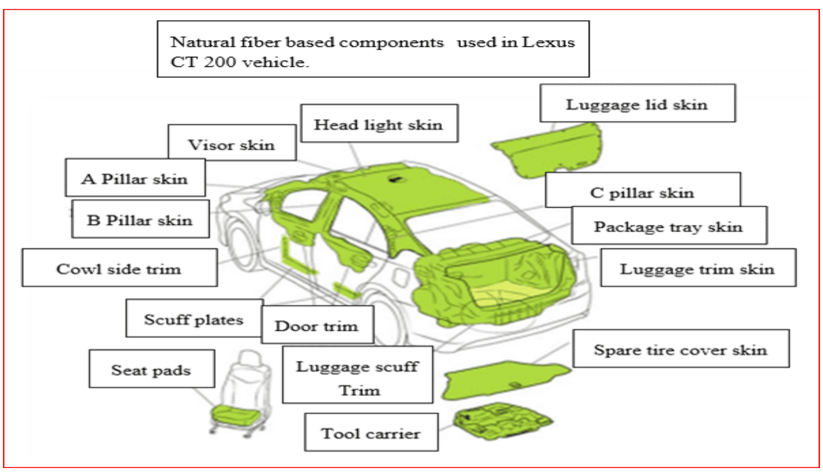

Figure 2. Natural fiber used in different section, Obed et al. 2016

Import of automotive including spare part Helaili studied. Ethiopia does not produce automotive components or associated items locally, hence it is dependent on imports for vehicles, trucks, buses/coaches, equipment/machinery, and replacement parts. The nation's current automakers work mostly on bus body assembly and construction, installing both wet and dry cargo compartments on foreign chassis that have been fitted with cabins [10]. it is currently understood that the company in this country uses mild steel including Luxury cross-country Bus (Yutong Bus) assembled by Bishoftu Automotive Engineering Industry.

Fiber et al and Issa et al explained why we should use NFC despite its shortcomings. While several aspects impact the use of natural fibers as reinforcement in polymer-based composites, different industries continue to find their renewability and affordability appealing. As a result, efforts to replace conventional materials with natural fibers are still being explored. Research in this field is very important because there are still a lot of unanswered questions. The most important requirements considered in automotive materials are lightweight, cost, safety crashworthiness, corrosion resistance, recyclability and life cycle consideration [11].

2. Material and Method

Data gathering: A combination of qualitative and quantitative data gathering techniques was used to achieve the thesis's goal. A sufficient understanding of the procedures to be adopted for the research methodology and data collection requirements was obtained by reviewing articles on composite materials, natural fibers, sources of natural fibers, fiber extraction methods, chemical treatments, fiber orientations, fiber hybridizations, volume fractions, manufacturing methods, and testing methods.

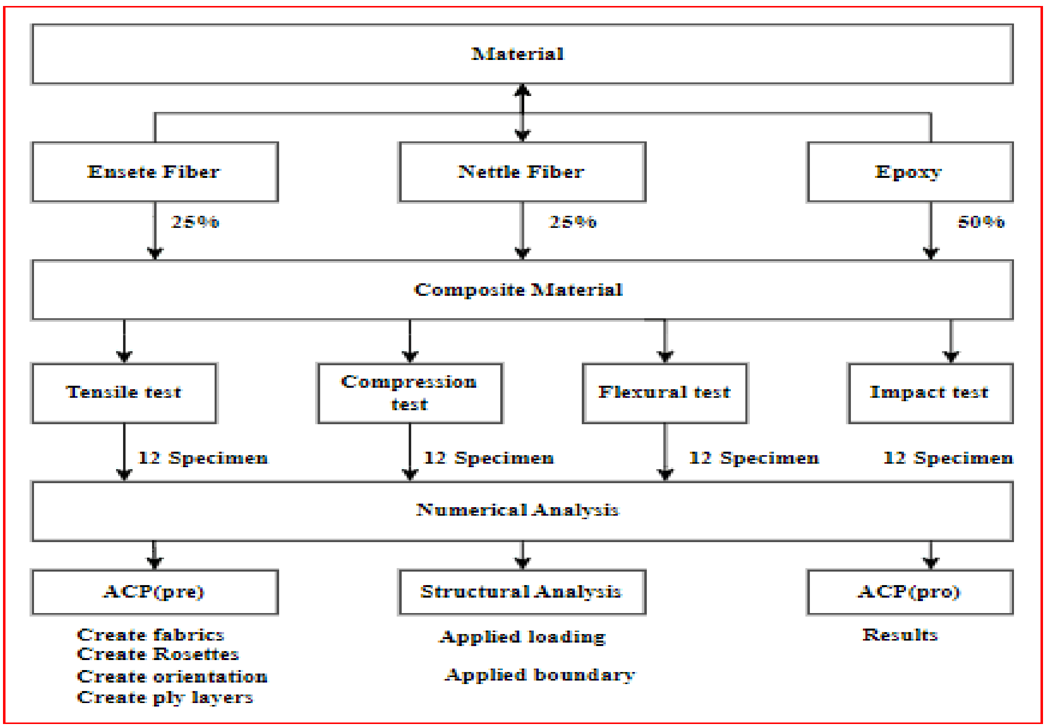

Figure 3. Research method flow chart

2.1. Materials

2.1.1. Preparation of composite from Ensete and Nettle hybrid fiber

Data collection: - To achieve the objective of the thesis, both qualitative and quantitative data collection methods were used. By reviewing articles about composite materials, natural fibers, source of natural fibers, fibers extraction methods, chemical treatments, fibers orientation, fiber hybridizations, volume fraction, manufacturing methods and testing methods has given sufficient knowhow on the procedure to be adopted to proceed with the research methodology and the data collection requirements.

Table 1. Material used for preparing natural composite material

S.No.	Material	Usage
1	Ensete and Nettle fibers	Both these Fibers are used as reinforcement with selected length of 55mm to 250mm.
2	Scissor	It was used to cut the fibers to required length
3	Mold	Materials with precise sizes and forms of mixed reinforcement and epoxy matrix were held and shaped using a mold that was made.
4	Epoxy	It served to secure and bind the strands that served as reinforcement.
5	Hardener	It is used to solidify composite materials and functions as a curing agent.
6	Wax	It is used to polish the mold surface and act as a releasing agent, making it easier for the composite to come free.
7	Container	It's used to make the combination of the alkaline solution.
8	Stirrer	It is used to combine the hardener and resin, as well as water and NaOH.
9	NaOH	It is an alkaline substance that is applied to the surfaces of fibers.
10	Electronic weight scale	It is used to measure weight of the materials during the composite fabrication process.

2.1.2. Fiber preparation

2.1.2.1. Ensete fiber

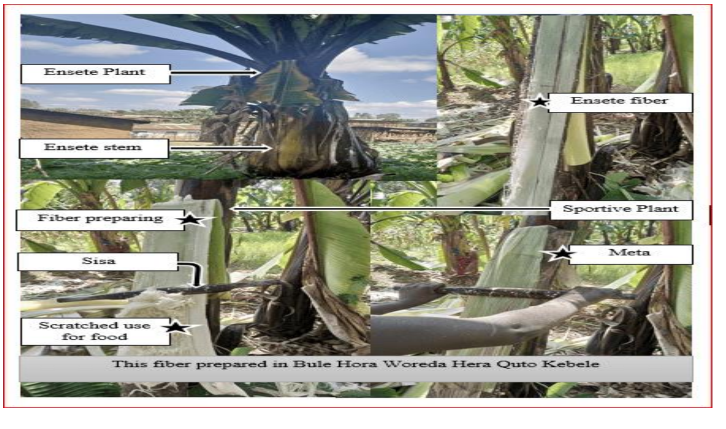

Figure 2.2. Ensete fiber preparation

The Ensete fiber (Figure 3.9A) is obtained from false banana plant. False banana which is readily available in western Guji Zone of Oromia is collected from local sources and fiber is extracted from them. Ensete scratching process is traditional and before starting scratching process first the upper part of the Ensete plant (leaf) is cut and removed and then the leave sheathes are peeled out step by step during the scratching process. Local people use traditional tools and materials to scratch and peel the leave sheathe of the Ensete. Some of the tools and instruments used for the process are: 'Sisa'- used to scratch the leave sheath of the Ensete. 'Meta'- used to hold and support the leave sheath. 'Cheku'- used to pulverize 'hami-cho' ('hamo') into smaller pieces. The fiber is sun-dried following extraction.

