Fabrication and Expermnetal Analysis of False Banana Jute Glass Fibers Reinforced Hybrid Composite for Automotive Body Panel Application

by

Fasil Andargie

A Thesis Submitted to

DEPARTMENT 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

Adama, Ethiopia

July, 2020

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Advisor: Mr. Mekonnen Liben (Asst. Prof.)

Co- Advisor: J Bhaskaran (Ph.D.)

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the thesis entitled "Fabrication and experimental analysis of false banana-jute-glass fibers reinforced Hybrid Composite for Automotive Body panel Application "in partial fulfillment of the requirements for the award the degree of master science in automotive engineering is an authentic record of my work carried out from October 2019 to June 2020 under the supervision of Mr. Mekonnen Liben (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 resources of information used in this thesis have been duly acknowledged.

Fasil Andargie	______________________	____________
Candidate	Signature	Date

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

Mr. Mekonnen Liben	______________________	_______________
Advisor	Signature	Date
Dr. J. Bhaskaran	______________________	_______________
Co-Advisor	Signature	Date

Approved by Board of Examiners

We, the undersigned, members of the Board of Examiners of the final open defense by Fasil Andargie Fenta have read and evaluated his thesis entitled "Fabrication and experimental analysis of false banana-jute-glass fibers reinforced Hybrid Composite for Automotive Body 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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Internal Examiner	Signature	Date
______________________________	_________	_________
External Examiner	Signature	Date

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TABLE OF CONTENTS

CONTENTS PAGES

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

ρc	Density of composite
mc	Mass of composite
Mr	Mass of resin
Vr	Volume fraction of resin
Vf	Volume fraction of fiber
Mb	Mass of bamboo fiber
ms	Mass of sisal fiber
L	Support span length of the specimen
b	Width of the specimen
M_{bmax}	Maximum bending moment
δ_{bmax}	Maximum bending

LIST OF ACRONYMS

SEM	Scanning Electron Microscope
FBF	False Banana Fibers
NF	Natural Fiber
UTM	Universal Test Machine
EOSN	Ethiopian Origin Stinging Nettle
DAVI	Dejen Aviation Industry
PVA	Polyvinyl Alcohol
HCF	Hybrid Composite Fiber
ASTM	America Society for Testing and Material
FRP	Fiber Reinforced Polymer
Hr.	Hour
mm	Millimeter
NF	Natural fiber
PP	Polypropylene
UD	Unidirectional
UTM	Universal testing machine
VHN	Vickers hardness number
GFRP	Glass Fiber Reinforcement Polymer
FBJGFRHC	False banana jute and glass fiber reinforced hybrid composite
JF	Jute fiber

ABSTRACT

The utilization of natural fibers in the field of composites is increasing day by day. This is since natural fibers are eco-friendly, easily accessible, non-abrasive, and economical. Natural fibers are emerging as low cost, lightweight, and environmentally superior alternatives to glass fibers in composites that are used in the automotive body panels, aerospace, transportation, and construction industries. The extensive research and development of new and improved materials such as composites are going on. The main goal of this thesis is the fabrication and experimental analysis of false banana-jute-glass fibers reinforced hybrid composite for automotive body panel application with variable fiber orientation. The manual method of false banana fiber extraction from the Gurage zone in northern Ethiopia and Jute fiber from G7 treading were used for collection. Finally, a 5% sodium hydroxide solution on natural fiber was applied for removal of further lignin, hemicellulose, and other fiber remnants to improve bonding & interfacial shear strength of the false banana and Jute fiber. Next, false banana-jute-glass fibers reinforced hybrid composite was fabricated with a method on the 40% of fiber weight with 60% of matrix weight to the total fiber volume based on Taguchi experimental design setup using hand lay-up technique. Then tensile, compressive, impact, and flexural tests were carried out to identify the best mechanical strength. finally the combination (orientation of [0^0 FBF with 45^0 JF]), (mixing ratio of 1:1), and (10% FBF with 20% JF) preferable with an average of 66.73 MPa tensile strength, 34.8 MPa, compression strength and (orientation of [0^0 JF with 90^0 FBF]), (mixing ratio of 1:1), and (20% FBF with 10% JF) preferable with an average of 350MPa flextural strangth and 8.22MPa impact strength to design the panel and the software analysis was done based on these values. Finally from the analysis energy absorption of composite material trunk lid outer panel can absorb 14.93kJ of energy out of vehicles collision energy of 110.85kJ whereas the existing outer panel absorbs 8.9412kJ energy out of 111.402 kJ collision energy due to its speed and mass.

Keywords: False Banana, Jute Fiber, Hybrid Composite, Body Panel, Polyester

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Many automobile industries are using metals to manufacture vehicle frame components due to its availability and simplicity of manufacturing. The weight of the material inside the car production sector influences the fuel consumption that is directly associated with the corresponding amount of emission to the ecosystem. As the load increases, it takes even more amount of fuel whilst the world gasoline availability is strolling out beside continuous price increment.

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).

Several merchandises like mobile phone cases, computer cases, toys, snowboards, tennis rackets, building/construction substances, musical tool parts, furniture, and plenty of increased have already developed from natural fiber composites. In a few instances, fantastic consequences can also be performed through the use of natural fiber composites reinforced with synthetic resources (Sanjay et al., 2016).

Now a days, natural fibers are attracting the attention of the researchers, professionals, engineers, and scientists all around the world for 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. low weight, low cost, non-abrasive, eco-friendly. 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 which 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

The main difficulty in automotive industries is the weight of the cars which immediately affects fuel consumption. For a significant increase in the amount of energy of automobiles more amount of steel is utilized which increases its weight.

The fuel intake and emission of automobiles are also other troubles in vehicle industries. Furthermore, it is tough to compromise the load and cost within the enterprise even for electric motors. In Ethiopia, the parts to be assembled are not manufactured right in the country. But there is an alternative vehicle production company out of Ethiopia like Japan which has imported spare parts and frame panels. However, some of the synthetic composite fiber body panels are fabricated in Ethiopia through Dejen Aviation Industry (DAVI). Besides the inputs for those agency depends closely on imported artificial fiber. This leads the organization for an additional cost.

The boot lid panel is a massive component which is most usually positioned at the rear of the automobile as a result of which affects fuel consumption of a vehicle. To encounter such problem using hybrid composite materials is of vital importance in decreasing the load.Mostly reserchers were done on natural fiber with the composition of one synthetic fiber with one natural fiber but the mechanical propertis was limited to some specific work.In this thesis combining one synthetic fiber with two natural fiber on the effect of natural fiber on the mechanical properties of the composite by decreasing the concentration of synthectic fiber. At the end choosing natural fiber based on fiber structure.Thuse, considering false banana and jute fiber because of similar in physical structure and have closer physical properties.

1.3. Objectives

1.3.1. General Objective

The general objective of this thesis work is fabrication and characterisation of false banana-jute-glass fibers reinforced hybrid composite material for automotive body panel application.

1.3.2. Specific Objectives

- ✓ Prepare and produce the composite specimen from false banana, jute fiber, and E-glass fiber;

- ✓ Test hybrid composite materials for mechanical properties such as tensile, compression, bending, and impact strength;
- ✓ Model and analysis the trunk lid outer panel using solid work and Ansys software respectively;
- ✓ Compare the properties of the boot lid outer panel with the existing one;
- ✓ Predicting the best mixing ratio which has the superior mechanichal strength of false banana-jute-glass fiber reinforced natural fiber composites using Taguchi method;

1.4. Significance of the Thesis

Significance of this thesis is as follows;

- ✓ It introduces Ethiopian false banana, jute fiber with polymer composite material for composite technology;
- ✓ It helps in reducing the weight of the vehicle body;
- ✓ Minimizes the cost to manufacture of boot lid panel:

1.4.1. Beneficiaries

Different groups of society get benefitted from this work; Like the one who can prepare the fiber starting from plant cultivation up to final composite material production. The automotive industries are the next beneficiary group and finally, it is good for the whole society by minimizing vehicle emission.