2.1.2.2. Nettle fiber

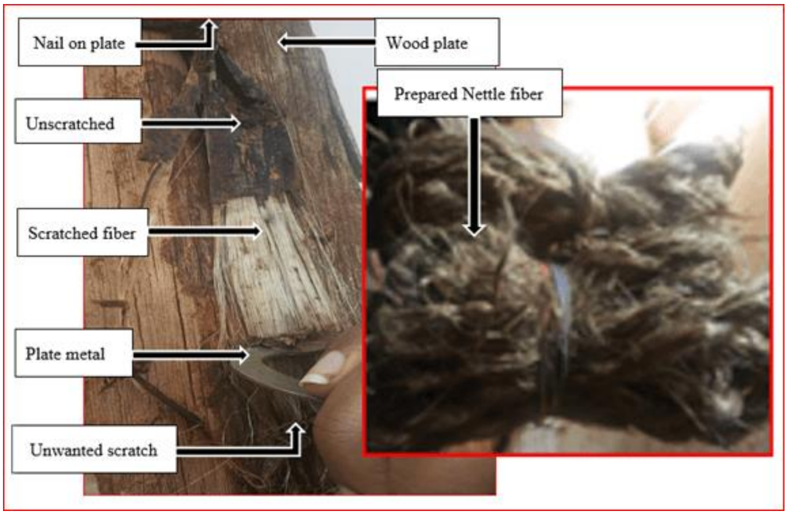

Figure 2.3 Nettle fiber preparation

For weeks, nettle stems were chopped and allowed to dry at room temperature. As previously indicated, the fibers were manually removed, and stinging nettle has a large potential for usage as reinforcement for composite materials [69]. As seen in Figure 3:2, nettle fiber is collected from the nearby jungle and removed by hand decortication and water retting procedures.

2.1.3. Fiber chemical treatments

Since the fiber-matrix interface serves as a binder and a stress transfer between the matrix and the fibers, it is primarily re-sponsible for the quality of the fiber-reinforced composite. By chemically treating fibers with substances like sodium hydroxide (NaOH), which changes the hydrophilic component found in natural fibers to hydrophobic using a NaOH solution, bonding between the fibers and the binder can be improved. To make this solution, combine 10% of the weight of NaOH pellets with 90% of the weight of distilled water. After being cut to the appropriate lengths, the fibers are immersed in the 10% NaOH solution for a full day. Impurities and cellulose components like pectin and lignin are eliminated during the soaking process [70]. The fiber is taken out and cleansed with distilled water to get rid of extra NaOH after 24 hours. The fiber is then allowed to dry for two days under the open sky. The fiber is let to dry completely before the procedure is finished. The process of soaking to washing with distilled water is shown in figure 3:3A to figure 3:3D.

2.1.4. Preparation of epoxy resin

The composite material is made from epoxy resin that weighs 1.15–1.20 g/cm³ and hardener that weighs 0.97–0.99 g/cm³. Both materials are bought from the local market. The hardener and epoxy resin were combined in a 10:1 ratio.

2.1.5. Composite preparation

The following is the sequential procedure for preparing a composite:

a) As previously said, extract the fiber.
b) Use distilled water and NaOH to treat the fiber until the pH is neutral.
c) Trim the fiber to the appropriate length.
d) Prepare a cold compression mold and mix the fiber and epoxy in accordance with the determined fiber/epoxy ratio.
e) Take out of the mold the composite.
f) The composite sample is now prepared.

In order to make it easier to release the composite plates once they have dried, it is crucial to clean and polish the mold with wax before adding the resin and hardener and filling it.

After the natural fibers are arranged in the mold according to the specifications, the epoxy and hardener mixture is poured into it. After that, it is compressed using a 25 kg weight that is positioned above the mold to help with consolidation. This setup is then maintained for a whole day. The composite solidifies after a full day, at which point the hardener helps the natural fibers and polymers stick together firmly. Next, the top (lid) of the mold and the composite separate while the lower attachment (steel plate) is carefully and slowly withdrawn from the edges. The sample is then carefully removed from the mold. Now the composite is ready for use. The figure 3:9A to figure 3:9M shows the entire process from fibers chemical treatment to the sample cut to size for the test.

2.1.6. Fiber orientation

Based on earlier research publications, four distinct orientations are chosen to examine and assess the mechanical characteristics of the fiber in various configurations. The chosen orientations consist of:

1. 0° of both Ensete and Nettle or horizontal fiber reinforcement,
2. Long Ensete at 0° and short Nettle at 90°,
3. Short Ensete at 90° long Nettle at 0°
4. Ensete and Nettle fibers at ±45° to each.

For each sample so prepared three tests each for tensile, compression, flexural and impacts were conducted. So, for sample with 45 degree orientation has 12 testing specimen, 0° degree has 12 testing specimen, long nettle and short Ensete (90° &0°) has 12 testing specimen and long Ensete and short nettle (0° &90°) has 12 testing specimen. Thus, overall 48 testing specimen were prepared.

The fiber orientation samples in detail are shown in the figures 3.4 to 3.7. Figure 3:4 is 0° Ensete and Nettle or horizontal fiber reinforcement that prepared for tensile testing. By this orientation there are 12 specimens according to their different shape, size and length.

The figure 3:5A and figure 3:6A shows Long Ensete and short Nettle (0°&90°) and short Ensete and Long Nettle (90°&0°) respectively. In this fiber orientation there are 24 different specimens are prepared as per required shapes, length and size. Figures 3:5B and 3.6B show the long fiber orientation or 0° and short fiber orientation or 90° orientation. Figure 3:5 shows the 45° Ensete and Nettle fibers orientation. It also has 12 different specimens according to their specification.

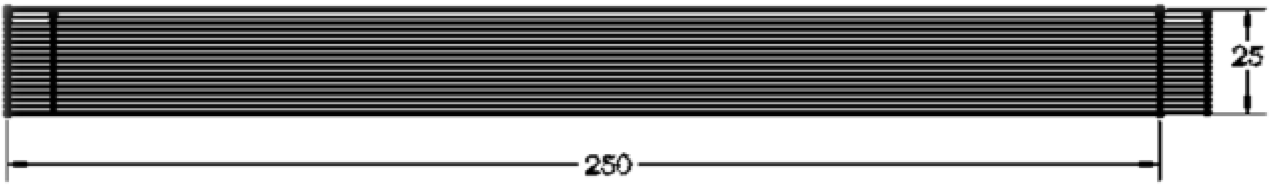

Figure 2.4. Ensete and Nettle or horizontal fiber reinforcement

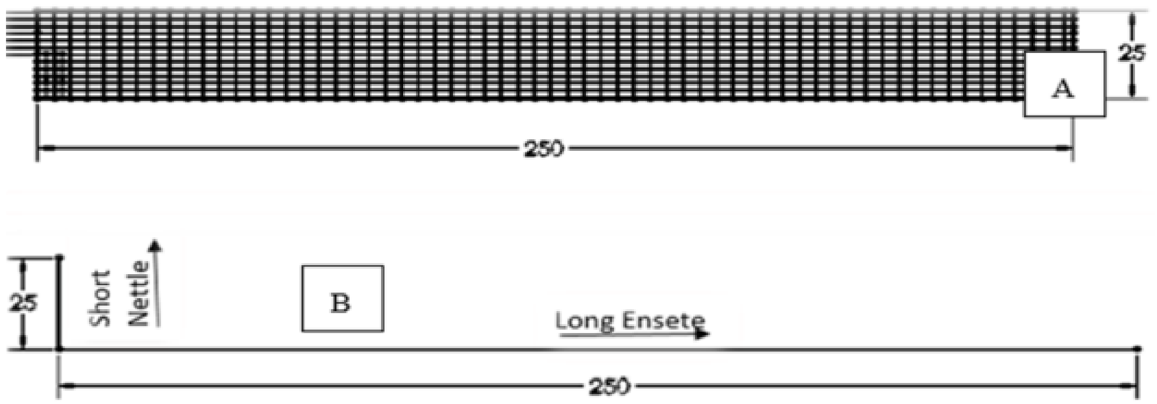

Figure 2.5. Long Ensete and short Nettle (0°&90°)

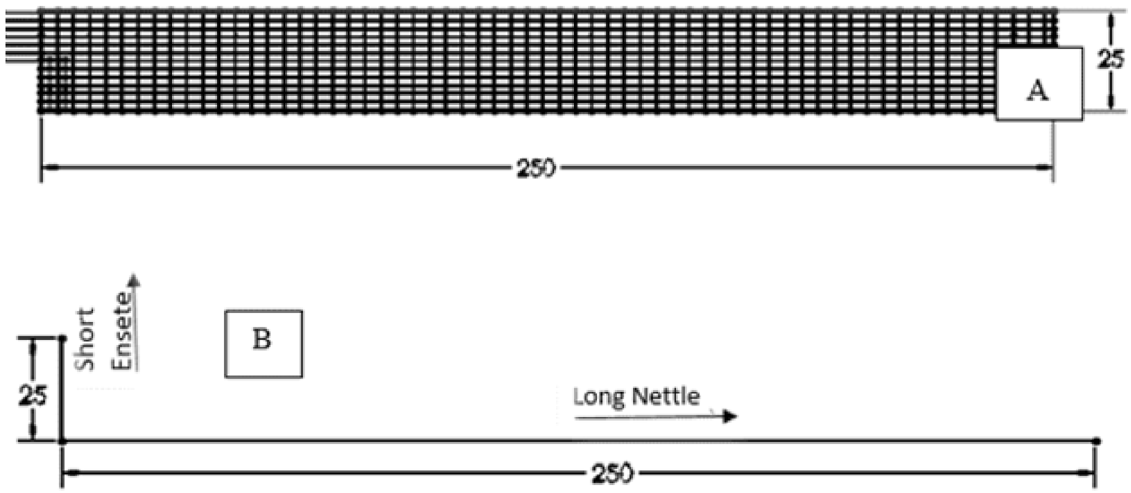

Figure 2.6. Short Ensete and Long Nettle (90°&0°)

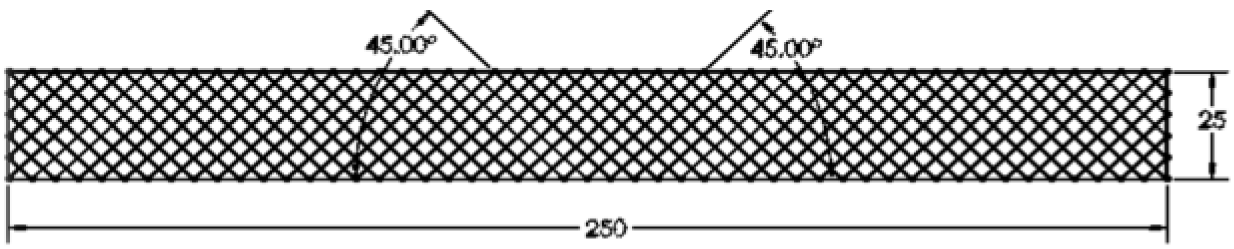

Figure 2.7. 45° Ensete and Nettle

2.1.7. Composite preparation

The figures 3.8 show the steps followed in preparing the sample product by open mold process using hand lay-up technique. The hand lay-up technique is the simplest and widely used composite processing methods. Surface treatment, mold preparation, lay-up process and curing were done as per standard procedure.

Step 1: preparing Ensete fibers and nettle fibers figure 3.8A and B

Step 2: preparing Epoxy resin, Hardener, and wax figure 3.8H

Step 3: mixing Epoxy with the Hardener figure 3.8C

Step4: required weight that weigh 25kg and spacer

Step5: applies the epoxy on the well prepared hybrid fibers figure 3.8J

Step6: Separating the composite from the mold after 24 hours

Step7: Universal Testing Machine (UTM) figure 3.8N, 3.8O and 3.8P

Step8: measuring the dimension of the specimen figure 3.8L (UTM) figure 3.8N, 3.8O and 3.8P

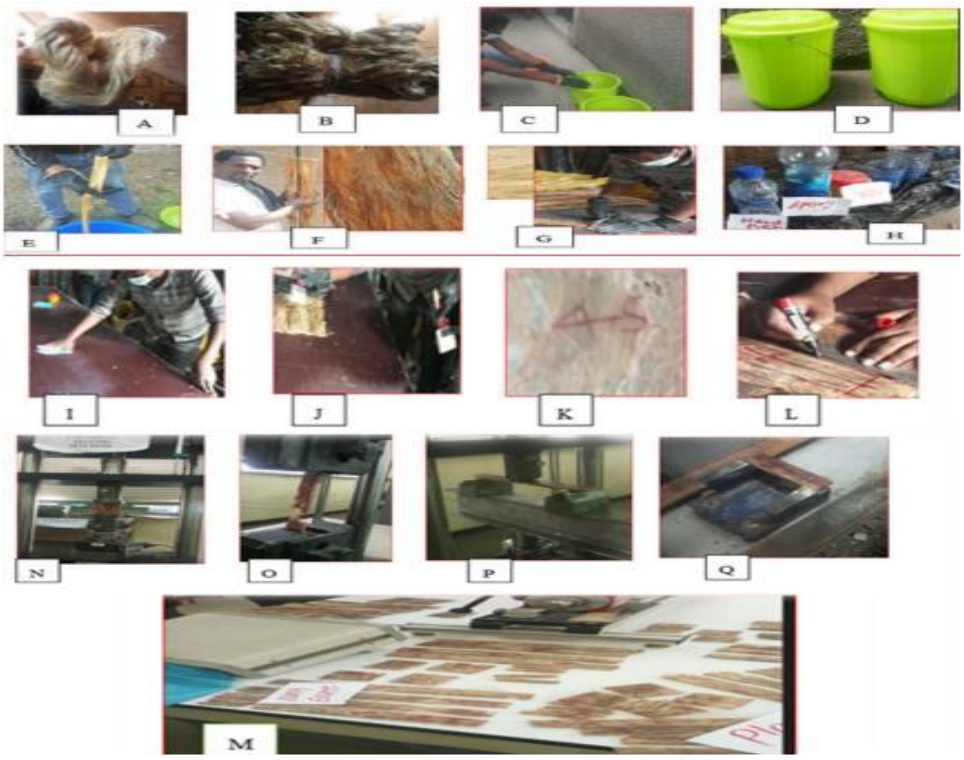

Figure 2.8. Steps of composite preparation

2.2. Cutting of Specimen with respect to Orientation

The longer fibers of Nettle and Ensete were chopped into the appropriate lengths. Using a pair of Ensete and Nettle fibers, the orientation was completed using fiber orientations of 0°, (0, 90)°, (90, 0)°, and ± 45°. Using the hand layup method, the prepared resin and hardener mixture were equally applied to the fibers (Fig. 3:9J). The mold was then covered with a plastic sheet, making sure that air bubbles did not form during pouring. After that, the mold was subjected to the necessary pressure and left to compress for a full day at room temperature. The composite was taken out of the mold and shaped into the desired shape after a full day. The test specimens' dimensions are shown in figure 4:1B, D, F&H. Tables 3:2 and 3:3 provide information on various orientations, the weight of the fibers and epoxy, and the quantity of specimens made.