1.5. Delimitation (Scope)

This work includes all the necessary steps of preparation of false banana, jute fiber, and E-glass fiber composite and testing its property, preparation of specimen from the prepared composite and modeling and analyzing of the boot lid outer panal also includedvin 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

Organization of the Thesis

The thesis was organized in the following chapters

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

Chapter 2: It covers the review 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 setup, 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 the characterization of composite materials, modeling, and FEA analysis is given in this chapter

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

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Composite Material

Composite substances are becoming more crucial inside the construction of buildings walls, beautify vehicle frame panels like interior and outside elements, substances for machines and industries, and aerospace structures. Nowadays automobile internal components like dash panels and binder plate on the internal elements of the panels are made from composite materials, along with front and rear bumper, spoilers, air dams, nook vanes, dashboards, mudguards, aerofoils, cab roof deflector, cab to trail frame hole seals, tractor and trailer skirting for drag reduction, extended side panels on heavy-obligation vehicles for frame edging and flight controls for airplanes, had been developed throughout the Nineteen Sixties for their weight savings over metallic and others styles of metals. New generation small and large vehicles are designed with partial composite materials structures and the repair of these advanced composite substances requires in-depth skills materials and tooling. The benefits of composite materials are their excessive strength, especially low weight, and corrosion resistance. Since the 1990s, herbal fiber composites are emerging so sensible alternatives in keeping with glass-strengthened composites into many applications (R Rajasekar, 2014).

2.2. Natural Fibers and Its Extraction

Natural fibers regularly referred to as skinny fibers, are extracted from plant life and are classified into three categories, relying on the part of the plant they are extracted from. Those are:

a. Fruit fibers
b. Stem fibers
c. Leaf fibers

Fruit fibers are extracted from the stop result of the plant, they are light and hairy, and enable the wind to raise the seeds. Stem fibers are discovered within the stem of the plant providing the plant its strength. Usually, they run at some point in the entire duration of the stem and are consequently very long. Fibers extracted from the leaves are tough and sturdy and shape a phase of the plant's transportation system, they're acknowledged as leaf fibers. The natural fiber is a type of renewable sources and a new generation of reinforcements and dietary supplements for polymer-primarily based totally materials. The improvement of natural fiber composite substances or environmentally best composites has been a hot subject matter currently due to the fact of the increasing environmental awareness.

Natural fibers are one such successful material that replaces the artificial substances and its products are relevant for the less weight and energy-conserving applications. The software program of natural fiber reinforced polymer composites and herbal-primarily based resin for replacing existing synthetic polymer or glass fiber bolstered supplies is huge. Automotive and aircrafts industries were actively emerging with special forms of herbal fibers, especially on hemp, flax, and sisal and bio-resins structures for their indoor components (R Rajasekar, 2014).

S. Mukhopadhyay and Fangueiro (2009) described fiber extraction strategies like Steam explosion and thermomechanical methods fall inside the first category at the same time as plasma, dielectric barrier techniques, and corona fall in the second. Several physical and chemical strategies have been used to alter the fiber floor to reason them to more appropriate for such applications. The thermoplastic polymers used as matrices are additionally inert Physical treatments have also been used to improve the reactivity of such polymers on the surface. Due to the presence of hydroxyl and other polar corporations of their constituents, natural fibers exhibit immoderate moisture absorption. Increased moisture decreases mechanical homes and offers a vital circumstance for biodegradation and dimensional instability.

Kotresh Sardar et al. (2014) investigated that fibers may additionally be collected from its plant with the aid of extracting the usage of guide or mechanical extraction procedures. Here continuous fibers are used to fabricate the herbal fiber composites. First, the natural fibers are cleaned in distilled water. The wiped easy natural fibers are dried in the sunlight. The dried natural fibers are again cleaned through the chemical cleaning process. In the chemical cleansing process, the 80% sodium hydroxide is blended with 20% distilled water. The dried herbal fibers dipped in the diluted sodium hydroxide solution. It’s once more dried in sunlight. The dried natural fibers are limit to the size of 300 mm with the useful resource of manually. The minimize natural fibers are used to fabricate the natural fiber composites.

2.3. Introduction of False Banana (Enset)

Enset (Enset ventricosum) is a genus of the banana circle of family and termed as false banana. It is a large leafy monocarpic evergreen perennial root crop and most important meals supply on the complete for the southwestern a section of Ethiopian highlands. Biogeographers and agronomists have considered the middle of the basis for enset agriculture to be the Ethiopian highlands (Daba and Shigeta, 2016).

The representative enset developing areas of southwest highlands Ethiopia. This does no longer suggest that enset is cultivated and used the simplest in these areas as meals. It is preferred ingredients in the southwest, central, and towns with the Ethiopian delicious food, kitfo. Figure 2.1 iillustrites that enset growing areas of southwest highlands Ethiopia Depending on the weather and Agro-ecology, the essential ingredients vegetation and food plan range from area to place in the country. More than one-6th of the Ethiopian population (nearly 15 million people) depends upon on enset (Admasu, 2002).

Fig. 2.1. False banana plantations

There are two methods of false banana fiber extraction adopted. These are stripping and decortications via means of a decorticator. Enset is an ordinary multipurpose crop that every botanical aspect is used for several material cultures. Enset is a large banana-like plant (Steven et al., 1997) and it’s all botanical parts. The leaves and pseudostems are applied for wrapping, sheeting to sit, thatching, making containers, shading from sunshine, and protective from rain (Daba and Shigeta, 2016). The sheaths, fiber, and leaf of the plant are used for residence construction, food wrapping, farm animals feed, and ropes (Borrell et al., 2020). It is likewise used for a variety of socio-financial and cultural values in the

Enset growing areas. Some kinds are wished for wonderful ritual things to do in big ceremonies and funerals.

2.4. Composition of False Banana Fiber

The carbohydrate part of the tremendous majority of plant life is composed of cellulose and hemicellulose polymers with minor quantities of exceptional sugar polymers such as starch and pectins. The aggregate of cellulose and hemicelluloses are referred to as holo cellulose and typically bills for 65 to 70 percentage of the plant's dry weight. When in contrast to special lignocellulosic vegetation banana pseudo-stem proven in Fig 2.2. has better cellulose content material probably due to the fact of the higher extent of fruit they help (W. E. Morton and Hearle, 2005).

Fig. 2.2. False banana pseudo-stem

Cellulose, hemicellulose, and lignin are the primary elements of lignocelluloses. The share of these elements in a fiber depends on the age, supply of the fiber, and the extraction situations used to acquire the fibers. The core (stem) section of the plant has higher cellulose composition than the leaf veins for this reason can be used as an economic provide of cellulosic fiber. Unlike cotton fiber, false banana fiber is multicellular with thin-walled cells and a greater lumen. The lumens are giant concerning the wall thickness. Cross markings are rare and fiber recommendations pointed and flat, ribbon-like character fiber diameter varies from 14 to 50 microns and the size from 0.25 cm to 1.3 cm, displaying the massive oval to the spherical lumen (Reddy & Yang, 2005). Compared to jute fiber which has a cellulose composition of 58 to 63 % the false banana plant consists of a greater composition of cellulose (60 to 67%) which is significantly adequate to be used for pulping see desk below. It has been expected that Out of the common plant composition 11% is the fruit, closing is fibrous (1 to 2%) and non-fibrous waste.

Cellulose: is a glucan polymer of D-glucopyranose units, which might be linked mutually by the usage of β-(1-4)-glucosidic bonds. Actually, the setting up block for cellulose is cellobiose for the motive that repeating unit in cellulose is a two-sugar unit (Roger M, 2014).

Hemicelluloses: In nature cellulose in no way takes area in pure form. The important additives observed at the same time with cellulose are hemicellulose, lignin, and pectins. In general, the hemicellulose fraction of flowers consists of a collection of polysaccharide polymers with a minimize DP than cellulose and containing specifically sugars.

Lignin: Lignin is amorphous, relatively complex, especially fragrant, polymers of phenyl propane units. All plant lignin consists in particular of three primary building blocks of guaiacyl, syringe, and p-hydroxyphenyl moieties, even even though different fragrant kind gadgets moreover exist in lots of unique kinds of plants about 70% of the lignin is located inside the secondary wall (James & Rowell, 2016).

Ash: The inorganic content material fabric of a plant is typically mentioned in its ash content material that is an approximate degree of the mineral salts and other inorganic rely on inside the fiber after combustion at a temperature of 575 ± 25 °C. The inorganic content may be quite immoderate in plant life containing big quantities of silica (James & Rowell, 2016).