Table 3:2. Fiber orientation and fiber Epoxy ratio

Fiber orientation	Fiber	Epoxy
0° Ensete & Nettle	Ensete 250g, Nettle 250g	500g
(0°,90°) Ensete & Nettle	Ensete 250g, Nettle 250g	500g
(90°,0°) Ensete & Nettle	Ensete 250g, Nettle 250g	500g
45° Ensete & Nettle	Ensete 250g, Nettle 250g	500g

Table 3:3. Number of specimens prepared for Testing

Fibers orientation	Kinds of sample	Number of specimen	Total number of samples
0° Ensete & Nettle	Tensile	3	12
	Compression	3	
	Flexural	3	
	Impact	3	
(0°,90°) Ensete & Nettle	Tensile	3	12
	Compression	3	
	Flexural	3	
	Impact	3	
(90°,0°) Ensete & Nettle	Tensile	3	12
	Compression	3	
	Flexural	3	
	Impact	3	
45° Ensete & Nettle	Tensile	3	12
	Compression	3	
	Flexural	3	
	Impact	3	
Grand total	-	-	48

2.3. Analysis and Evaluation of the properties of Ensete and Nettle fibers composite

In this study tensile, compression, flexural and impact tests are selected. Because they are commonly used to evaluate the mechanical properties of hybrid natural fiber polymer composites. These tests can help to determine the strength, stiffness, toughness and ductility of the composites, which are important for their potential applications in various fields.

2.3.1. Tensile Strength Test

This study's primary objective was to evaluate the tensile characteristics of composites composed of hybrid Nettle and Ensete fibers. For the tensile test, twelve specimens with fiber orientations of 45°, 90°, and their counterparts, as well as 0°, 90°, and their counterparts, were ready. The test samples measured 250 mm in length, 25 mm in breadth, and 6 mm in thickness. During the test, axial stress was applied through the UTM and both ends of the specimen while the specimens were safely held in the grips of the apparatus. When evaluating a material, common points of interest are: peak stress (PS) or ultimate tensile strength (UTS).

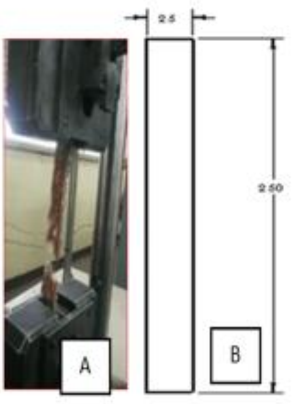

Figure 2.9. UTM Tensile strength test

2.3.2. Numerical Analysis

To evaluate Total Deformation, Maximum Stress and strain, the boundary condition was set to the model of the material. The mechanical properties of each group of composite material parameters are added to the ANSYS data to conclude the final overall results of this model. In this work, with the aid of ANSYS Workbench 2022R2 software, finite element analysis ANSYS Composite PrepPost ACP (Pre) was used as a numerical tool. For tensile test specimen of 250 X 25 X 6mm was used and the practical condition of 1370.72N tensile load on the specimen was recreated as the specimen was subjected to fixed support on one end and the tensile load of 1370.72N was applied on another end. The test specimen was created according to the tensile test DIN EN 50106 standard by ANSYS Design Modeler. The meshing process has been completed by selecting the volume then the profile of the element was appointed as shape of the specimen. This meshing includes a complete number of elements and overall number of nodes.

Figure 2.10. Geometry representation of tensile specimen

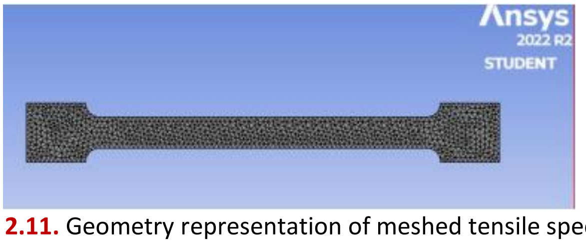

Figure 2.11. Geometry representation of meshed tensile specimen

Properties of Outline Row 4: TensileNFCMT

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	0.011	g cm^-3		
4	Orthotropic Elasticity				
5	Young's Modulus X direction	473	MPa		
6	Young's Modulus Y direction	475	MPa		
7	Young's Modulus Z direction	474	MPa		
8	Poisson's Ratio XY	0.35			
9	Poisson's Ratio YZ	0.33			
10	Poisson's Ratio XZ	0.36			
11	Shear Modulus XY	4.73	GPa		
12	Shear Modulus YZ	4.88	GPa		
13	Shear Modulus XZ	4.6	GPa		

Figure 2.12. Static structural engineering data of tensile specimen

Figure 3.12 is a direct screenshot of the engineering data when the tensile specimen was filled. The properties of orthotropic elasticity such as young's modulus x, y, and z as well as Poisson's ration of this natural composite in terms of xy, yz, and xz as well as shear modulus xy, yz, and xz are all found in figure 3.12.

3. Results & Discussions

In this chapter, the results of the experimental and numerical investigations on the mechanical properties of hybrid natural composite specimens are presented and discussed. The results of tensile strength, flexural strength, impact strength, and compression strength properties and ANSYS analysis results obtained are discussed. For this experimental test, 48 specimen were prepared with different fiber orientations to determine the effects of fiber strength with same matrix volume fraction.

3.1. Tensile Strength Test result

The tensile strength of a material is the maximum stress that it can withstand before breaking under tension. It is an important parameter to evaluate the mechanical performance of composite materials. The tensile strength was calculated by dividing the maximum force by the cross-sectional area of the specimen. The results of the tensile strength test are presented and discussed in this section.

Graph 4.1 shows the relationship between the fiber orientation and the tensile strength of the hybrid natural composite specimens. The x-axis represents the fiber orientation in degrees, and the y-axis represents the tensile strength in megapascals (MPa). The graph shows that the tensile strength increases with the fiber orientation from +/-45 degrees to 0 degrees. The specimen with 0 degree orientation has the highest tensile strength of 9.13 MPa, while the specimen with +/-45 degree orientation has the lowest tensile strength of 3 MPa. This indicates that the fibers aligned parallel to the loading direction can resist the tensile stress more effectively than the fibers aligned at an angle or perpendicular to the loading direction.

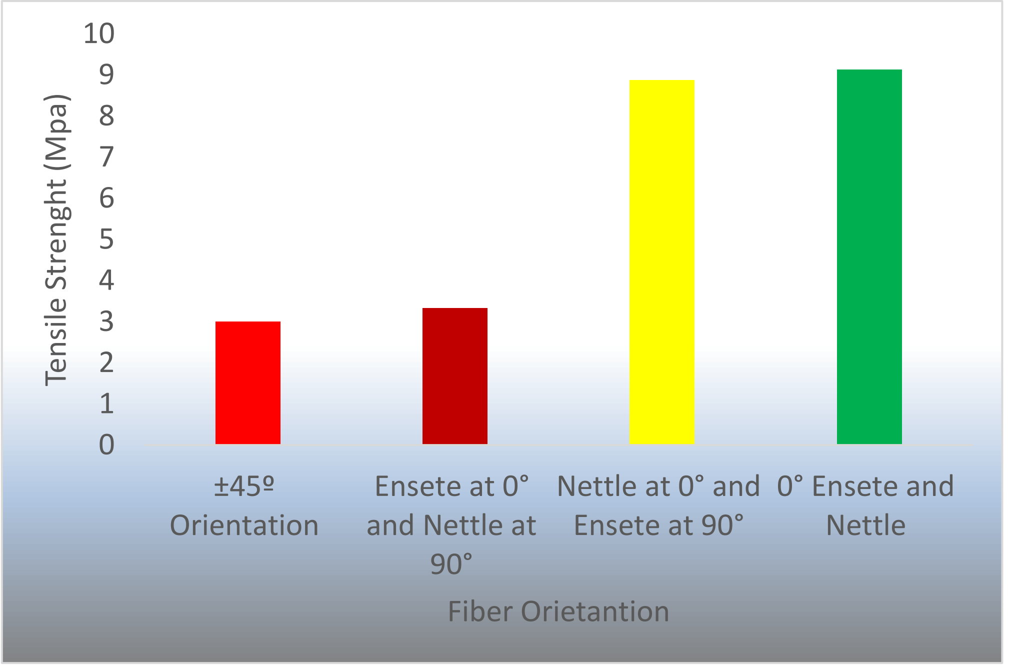

Figure 3.1. Tensile strength test result

3.1.1. Tress strain Diagram

The ultimate tensile stress, modulus of elasticity, tensile strain, and stress-strain curve were measured and calculated based on the following equations [87].

$\sigma = {}^{F}/_{Ao}$.. Eq (4.1),

$\varepsilon = {}^{lo}/_{l}$...Eq (4.2)

E = ${}^{\sigma}/_{\varepsilon}$...Eq (4.3)

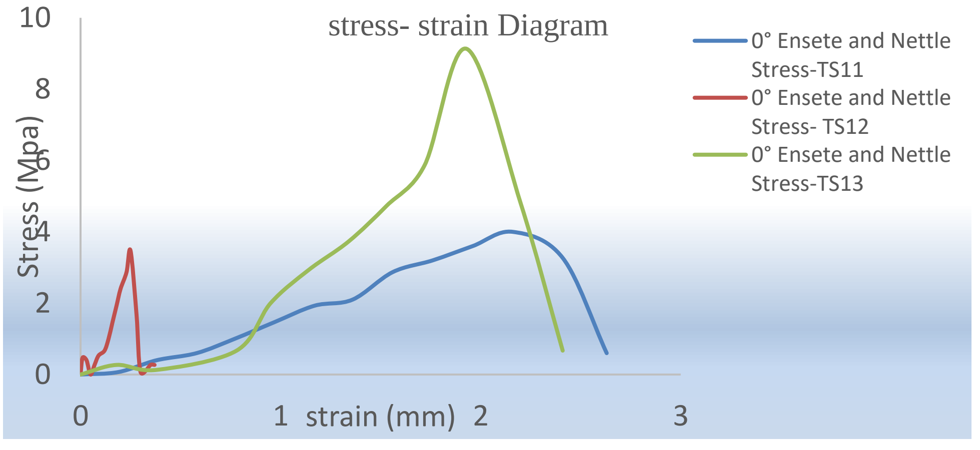

Figure 3.2. Ensete and Nettle of the tensile 3

Figure 3.2 presents the result concerning tensile strength test of 0° Ensete and Nettle of all three (3) spaceman. The strain of 0° Ensete and Nettle TS13 increased up to 1.93%. After 1.93% strain failure of the specimen occurred. Based on the results, the 3rd specimen has the highest stress values, which means it can withstand more load and deformation before breaking. The second have lower stress values, which indicate lower strength. The first specimen has a higher strain value than the second one, which means it can elongate more before breaking. The reason for the variation in the results is fabrication method. Fabrication method can affect the fiber distribution, orientation, alignment, and bonding with the matrix.

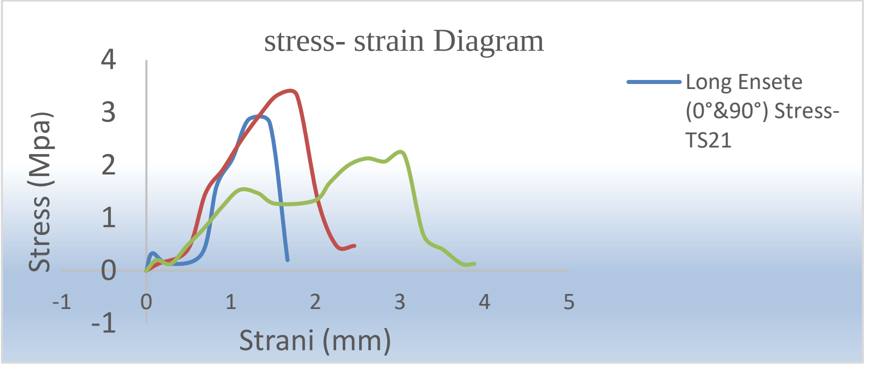

Figure 3.3. Long Ensete and short Nettle (0°&90°) of the tensile 3 specimen

Figure 3.3 shows the result of tensile strength test for Long Ensete and short Nettle (0°&90°) fiber orientation of all three (3) specimen. The percentage strain rate of Long Ensete and short Nettle (0°&90° of TS22 increases for the first elongation from 0% up to 1.78% and afterwards failure happened. Based on the results, the 2nd specimen has the highest stress values, which means it can withstand more load before breaking. The 3rd have lower stress values, which indicate lower strength. The first specimen has a lower strain value than 2nd and 3rd, which means it cannot elongate more before breaking. As it was said in the beginning the reasons for the variation in the results is fabrication method. Fabrication method can affect the fiber distribution, orientation, alignment, and bonding with the matrix.

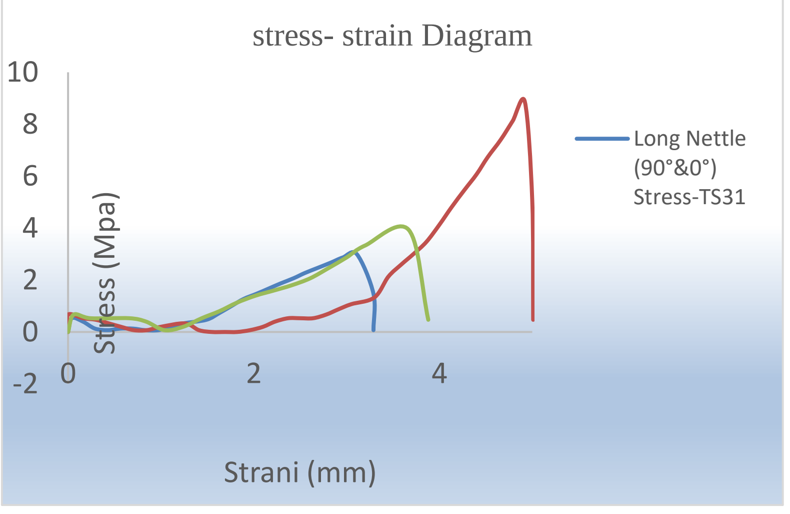

Figure 3.4. short Ensete and long Nettle (90°&0°) of the 3 specimens

Figure 3.4 shows the result of tensile strength test short Ensete and Long Nettle (90°&0°) fiber orientation, the percentage strain rate of short Ensete and Long Nettle (90°&0°) of TS32 increased for the primary elongation from 0% up to 4.92% the failure occur after 4.92% strain. Based on the results, the 2nd specimen has the highest stress and strain values, which means it can withstand more load and deformation before breaking and it can elongate more before breaking. The 1st have lower stress and strain values, which indicate lower strength and lower deformation. The 3rd specimen has a medium stress and strain value. The reason for the variation in the results is the same reason as stated earlier.