Extractives: The extractives are a crew of cell wall chemical compounds mostly which include fats, fatty acids, fatty alcohols, phenols, terpenes, steroids, resin acids, rosin, waxes, etc. These chemical substances exist as monomers, dimers, and polymers. They derive their identity with the aid of the skill of being chemical compounds that are eradicated through the way of one of several extraction approaches (James & Rowell, 2016).

2.5. Fiber Extraction of False Banana or Enset

There are two methods of false banana fiber extraction adopted. These are stripping and decortications by using way of a decorticator.

a) **Stripping:** The most largely used and oldest technique of putting off fibers from the leaf sheaths consist of two fundamental operations: first, setting aside the fibrous outré layer from every leaf sheath, this outer layer being termed “tuxy” and the operation “tuxying”; and second getting rid of pulpy material, as a final result freeing the fiber strands from the tuxy, the operation being termed stripping or cleansing. Both operations want to be done as soon as possible after the stalk is felled. The tuxying operation is frequently completed internal the field. The workman inserts a point of a knife between the outer and middle layers of the leaf sheath, liberating a cease of the outer layer 1 to three-inch huge. This strip or tuxy is pulled off the whole period of the sheath. When all tuxies are removed from the leaf sheath, it is miles eradicated from the stalk and allowed to remain on the sector for natural fertilizer. Usually, each different workman choices up the tuxies and comprises them to the location whereby the stripping or cleaning operation is to be achieved (W. E. Morton & Hearle, 2005).

b) **Decortications:** False banana fiber is also cleaned through a decorticator. Small spreaders machine used to separate fibers from the stem of the plant (W. E. Morton and Hearle, 2005).

2.6. False Banana Utilization in Ethiopia as a Source of Fiber

G-7 alternate and enterprise P.L.C is attempting to practice FBF for sack manufacturing via mixing it with the imported jute (BTD and BWCA). G-7 receives fiber from unique places of southern Ethiopia; by using traditional trademark Alaba and Sidamo. These fiber verities are one-of-a-kind in look and form. The Alaba kinds are coarse, rigid, hard, brittle, and long (averaging about 1m). It is also entirely separated from the leaf however now not chemically modified to decorate Processability. The Sidamo sorts are very short and are no longer surely separated from the leaf for fiber use. So, the manufacturing unit used to be now not receiving the fashioned fiber. Some of the discrepancies mentioned internal the SNNPRS Agricultural Bureau Enset estimates can be attributed to the zonal and wereda of the MoA in their inexperience at the estimation of hectares and yields states in Table 2.1. (Getu, 2019).

Table 2.1. Enset Products SNNPR

Zone	Hectors	Fibers (Qtl)
Guraga	52,400	386,800
Hadiya	18,013	108,075
N.Omo	55,609	389,263
Kenbata,Alaba,Tembaro	11,689	93,568
Sidamo	43,334	476,674
Yem	5,020	10,000
Amare	4000	16,000

2.7. Historical Background of Jute/False Banana for Spinning

Early proof indicates that wrapping fabrics, twins, ropes, and cordages had been being crafted from low-price fiber, which used to be available in big quantities. Among these, bast fibers like jute, flax, hemp, ramie, and leaf fibers like abaca; one of the false banana fibers and fibers like sisal and henequen are the principal uncooked supplies used for packing industries (Roger M, 2014). The most generally operated jute spinning system consists of two ranges of carding accompanied via three ranges of drawing and because of this a spinning stage. False Banana Fiber is blast fiber used for the production of the sack, burlap, and wire as packing cloth for tufted carpets. The manufacturing strategies of pretending banana fibers are demonstrated below.

2.8. Physical and Chemical Properties of False Banana and Jute

Tenacity modulus and elasticity: When we see in the Table 2.2 the load elongation or stress-strain assets, banana fiber has much less tenacity and elasticity assets than jute fiber (W. E. Morton and Hearle, 2005).

Table 2.2. Physical properties of Banana compared with Jute

Physical properties	Banana fiber	White jute	Tossa jute
Single fiber tenacity(gf/tex)	46-64	35-45	35-45
Single fiber extension at break(%)	2.9- 4.3	1-2.5	1-2.5
Fibere bundle tenacity(gf/tex)	24-30	13-29	15-31
True density(g/cm^3)	1.31-1.33	1.44	1.45
Apparent density(g/cm^3)	0.62-0.86	1.23	1.23
Fluxtural rigidity	33-40	4-6	4-6
Length of new fiber(cm)	34-85	-	-
Moisture regain at 65%	14-15.2	12	12
Fiber porosity(%)	35-53	14	14

Water absorbency: FBF has a better capability for water-release and water absorbability. Fig 2.3 and Fig 2.4 display the water-absorption and water-launch capability of false banana, jute, and cotton fibers were compared.

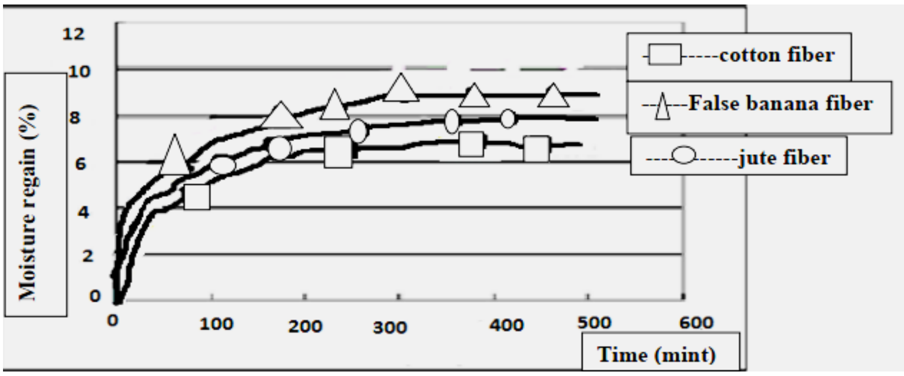

Fig. 2.3. Water absorption of cotton, jute, and false banana fibers (Anhwange et al, 2014).

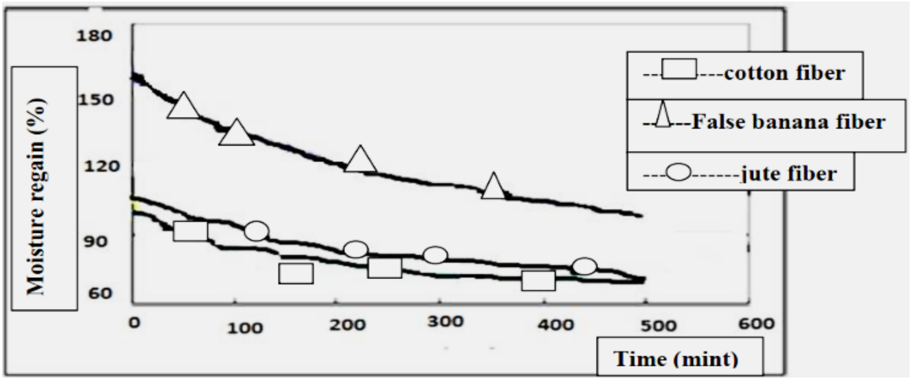

Fig. 2.4. Water-release of cotton, jute, and false banana fibers (Anhwange et al, 2014).

It may additionally be visible from the figures; false banana fiber has better water absorbability and water release. In Fig. 2.4 the false banana fiber shows the better potential of water absorption. This is due to the higher content material fabric of non-cellulose substances in false banana fiber, the decreased crystallinity inside the fiber structure.

2.9. Jute Fiber

Jute is the most typically used natural fiber as reinforcement in reen composites. Jute is a structure of bast fibers from the Tiliaceae family and having a scientific call is Corchorus capsularis due to the fact it is extracted from flowers of Corchorus, it is one of the low-price natural fibers and is nowadays the blast fiber with the most manufacturing volume. Jute is intuitive to the Mediterranean on the other hand in current times Bangladesh, India, China, Nepal, Thailand, Indonesia, and Brazil grant the finest type for the growth of jute (Singh et al., 2018).