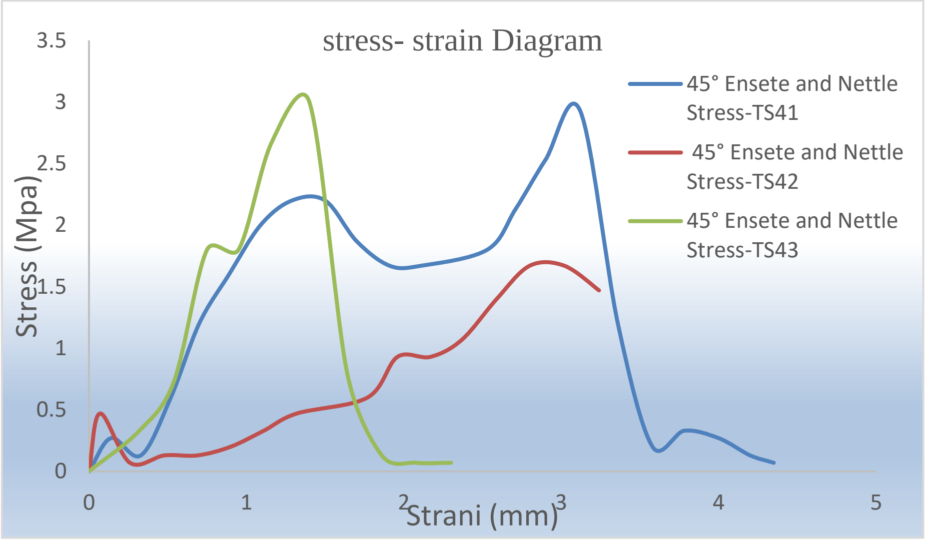

Figure 3.5. 45° Ensete and Nettle of the tensile 3 specimen

Figure 3.5 presents the result of tensile strength test of ±45 degree fiber orientation. The percentage strain rate of ±45° Ensete and Nettle fibers orientation test of TS43 increased up to 1.4% and later it was failed. Based on the results, the 3rd specimen has the highest stress and strain values, which means it can withstand more load and deformation before breaking. The second has lower stress and strain values, which indicate lower strength and lower deformation than both specimens. The first specimen has a higher strain value than the second one, which means it can elongate more before breaking than second.

3.1.2. Numerical Analysis

All parameters are analyzed by ANSYS software. By using ANSYS Workbench 2022R2 software the tensile, compression, and flexural tests of hybrid natural composites by modeling the geometry, material properties, boundary conditions, and load-ing of the specimens and solving the governing equations numerically. Various post-processing analyze result, the output data such as maximum stress, maximum strain, and total deformation are described.

3.1.2.1. Tensile analysis

The maximum stress, maximum strain, and total deformation of model and analyzed natural fiber composites that per-formed under loading and boundary conditions are shown in figure 4.9. This study shows that the test previously done by UTM was repeated with ANSYS with the same data to verify the validity.

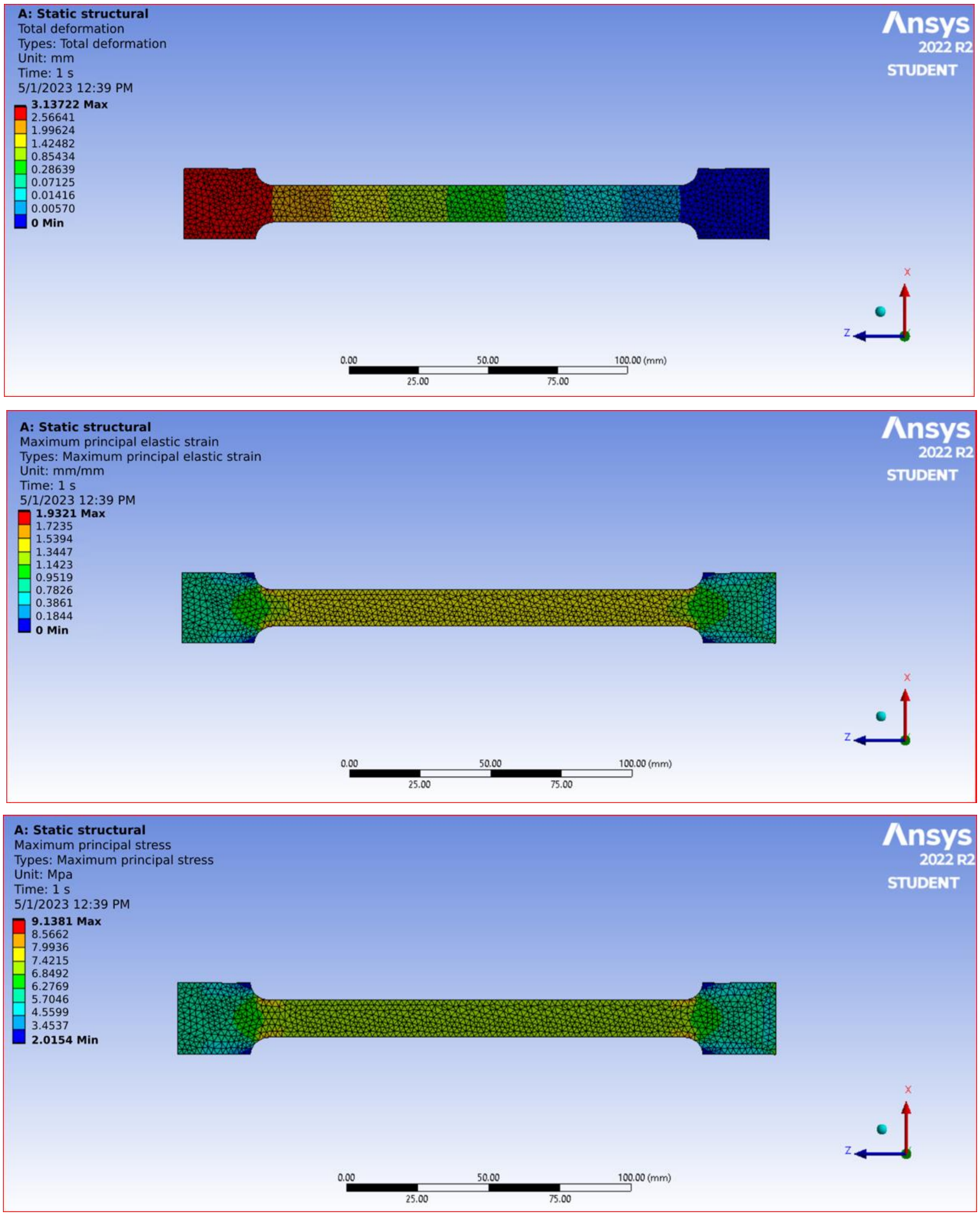

Figure 3.6. Total deformation, maximum stress and elastic strain of tensile specimen.

Fig 3.6 illustrates the results of the ANSYS analysis, the colors change according to different maximum stresses. These three figures show the results obtained from the ANSYS analysis. The first shows maximum deformation, the next maximum strain, and the last maximum stress. Further details are shown in the table 3.1 and table 3.2.

Table Error! No text of specified style in document.**.1.** Tensile model numerical analysis Results

Object Name	*Total Deformation*	*Maximum Stress*	*Maximum Elastic Strain*
Results			
Minimum	0.mm	3.9876MPa	0.0235mm/mm
Maximum	3.137mm	9.1385MPa	1.9368 mm/mm
Average	1.568mm	6.56300MPa	0.9801mm/mm

The other is to compare experimental value with ANSYS value. Before comparing it the error percent must be found. According to H. Patil [88]. The error (%) is calculated by using the formula: Error (%) = (ANSYS value- Experimental value/Experimental value) x100.

$Err_P = (\frac{ANv-Exv}{Exv})$ x100 = $(\frac{3.13722-3.05}{3.05})$ x100 = 2.85

$Err_P = (\frac{ANv-Exv}{Exv})$ x100 = $(\frac{9.1381-9.13}{9.13})$ x100= 0.09

$Err_P = (\frac{ANv-Exv}{Exv})$ x100 = $(\frac{1.9321-1.93}{1.93})$ x100 = 0.1

Where Err_P,error percent (%) is, AN_v is ANSYS value, and E_{xv} is Experimental value.

Table Error! No text of specified style in document.**.2.** Comparison of ANSYS simulation and experimental value of tensile

Output parameter	**Experimental value**	**ANSYS value**	Err_P **(%)**
Total deformation(mm)	3.05	3.13722	2.85
Maximum stress (MPa)	9.13	9.1381	0.09
Maximum elastic strain (%)	1.93	1.9321	0.1

When compared the output parameters such as total deformation, maximum stress, and maximum elastic strain from both the experimental and numerical methods. I compared these output parameters with the experimental data using Excel software. Table 4:2 shows that the output parameters from ANSYS simulation are in good agreement with the experimental data, with an error less than 3%. This indicates that ANSYS software can accurately predict the tensile behavior of the composite material under uniaxial loading condition.

3.2. Discussion

3.2.1. Analyze the properties of the Ensete and Nettle fibers

The ultimate tensile strength of composites is continuously raised from ±45° orientation to 0° Ensete & Nettle of fibers orientation. These are the results that it has increased 3Mpa, 3.33Mpa, 8.87Mpa and 9.13Mpa respectively.

The composite specimens bending resistance also raised up 17.36Mpa to 38.19Mpa. 0° Ensete & Nettle have the better flexural test result. The impact strength decreased from 7.5 to 4 J that mean from Short Ensete & Long Nettle (90°, 0°) to 0° Ensete & Nettle. The Long Ensete & short Nettle (0° &90°) and ±45° orientation are between these 7.5 joule and 4 joule. The compression strength result according to fiber matrix-different orientations, shows as following. The ultimate compression strength of composites is continuously raised from ±45° orientation to 0° Ensete & Nettle fibers orientation starting form 6.23Mpa, 12.97Mpa, 32.17Mpa and 45Mpa respectively.

From testes result the value of maximum tensile strength, Flexural strength, compression strength and impact strength are presented in the table 4.8 based on the maximum values of the four specimens for each test condition.

Table Error! No text of specified style in document.**.3.** Mechanical strength of different fiber orientation

Fibers orientation	**Tensile strength (MPa)**	**Modulus (MPa)**	**Flexural strength (MPa)**	**Compression strength (MPa)**	**Impact strength (joule)**	**Failure strain (%)**
0° Ensete & Nettle	9.13	473	38.16	45	4	1.93
Short Ensete & Long	8.87	180	13.89	32.17	7.5	4.92

Nettle (90°& 0°)						
Long Ensete & short Nettle (0° &90°)	3.33	215	17.36	12.97	4.5	1.55-1.78
±45° orientation	3	215mpa	17.36	6.23	5.5	1.40

3.2.2. Discussion of weight, cost, and environmental impact analysis

The results showed that hybrid Ensete and Nettle natural composite material had the lowest mass (1000g) and the highest percentage of weight saving (85.95% and 31%) compared to mild steel (7109.38g) and synthetic fiber (1448.94g), respectively, for the same volume. This is consistent with previous studies that have reported the advantages of natural fibers over synthetic fibers in terms of mechanical properties, environmental impact, and cost-effectiveness [M. Li *et al and* Furtado, A. L. Araújo, A. Silva]. The results of this study have important implications for the development of natural composite materials for various interior automobile parts, such as interior door panels, dashboard, interiors roofs, and luggage trim skin component. By using natural composite materials instead of mild steel or synthetic fiber, there is reduction of energy consumption, greenhouse gas emissions. This indicates the Ensete and Nettle fibers have less mass per unit volume than the others. The density of mild steel is 7.85 g/cm3 according to the density specifications of common metals [92]. And synthetic carbon fiber also has a high density 1.6 g/cm3 [93]. This indicates that it is have high mass per unit volume than hybrid Ensete and Nettle composite.

In terms of price, findings of the study were that natural fiber had lower price. It also had some environmental advantages over the other conventional materials. One of the implications of these findings is that natural fiber could be a viable alternative to mild steel and synthetic fiber for certain applications where, lightweight is important factors.

The use of conventional materials in automotive applications has significant negative impact on environmental throughout their life cycle. According to researchers, the problem is exacerbated due to their high energy consumption, resource depletion, waste generation, and greenhouse gas emissions. Alternative materials such as natural fibers like Ensete and Nettle can offer potential solutions to address these problems by reducing the environmental impacts and improving the performance of automotive components.

3.3. Identify the Ensete and Nettle fiber's potential to use as vehicle body panel

The mechanical test experimental results were compared with the previous experimental researches. Based on competitive properties of tensile, flexural, impact strength. Prezas F, Aida L, Fonseca AP [94]. Tensile modules of a natural fiber can be used in automotive applications even if it is 258 MPa. Yonas Tsegaye [95]. Another important point is that although a natural fiber has a strength of only up to 5.48Mpa, it is recommended to use it for light weight applications including production of internal door panel and Automobile dashboard bodies.

Greta K, Haag K, Müssig J. [96]. It is also laid down that a natural fiber with a flexural strength of 9.46Mpa can be used for these purposes as further mass reduced, sustainable interior panels used as non-visible and visible design elements in the vehicle. Using these ideas as a starting point.

3.3.1. Comparison of the Previous Works and discuss the implication

As shown in the table 3.4 bending strength which is found in the current work is higher when compared to previous work. In tensile strength also there is an improvement between the studies. All other parameters like compression and impact are included.

Table Error! No text of specified style in document.**.4.** Comparison with previous works

Bending (flexural) Comparison				
Fiber Epoxy ratio	Fiber orientation	Strength(MPa)	reference	Author
Asymmetric composition	0 degree	9.46	Previous work	K. Greta, K. Haag, and J. Müssig
18%& 92%	unidirectional	16.89	Previous work	Prasad L, Kumain A, Patel RV, Yadav A, Winczek
50%& 50%	0 degree	38.19	Current Work	Current Researcher
Tensile comparison				
Fiber Epoxy ratio	Fiber orientation	Strength(MPa)	reference	Author
30% &70%	Chopped	5.48	Previous work	Jonas Tsegaye
40%& 60%	Unidirectional	7.9	Previous work	Malkapuram R, Kumar V, Negi YS.
50%& 50%	0 degree	9.13	Current Work	Current Researcher
Compression comparison				
Fiber Epoxy ratio	Fiber orientation	Strength(MPa)	reference	Author
23%&77%	(0,90) degree	37.92	Previous work	Zewdie Alemayehu
50%& 50%	0 degree	45	Current Work	Current Researcher
Impact comparison				
Fiber Epoxy ratio	Fiber orientation	Strength(MPa)	reference	Author
18%& 92%	unidirectional	3.2	Previous work	Prasad L, Kumain A, Patel RV, Yadav A, Winczek
50%& 50%	0 degree	7.5	Current Wor	Current Researche

The method used to prepare the composite affects the parameters strength. According to the description from Table 3.4 the strength of all parameters increased after the method of composite preparation was changed to some extent. When it comes to changing the method of making composites, strength can be increased by changing the amount of fiber and matrix mixture between fiber and epoxy. The changes in one by one, flexural from 9.46Mpa to 38.19Mpa, tensile from 5.48Mpa to 9.13Mpa, compression from 37.92Mpa to 45Mpa, and impact from 3.2 to 7.5Mpa were obtained. Due to changing the method of composite preparation it increased the mechanical properties.