The Overall world manufacturing of jute fiber is round 2300×10^3 to 2850×10^3 tones. Jute can enhance 2 to 3.5 m in peak and are very brittle, with a low extension to spoil due to the fact of the excessive lignin content (up to 12 to 16%). Jute fibers have an awful lot less resistance to moisture, acid, and UV light. Conversely, their fantastic texture, as well as their resistance to warmness and fire, are providing a wider variety of packages in industries such as textile, construction, and automotive as shows in Fig 2.5. the digital view of the jute plant and different form of jute fiber available (Wang et al., 2011).

Fig. 2.5. (a) Jute plant; (b) Raw jute fabric; (c) Unidirectional jute fiber; (d) Woven jute fiber.

2.9.1. Physical and Mechanical Properties of Jute Fiber

As the all-natural fibers are lignocellulosic they possess higher acoustic insulation residences alongside the unconventional thermal residences as in contrast to the different artificial fibers. Usually, mechanical houses of synthetic fibers are greater in comparison to natural fibers, but that may be besides larger by way of awesome floor remedy of fibers as alkali remedy, silane treatment, etc. Natural fibers are possessing excessive special modulus, an excessive special energy, low densities, etc. Are the reasons, of excessive demand within the industries for the development of the composites. The tensile electrical energy of glass fiber is more than that of plant fibers, however the precise modulus of natural fibers is better than that of glass fibers. Due to those reasons, the herbal fibers are extensively used for the one of a kind packages in inexperienced composites (Singh et al., 2018).

Fiber traits are the primary parameters for reinforcing the performance of the herbal fiber strengthened polymer-primarily based composites. It has been located in viewed one of the studies that moisture content material is having a huge impact on the organic overall performance of natural fiber bolstered polymer composites (Faruk et al., 2012).

2.10. Natural Fiber Treatment

One of the types of chemical changes on natural fibers to be used in natural fiber-bolstered composites is reviewed. Chemical treatments consisting of alkali, silane, acetylation, enzoylation, acylation, maleated coupling agents, isocyanates, permanganate, and others are discussed.

Tabil et al. (2007) described the chemical remedy of fiber aimed at improving the adhesion between the fiber floor and the polymer matrix can additionally now not handiest modify the fiber surface on the other hand also increase fiber strength. Water absorption of composites is diminished and their mechanical residences are advanced.

Physical redress is finished on herbal fibers for two reasons:

✓ Separation of the fiber bundles into personality filaments step one of the usages of the natural fibers for composites is the separation into personality filaments. Processes to date used to do away with lignin are chemical treatment or chemo-mechanical treatment. Water-retting, which used to be previously the method of preference due to the truth of tremendous fiber, produces environmentally unacceptable fermentation waste.

✓ Modification of the fibers for composite programs the floor of the fibers may be modified with the useful resource of bodily or chemical means. The way is to roughen the flooring to enhance the contact area and facilitate mechanical interlocking.

2.11. Fiber Orientation

The electricity and stiffness of a composite buildup count on the orientation collection of the plies. The realistic range of electricity and stiffness of carbon fiber extends from values as little as those provided via fiberglass to as immoderate as those furnished through titanium. This variety of values is determined through the orientation of the plies to the applied load. Proper preference of ply orientation in most useful composite substances is quintessential to offer a structurally efficient design. The aspect might also require 0° plies to react to axial loads, ±45° plies to react to shear loads, and 90° plies to react to thing loads. Because the electricity diagram requirements are a characteristic of the carried out load route, ply orientation, and ply collection has to be correct. The duration of a restore needs to update every damaged ply with a ply of the equal fabric and ply orientation. The fibers in a unidirectional fabric run in one direction and the electrical energy and stiffness are exceptional within the course of the fiber. Pre-impregnated (prepreg) tape is an instance of a unidirectional ply orientation. The fibers in a bidirectional fabric run in two directions, commonly 90° apart. A simple weave cloth is an instance of a bidirectional ply orientation. These ply orientations have electricity in each direction alternatively no longer necessarily equal energy. The plies of a quasi-historic layup are stacked in a 0°, –45°, 45°, and 90° collection or a 0°, –60°, and 60°series. These styles of ply orientation simulate the houses of isotropic cloth. Many aerospace composite buildings are manufactured from quasi-isotropic supplies (Singh, 2016).

2.11.1. Unidirectional (Tape)

Unidirectional prepreg tapes had been the standard inside the aerospace industry for many years and the fiber is commonly impregnated with thermosetting resins. The most commonplace method of manufacture is to attract collimated raw (dry) strands into the impregnation system wherein hot melted resins are mixed with the strands of the usage of warmness and pressure. Tape merchandise has high power in the fiber direction and truly no energy across the fibers. The fibers are held in place by the resin. Tapes have higher electricity than woven fabrics.

2.12. Bidirectional (Fabric)

Most fabric constructions provide higher flexibility for layup of difficult shapes than immediately unidirectional tapes offer. Fabrics provide the option for resin impregnation either with the aid of the solution or the hot-melt manner. Generally, the fabric used for structural programs use like fibers or strands of the same weight or yield in each the warp (longitudinal) and fill (transverse) directions. For aerospace structures, tightly woven cloth is commonly the choice to store weight, minimizing resin void size, and retaining fiber orientation at some factor of the fabrication machine. The bellow fig. 2.6 showing bidirectional and unidirectional fiber association of composite material (Singh, 2016).

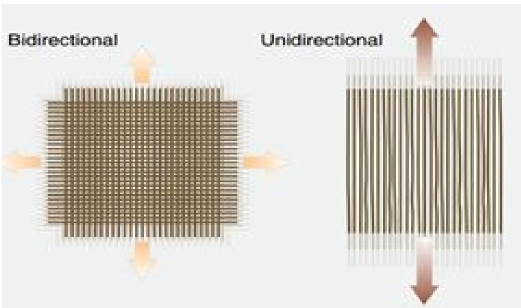

Fig. 2.6.Bidirectional and unidirectional

Most cloth constructions grant increased flexibility for layup of complicated shapes than at once unidirectional tapes offer. Fabrics offer the choice for resin impregnation both using answer or the hot-melt manner. Generally, the material used for structural programs use like fibers or strands of the identical weight or yield in every the warp (longitudinal) and fill (transverse) directions. For aerospace structures, tightly woven material is generally the desire to save weight, minimizing resin void size, and holding fiber orientation at some point in the fabrication device (Singh, 2016). Table.2.3 showing Properties of natural fibers and synthetic fibers relationship for composite material (Singh, 2016).

Table 2.3. Properties of natural fibers and synthetic fibers

Aspects	Property	Natural Fiber	Synthetic Fiber
Technical	Mechanical property	Moderate	High
	Moisture sensitivity	High	Low
	Thermal sensitivity	High	Low
Environmental	Resource	Infinite	limited
	Production	Low	High
	Recyclability	Good	Moderate

2.13. Basic Constituents of Composites

2.13.1. Matrix Material

The roles of the matrix in a fiber-reinforced composite are (Sanjay and Mazumdar, 2002)

- ✓ to keep the fibers in place
- ✓ to transfer stresses between the fibers,
- ✓ to provide a barrier against an adverse environment, such as chemicals and moisture, and To protect the surface of the fibers from mechanical degradation (e.g. by abrasion).

The reason for a composite matrix is to bind the reinforcement together and to switch load among fibers. This binding is made due to the fact of the cohesive and adhesive characteristics of the matrix material (Naveen Konnur., 2014).

The matrix performs a top function within the tensile load-carrying capability of a composite shape (Valadez et al., 1999). Besides, the decision of a matrix has the main influence on at the compressive, interlaminar shear in addition to in-plane shear homes of the composite cloth. The matrix offers lateral aid in the direction of the possibility of fiber buckling under compressive loading, for this cause influencing largely, the compressive power of the composite material. The processing and defects in a composite fabric remember strongly at the processing characteristics of the matrix. For example, for epoxy polymers used as a matrix in loads of aerospace composites, the processing traits embody the liquid viscosity, the curing temperature, and the curing time (Naveen et al., 2015).

Various matrix substances have been used either commercially or in research. Among these, thermoset polymers, collectively with epoxies, polyesters, and vinyl esters, are greater oftentimes used as matrix cloth in non-stop or lengthy fiber-reinforced composites, mainly because of the comfort of processing due to the fact of their low viscosity. Thermoplastic polymers are extra generally used with brief fiber -strengthened composites which can be injection-molded; however, the interest in the non-stop fiber-bolstered thermoplastic matrix is growing. Metallic and ceramic matrices are mainly taken into consideration for high-temperature applications (Valadez et al., 1999). Fig 2.7 shows below confirmed that the broad classification of matrix substances (Valadez et al., 1999).

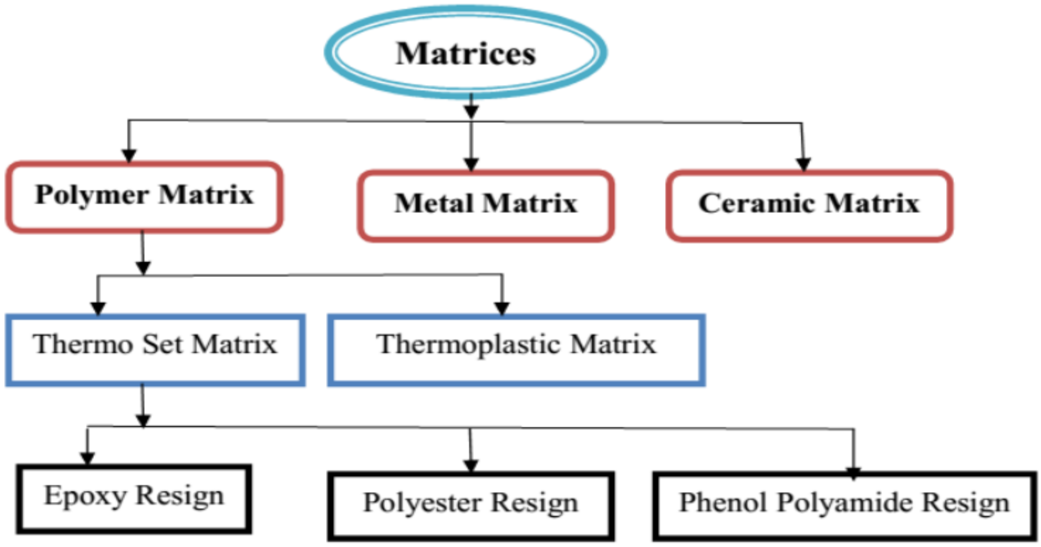

Fig. 2.7. Classification of matrixes materials

2.14. Reinforcement Materials

The cause of the reinforcement in a composite cloth is to expand the mechanical homes of the neat resin device (Ashik and Sharma, 2015). All of the extraordinary fibers utilized in composites have terrific residences and so affect the residences of the composite is one of a kind ways. For most of the applications, the fibers want to prepare into some shape of sheet, recognized as a fabric, to make managing possible.

2.15. Natural Fiber Composites preparation and Fabrication Techniques

A composite is a bodily material which consists of or greater fundamental elements are combined at a macroscopic stage and don't seem to be soluble in each other. Natural fiber-reinforced polymer composites have helpful residences such as low density, much less expensive, and reduced solidity when associated to artificial composite products, as a result providing benefits for utility in industrial requests (car industry, buildings, and constructions); companies are ever-changing to composites to plan one of a kind additives like ford (Mondeo cd 162, focus) use composite for ground plates, door inserts, door panels, b-pillar, and boot-liner (Kotresh Sardar, 2014).

Jute fiber-epoxy composite is organized by way of hand lay-up method the utilization of an open kind mold made of moderate steel plate has been used. For that, a mylar sheet is placed on the lower a part of the mildew for a superb floor give up and easy removal of composite from the mold further to its wax is also used to cowl the flooring of mylar sheet for effortless withdrawal of composite from mylar sheet. Then the epoxy resin has been lined on the mildew (1 to 1.5 mm) thickness and jute fiber located on it. After doing away with the tricked air with the help of metal curler rolled on the layer, thereafter some other layer of epoxy resin has been poured on the mildew and the higher a phase of the mold is placed on side plates, which is placed on both aspects of the lower section of mildew (Srivastava, 2017).

All those strategies fall under a principle known as polymerization. Polymerization is the method of linking a giant vary of artificial molecules collectively to shape an unbending structure. Glass fiber bolstered polymers are used in mixed with herbal fibers to improve the ordinary performance of composite material applications. Fig 2.8 shows typically used fibers and matrices in natural composite production (TP Sathishkumar, 2014).

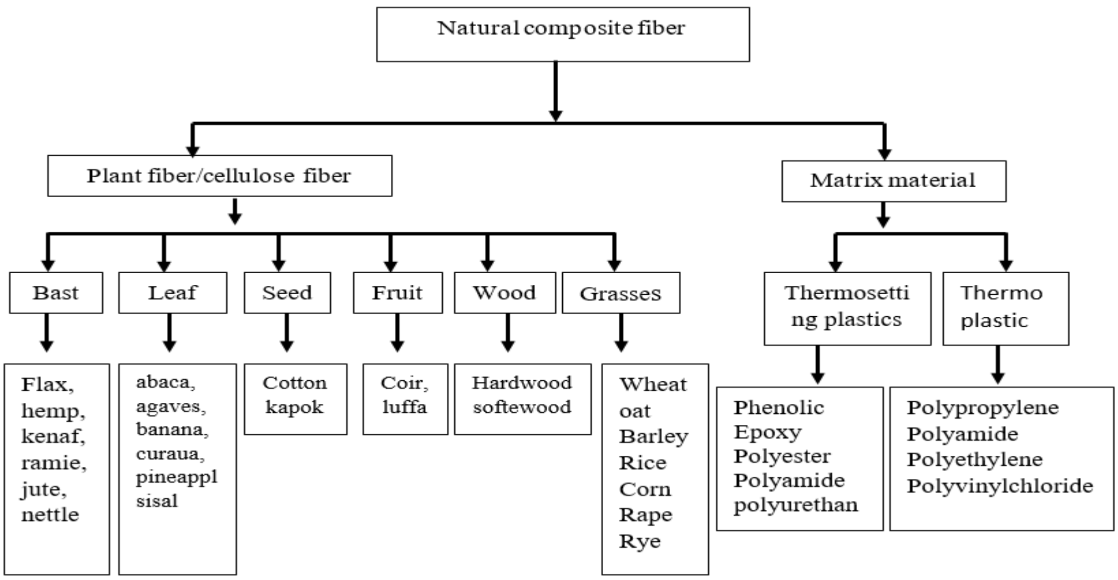

Fig. 2.8. Commonly used natural fibers and matrices for polymer composites

The composite merchandise is too many and cowl an extensive location of applications ranging from an engine valve to a plane wing. The fabrication technique varies from one product to the other. Some common composite fabrication strategies are described below.

I. **Spray layup:** illustrated in Fig 2.9 under is an open mold approach that should produce complicated parts larger economically than hand lay-up (Sabu Thomas, 2012). Chopped fiberglass reinforcement and catalyzed resin, and in a few cases, filler materials, are deposited on the mold surface from an aggregate chopper/spray gun. Rollers or squeegees are used to manually forged off entrapped air and work the resin into the reinforcements. Woven cloth or woven roving is frequently delivered in precise areas for greater strength. General purpose, room temperature remedy polyesters are usually used to produce such actors as truck camper shells and bathe stalls. As in hand lay-up, gel coats are used to grant a superb colored part surface.

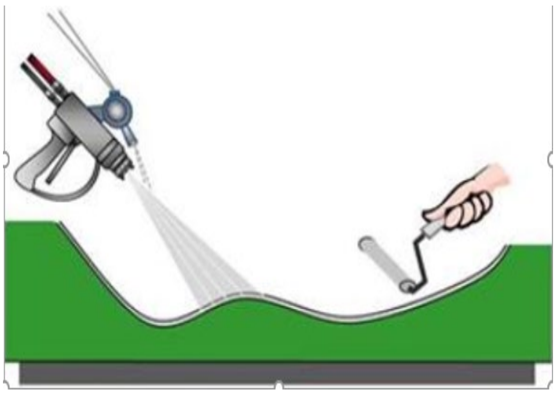

Fig. 2.9. The spray-up technique

II. **Compression molding:** Compression molding is a closed mold system finished with matched steel molds utilizing. Sheet Molding Compound (SMC) and bulk molding compound (BMC) is broadly used thermosetting-based molding compounds (Sabu Thomas, 2012). A weighted price of SMC or BMC, or a perform of glass reinforcement fashioned to the mold is placed on a press ranging in length from 300 to 4,000 tons. Resin is brought with the preform even as SMC and BMC contain all additives which include fiber, resin, fillers, catalyst, etc. Heat and stress are applied, with temperature stages of 225 to 325 of and 150 to 1,000 psi stress required curing elements. Cycles can variety from much less than one to 5 minutes. Typical thermoset resins used in compression molded components are polyesters, vinyl esters, epoxies, and phenolic. Compression-molded merchandise varies from dinnerware, trays, buttons, appliance housings, huge containers, electrical, to leisure vehicle frame panels which include snowmobiles, and jet skis.