Figure 3.7 show that the stress values obtained by means of ANSYS analysis are similar to real results. A measurement error for such values is less than 3 percent. This indicates that the output parameters from ANSYS simulation are in good agreement with the experimental data.

Before telling the application of this research, we will look at the aspects of previous research. The minimum strength of automobile interior natural fiber door panels can vary depending on the specific requirements and standards set by the manufacturer. However, in general, these.

Bundele S [97]. If forces ranging from 600N to 1000N are applied to automotive interior door panels in various places and then if the material does not break, it is recommended that the material be used for this service. As per the test results, maximum stress natural hybrid fiber composite of Ensete and Nettle yielded 1370.72N force for tensile test as well as 13,680N force for compression test, 850 N force for flexural. Therefore Ensete and nettle hybrid natural fiber can withstand this force if applied to it and will be used for automotive interior door panel.

Yudianto A [98]. Any natural fiber can be used for automobile dashboards if it has a compression strength of 9.28Mpa and a tensile strength of 7.17Mpa. According to this study, the compression strength of around 45Mpa and tensile strength of around 9.13Mpa have been found and the natural fiber hybrid from Ensete and Nettle will be used for automobile dashboard applications.

The UTM test results show that the hybrid natural fiber composite has better tensile, compression, flexural, and impact properties than the single natural fiber composite, (Ensete) and sisal fibers as reinforcement, and Hemp and Nettle Fiber-Reinforced for automotive applications. The ANSYS analysis results show that the hybrid natural fiber composite has optimal mechanical performance when the fiber content is 50%, the fiber orientation is 0°, and the processing method is hand layup. These results are consistent with the UTM test results. The cost, weight, and environmental impact analysis results show that the hybrid natural fiber composite is more economical, lightweight, and eco-friendly than the single natural fiber composite for automotive applications. Currently, Automobiles that use shit metals for interior doors are Ford model A and Chevrolet bel air while those use synthetic fiber are Ford GT, Lamborghini Aventandor and Bugatti chiron. According to the results of this study, these vehicles can reduce their weight and environmental pollution by using this natural composite.

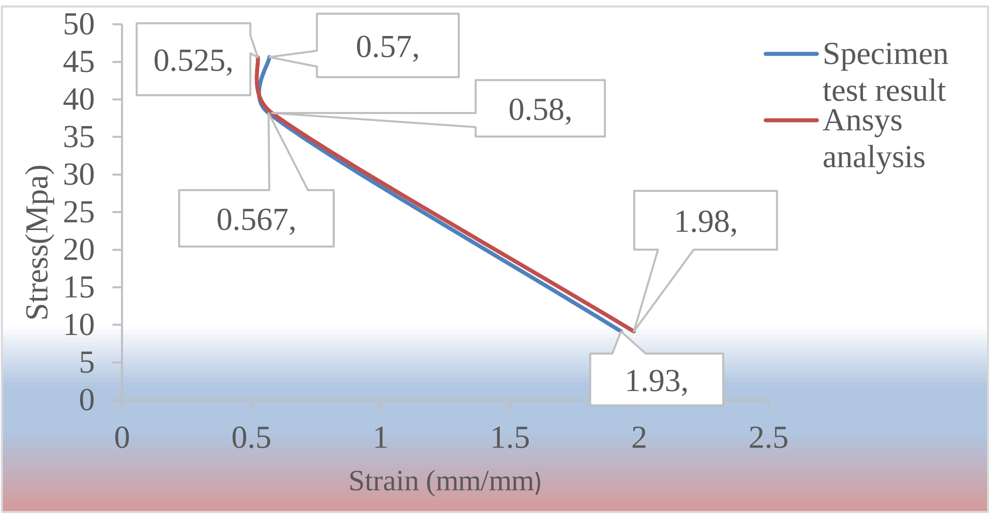

Figure 3.7. Comparison of experimental with simulation result

4. Conclusion

Natural fibers are due to its advantages in terms of weight reduction of vehicles and because its price is much lower than the price of conventional materials and it not cause serious impact on the environment, the demand of natural fibers in automotive industry is increasing from time to time. Despite a significant research so far done, they are yet to achieve full commercial potential, and only few parts are being replaced with natural fiber, and their demand in the industry is expected to continue rising.

In this research the suitability of use of Ensete and Nettle fiber composite in various orientation was studied and analyzed with ANSYS Workbench 2022R2 software. The samples of orientations prepared and examined are 0° Ensete and Nettle, Long Ensete and short Nettle (0°&90°), short Ensete and Long Nettle (90°&0°) and ±45° Ensete and Nettle fibers and tested and analyzed for their respective mechanical properties.

The Ensete fiber and Nettle fiber volume fraction ratio was 1:1 and hybrid fiber and epoxy resin also 1:1 volume fraction ratio. The mechanical properties will be change with change in fibers orientation. The specimens of tensile, flexural, compression and impact properties were based on ASTM standard testing methods.

Orientation of 0° Ensete and Nettle Fiber has greater Tensile strength, Flexural strength and compression strength than other fiber orientations. Long Nettle and short Ensete (0°&90°) orientation has greater impact strength than other fiber orientation. All mechanical properties of ±45-degree hybrid fiber orientation is less than all other fiber orientation. Generally 0° fiber orientation has better mechanical strength performance than all others. 0° Is easier to stretch by hand and simple to control its distribution so it has better strength. A measurement error for all values is less than 3 percent. This indicates that the output parameters from ANSYS simulation are in good agreement with the experimental data.

Taking into account the experimental data, it can be concluded that the natural fiber from Ensete and Nettle plants can be considered as an alternative of other natural fibers and as reinforcement of polymer matrix composites, used for light and medium load applications such as interior door panels, dashboard, interiors roofs, and luggage trim skin component.

4.1. Future Work

This thesis, mainly examined the effects of Ensete and Nettle hybrid fiber on the mechanical properties of composite material with different fiber orientations: 0°, (0° & 90°), (90° & 0°) and ±45°. However, there are other related research areas that could further enhance the performance of natural fiber composites. For future studies, I suggest the followings:

Explore how the fiber orientation and volume ratio, as well as the addition of fillers, influence the mechanical properties of the composite.

To compare the mechanical properties of Ensete and Nettle fiber reinforced epoxy resin composite with other types of natural fibers and synthetic fibers.

Use SEM to investigate the microstructure, properties and fracture behavior of the composite, and the interfacial bonding between the natural fibers and the matrix.

This study only measured the properties and performance of the composites under static loading conditions. Therefore, further study should on the composites under dynamic loading conditions.

Since the fiber processing method affects the quality of the fiber, the strength of the composite will be improved if the processing method of Ensete and Nettle fibers is changed from the current hand processing to modern machine processing.

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