III. **Injection Molding**: Material granules for the element are fed through a hopper right into a heated barrel, melted the use of heater bands, and the frictional motion of a reciprocating screw barrel. The plastic is then injection via a nozzle proper into a mold hole area in which it cools and hardens to the configuration of the cavity.

IV. **Hand Lay-Up Technique:** Hand lay-up is the oldest simplest, and the most generally used approach for the manufacture of each small and big reinforced merchandise as shown in Fig 2.10 (Sabu Thomas, 2012).

Hand lay-up is an open molding procedure to supply a polymer composite product. A flat surface, a hollow space or a positive-formed mold, made from wood, metal, plastic, or a combination of those substances might also use for the hand lay-up method. A mold launch agent is applied onto the mildew floor for ease of removing completed composite merchandise. The laying-up of a component starts with making use of a gel coat to the mold surface (Sabu Thomas, 2012). It is a resin-wealthy layer and the cause is to save you the fibers from performing on the molding floor. The composites are then prepared by way of putting a fiber reinforcement and by way of including polymer resin onto it. A roller is used to consolidate the composites and the composites are made layer with the aid of layer. The system is repeated with more layers until the desired thickness is obtained. Then the composites are cured at room temperature or in an oven. Thermosetting resins like unsaturated polyester, vinyl ester, and epoxy are a number of the most generally used resins.

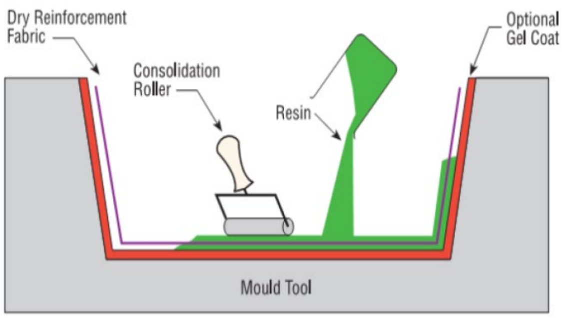

Fig. 2.10.Hand layup technique

2.16. Vehicle Body and Natural Fiber Composite Overview

Singh et al. (2018) automotive tend to turn out to be heavier as the safety and comfort functions are stepped forward, however, the call for better gas efficiency and decrease environmental impact is also rising this is at once influenced the fashion closer to the reduction of motors so he reviews in his paper the improvement and fashion in aluminum alloy sheet for automotive body panels. Automotive weight reduction has been carried out traditionally by lowering the thickness of steel-sheet frame panels by growing the electricity of the steels, however, this technique is limited due to the resultant reduction in panel stiffness. For this reason, lighter substances are being studied considerably to replace the steels for the example trunk lid, hood door as indicates in Fig.2.11 (https://www.kobelco.co.jp)

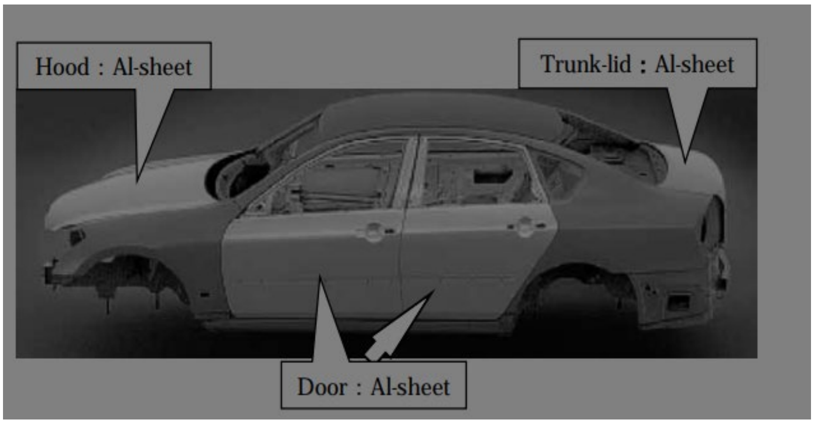

Fig. 2.11.Car Body Panels

Ansari et al. (2015) studied that strength conservation and environmental pollution end up a serious situation across the world; European and lots of advanced countries are learning and growing electric cars to reduce gasoline consumption and exhaust emissions. They examine how to boom the battery potential to boom car mileage. However, the electric vehicle has a fantastic problem in use that the automobile may be very heavy because of the battery weight, price potential, and body structure, so that electric automobile mileage decreases.

Singh et al. (2018) studied the use of jute fibers as reinforcement for the development of composite substances. Nowadays growth in gasoline prices, depletion of fossil fuels, worldwide warming are the major issues that pressure the researchers to work inside the location of green composites. And additionally motioned that, jute fiber-reinforced composites are not limited to textile packages most effective but additionally update old substances inclusive of metal and wood for numerous applications like a car, structures, toys, and furniture. It has been planned as the capability fabric for the substitute of synthetic fibers polymer composites. Jute fibers are one of the herbal fibers that are easy to be had and inexpensive and are having proper mechanical properties

Joshi et al. (2004) reviewed that a few composite components (For the car sector), previously manufactured with glass fibers are produced with natural fibers. Applications including door panels, trunk liners, tool panels, indoor roofs, parcel shelves, among other indoor components, are already in use in European cars because of the extra favorable economic, environmental, and social components of the vegetable fibers.

Srinivasan et al. (2014) studied the hybrid composites made of natural fibers namely, banana and flax fibers. The structural build-up is such that one layer of banana fiber is sandwiched between layers of flax fibers using a hand layup approach with a volume fraction of 40% the usage of Epoxy resin and HY951 hardener. Glass fiber reinforcement polymer (GFRP) is used for lamination on both surface properties.

Mehamud et al. (2016) studied and explained the characterization of the exceptional weight of a composite, herbal fiber epoxy composites, by way of the usage of hand lay-up technique and mechanical testing system via the technique of traditional extract fiber, simply via the use of steel and a human hand to rub the root of the banana to remove the gel aspect from fiber parts. Four sets of samples are prepared, one set is 5% banana fiber with 95% epoxy resin, the second one set is with 10% banana fiber with 90% epoxy resin, the third set is 15% banana fiber with 85% of epoxy resin and the fourth set is 20% banana fiber with 80% of epoxy resin, All of the specimens are on 0/90-degree (directly unidirectional) orientation fibers. Depending on the proportion of composite in resin, from 80% - 95% via weight, which increases the mechanical properties. SEM the usage of to assess fiber, floor structure, and fractured internal structure. The Experiment results are impact strength, tensile electricity, and flexural energy are multiplied with a similar proportion as the amount of epoxy (resin) extended. The experimental result concludes that higher tensile, Impact and flexural energy exist at a proportion of 80% epoxy resin with 20% banana fiber.

Rao et al. (2018) studied that Natural fiber-primarily based composites are drawing in several researchers and scientists due to their Eco-incommoding nature and unique properties. Banana fiber is one of the feature fibers with better mechanical properties. They are ease and to an incredible volume accessible in nature. Their handling isn't always a hard correlation with the regular filament's generation. Banana fiber is mixed with exclusive kinds of composites to grow its mechanical properties. The ratio of mixing the composites will range from the type of fiber is used. Combined with another sort of fibers at the side of epoxy or another type of resin mechanical properties could be changed. Banana fiber is one of the natural fibers that have high tensile electricity of fee 600Mpa.

Getu, A. (2019) studied the structure, and characterization of False banana fibers(FBF) by physio-chemical treatment. One of the components was used for softening fake banana fiber or yarn for the production of different FBF merchandise like sack, mat, or carpets of supple feel and stepped forward texture on an industrial scale. Some crucial physiochemical properties of those fibers changed due to chemical (silicon softener, NaOH, Na2CO3, H2O2, MgSO4) and bio-chemical (Aloe Vera, castor oil, cottonseed oil, fat, and soap) treatment. Natural fiber (NF) from fake banana is a number of the widely used herbal fibers within the Southern part of Ethiopia.

Mohammed et al. (2015) studied about energy conservation and environmental pollution emerge as a serious concern across the world; European and many devolved countries are discovering and developing electric vehicles to lessen gas consumption and exhaust emissions. They take a look at how to grow the battery's ability to boom vehicle mileage. However, the electric automobile has an extraordinary problem in use that the car may be very heavy due to the battery weight, charge capability, and frame structure, so that electric vehicle mileage decreases.

Alma Hodzic et al. (2014) investigated that weight is one of the basic fuel economy factors for automobile design as shown in Fig 2.12.

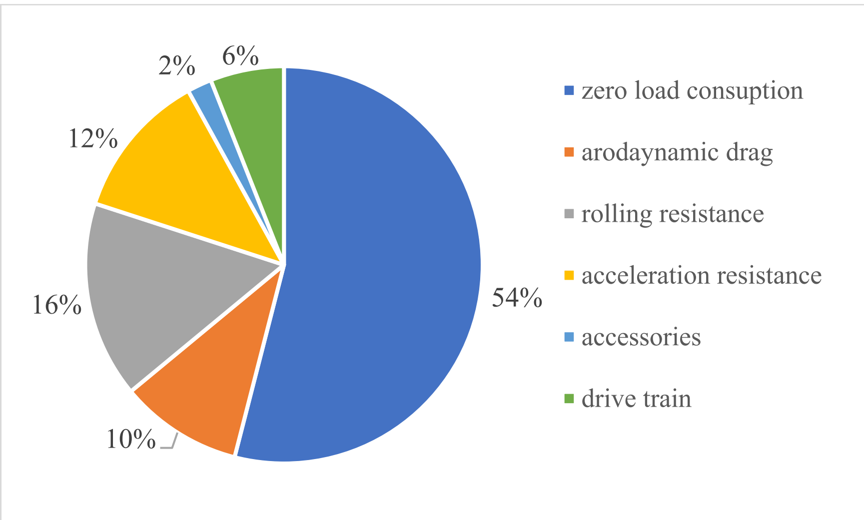

Fig. 2.12.Impact of vehicle weight on NEDC (New European Driving Cycle)

E. Ikpe et al. (2017) studied that lighter materials are being developed to reduce automobile's weight for cost and emission reduction; out of those lighter materials, composite materials have been investigated for their probable use as impact energy-absorbing elements as shown in Table 2.4.

Table 2.4.Comparison of Average energy consumption and CO_2 emissions

	All steel body	All aluminum body	Change/kg
Gross vehicle weight	2500kg	2075kg	1kg
Average energy consumption	11.8L/100km	9.9L/100km	4.47ml/100km
CO_2 emissions	220g/km	199g/km	0.0494g/km

Horstemeyer et al. (2009) investigated that occupant safety may be analyzed and enhanced via maximizing energy absorption of structural additives during effect has been prevalent for vehicle designs via many manufacturers. It turned into investigated that the similarities and variations between designing vehicular structural additives experience aspect impacts primarily based upon two distinct criteria:

- ✓ The energy absorption of collapsed components in the absence of a dummy and
- ✓ An injury metric–based approach with the responses of the dummy as the bases.

To decrease weight and a constraint at the lateral intrusion distance, the designs are based on both standards that were evaluated underneath the identical side-effect scenarios. The optimization happened at the thicknesses of side-door components as design variables and as a consequence is a length optimization problem. To lessen the computational costs of optimization, involving expensive crash simulations, the radial basis function approximations of goal and constraint capabilities were adopted. Both side-effect simulations (dummy-interactive and without a dummy) had been accomplished by way of the usage of FMVSS standard shifting deformable barrier (MDB), with all wheels turned around 270 from the longitudinal axis, impacting a stationary check automobile with a 54 km/h (33.five miles/h) last speed. For an average passenger car, the left edge of the MDB is 940 mm (37 in.) in advance of the midpoint of the impacted automobile wheelbase. The MDB has a complete mass of 1367 kg (3015lbs). The aluminum honeycomb of the barrier face is specified through the layout. The bottom edge of the MDB is 280 mm (11in.) from the floor Generally due to its weight factor using steel to build the car frame has numerous related problems. The number one issue is the load that is chargeable for gas consumption again leads to economic inflation. Composite substances can update current steel, nonstructural cloth additives due to their comparable power absorption capability. The composition can be from any aggregate that gives a higher overall performance in weight, life, and economy.

Mehamud et al. (2016) identified that composites fibers from the natural sources provide indisputable benefits over artificial reinforcement substances which include low cost, low density, non-toxicity, comparable power, and minimum waste disposal problems. In the prevailing test banana fiber, strengthened epoxy composites are to be fabricated and the mechanical houses of these composites are to be evaluated. The composite samples with one-of-a-kind fiber extent fractions are to be organized via the usage of the hand lay-up process. The samples are to be subjected to mechanical testing which includes tensile, flexural, and effect loading.

Patil A.S. and N.B. (2019) observed that easy plate made from jute fiber, epoxy resin (AY-105), and hardener (HY-951) within The density and dynamic viscosity of epoxy at 25^0C is 1.109 g/cm3 and 11789 Pa. respectively and finally compare jute fiber with regular fiber composite. Surface treatment was completed on jute fibers to produce powerful jute reinforced fiber epoxy composites. An improvement has been observed inside the bodily appearance of the jute fiber while reading with the bleaching agent. At three different temperature conditions, a silane remedy was carried out at the bleached jute fibers. The mechanical properties showed an enhancement because of silane treatment. Also, the liquid retaining capability of the handled fibers multiplied which indicates higher wetting homes of the jute fibers. Finally, Successful fabrication of the bidirectional jute fiber reinforced epoxy composite has been finished using the hand lay-up technique. They finish that from the look at of the jute epoxy composite, Jute fiber composite gives higher tensile energy, flexural power, Compression electricity, Impact strength, and Long jute fiber electricity is greater than the fast jute fiber.

T. Madhusudhan (2016) states that the composites from natural fibers and fillers as a sustainable alternative material for a few engineering packages, specifically in aerospace and vehicle productions. Natural fiber composites are greater attractive due to their highest specific electricity, lightweight, biodegradability, and low cost. They studied that the hybrid composite is inside the form of jute/glass fiber, sisal/glass fiber, herbal rubber/glass fiber, herbal rubber/jute fiber. For the hybrid composite, the epoxy resin is used as a binder. Epoxy resin in the hybrid composite will result in a sturdy bond for the substances. By adding the filler to the composite cloth, we can also improve the overall performance of composites and that they used the silicon carbide as a filler. Natural fibers which include sisal and jute fiber composites substances are replacing the glass and carbon fibers due to their smooth availability and cost. Natural fibers are lighter and cheaper, however, they have got low mechanical residences than glass fibers. The addition of herbal fiber to the glass fiber could make the composite hybrid and glass fiber has a high electricity/weight ratio. Natural fibers along with sisal and jute fiber composites substances are replacing the glass and carbon fibers due to their easy availability and cost. Natural fibers are lighter and cheaper, however, they've low mechanical homes than glass fibers. The addition of herbal fiber to the glass fiber can make the composite hybrid and glass fiber has high energy/weight ratio then they finish the following the aggregate of the beneficial residences of two specific substances, making them a versatile material within the subject of engineering and technology.

- ✓ The hybrid composites of jute/E-glass fiber have better properties than that of the jute fiber.
- ✓ The hybrid composite has better strength as compared to the composite fabricated separately. The mixing of natural fiber with Glass-Fiber reinforced polymers are finding increased applications.

Sanjay and Yogesha (2016) studied the hybrid effect of composites fabricated from jute/E-Glass fibers is fabricated with the aid of hand layup technique using LY556 Epoxy resin and HY951 hardener. It is determined that the hybrid composite has better power in comparison to jute fiber composite fabricated one after the other with glass fiber. The incorporation of glass fiber in jute fiber composites complements the mechanical houses and it increases the usage of natural fibers in various applications. States that Natural fibers offer both price savings and discount in density when as compared to glass fibers. Natural fibers are an alternative aid to synthetic fibers, as enforcement for polymeric materials for the manufacture is cheap, renewable and environment-friendly.

2.17. Automotive Body Panel Materials and Analysis in the Past

Terciu et al. (2012) presented the finite element analysis of an automotive door trim panel made of lignocelluloses composites to determine the stresses and displacements in case of a door slam simulation. In research was investigated new lignocellulose 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 value displacements decrease is due to greater rigidity of lignocellulose material and smaller mass of the panel, given its reduced thickness. Since when slamming the door, the 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 the 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; 30

Sandeep et al. (2012) this study described the drawbacks of the existing automotive panel like door structure and suggest design changes to overcome the present drawbacks. Some of the major problems in the automobile door are taken as a 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 the 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 the weight of a door inner panel by using less thickness high strength material; reduce cost by replacing molded trim with the hard pad. It was successfully solved the water leakage problem by modeling the 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.

S.vinary and S.srikari (2012) 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 panel. It is applied by adding 30% of glass-filled on the existing steel materials. It improves strength, stiffness, and manufacturability.

Tawanda and Charles (2011) used FEM 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

Vijayan.P, (2016) studied design and analyze of the Side impact on the lightweight 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 at different speeds and the crashworthiness is studied. The analysis is done at different speeds and the crashworthiness is studied. Final analysis results are compared with the Federal Motor Vehicle Safety Standard for crashworthiness and the best of the result will be concerning lightweight design. The car door model assembly of outer and inner panel is done using modeling software CATIA P3 V5R14 and also analyzed using it.

2.18. Boot Lid or Trunk Lid

It is the section of the auto which located the rear Side phase of the car used to close and open the baggage or storage compartment.it is the main rear section that confronted the drag pressure due to the fact of the shape or the graph on these pare. There is a wake section around the boot lid so it affected through aerodynamic pressure. And also, the part has confronted the rear collision however collision in most cases secondary because in particular the collision in the rear bumper. so after the bumper crush subsequently the power transfers to the boot lid. Now a day computerized boot lid or trunk lid has been added to the mass must be light to attain this specific future of boot lid. Especially, aluminum alloys have begun to be used for several automobile parts for its low precise gravity (approximately 1/3 of steel). Now the use of aluminum alloy is not limited to traditional castings such as engine blocks however extends to hoods, trunk lids, outer panels such as doors and protection covers such as warmness insulators Fig.2.13 below shows the outer panel of the vehicle body (https://informationparlour.com)

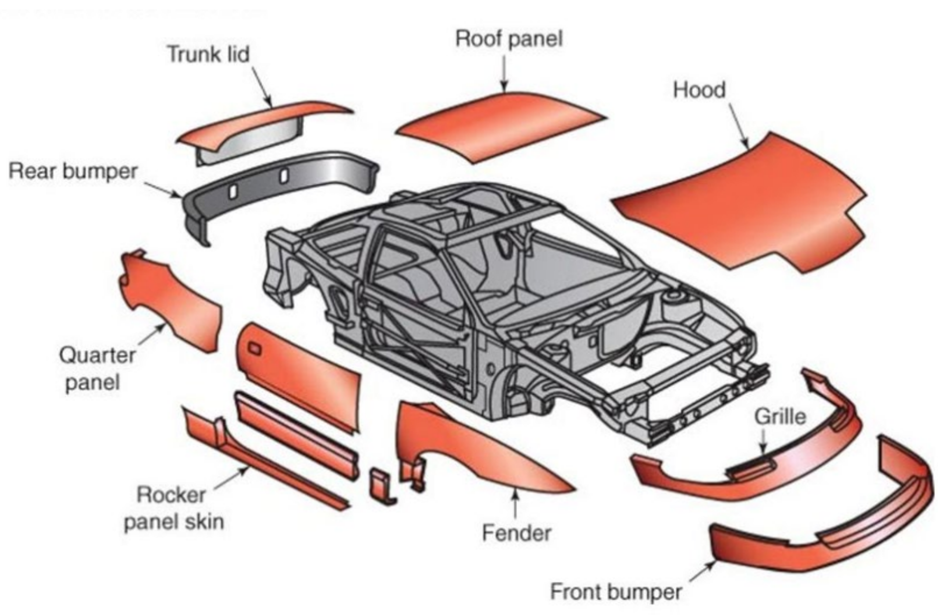

Fig. 2.13. Outer panel of the vehicle body

At the end, coming to choose the natural fiber which is enset or false banana fiber, jute fiber, and synthetic fiber of E-glass because of: -

- ✓ False Banana fiber is one of the typical fibers with well mechanical properties. They are easy and great extent accessible in nature. Their handling isn't a hard association with the normal filament's generation. Banana fiber is mixed with different types of composites to rise its mechanical properties (Rao et al., 2017).
- ✓ The other interesting thing is both plant fiber is similar in structure and has closer physical properties. Therefore they can be easily hybridized. Additionally, both fibers have almost close up physical properties (Mochane et al., 2019).
- ✓ best results achieved through the use of natural fiber composites reinforced with synthetic materials like E-glass fiber. (Sanjay et al., 2016).
- ✓ natural fibers like jute, hemp, flax, and sisal have been a part of high-tech development and began to remove their neglect and is gaining favorite over glass fiber and carbon fiber due to their low-cost and low weight characteristics (Furqan et al 2015). from those listed above natural fiber have better mechanical properties but because of availability jute is better to select.

Summary

Generally, to summarize this chapter, several experimental investigations were done to characterize the mechanical properties of the false banana, jute, and glass fiber reinforced composite materials. Through an exhaustive literature review, it has been observed that the study of mechanical behavior of sisal, bamboo, false banana, jute, etc fiber hybrid with other synthetic fiber, specifically hybrid false banana, jute, and glass 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, 60/40, 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%) and the mixing ratio of hardener varies from 1-3% of the polyester resin in weight ratio.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Materials

The mathod used in this work beginning from descriptions of this composite material, two mains composite components were considered the reinforcement (False banana fiber, jute fiber, and E-glass fibers), and matrix (resin) constituents.

3.2. Materials for the Preparation of Hybrid Composite

Resins are of maximum importance inside the composite's markets as they bind the fibers collectively and help create the material's energy and stiffness characteristics. There are two varieties of resin systems: thermoset and thermoplastic. In a thermoset, the resin molecules are locked together irreversibly after a thermal therapy; it is a one-manner treatment that can't be undone. In a thermoplastic resin, the chemical link that's bonding the molecules together may be broken again and again by growing the temperature regularly which reasons the matrix to head 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 within the composite industry: Polyester, Vinyl Ester, Epoxy, and Phenolic Resins; Among distinctive thermoset, resin polyester is used for this work.

I. **General Purpose Polyester Resin** is shown in Figure 3.1. was used as a binding material which is otherwise known as a matrix material to make a perfect bond between the fibers. It is mostly used thermoset plastic in polymer matrix composites industry due to its low cost, availability, suitable for hand lay-up at a convenient atmospheric condition.

The main application of resins: (Naveen Konnur, 2014).

- ✓ for the construction of small, medium-sized boats and other applications.
- ✓ Suitable for general-purpose industries, artificial rock, dustbin, road signage.
- ✓ FRP furniture and panels.
- ✓ Suitable for application where good wetting and impregnation of reinforcement required

Fig. 3.1.GP polyester resins

Polyester Resins are shown in the above Figure 3.1 the most widely used resins in the composites industry and were used in this work also. Sometimes referred to as Fiber glass Resins, Polyester Resins are less expensive, offer some corrosion resistance, and more tolerant than epoxies. The majority of all fiberglass parts are constructed using Polyester Resins because they are easy to use, fast curing, and tolerant of temperature and catalyst extremes.

II. **Catalyst:** This is colorless liquid however assumes yellowish color due to impurities formed using air oxidation. It is commonly soluble in polar solvents and commonly reactive to amines. GP Polyester Laminating Resin ought to be combined with MEKP Catalyst at a ratio of 1-3%, by way of weight. Resin to catalyst ratios above is indexed as parts with the aid of weight even though parts by extent will efficaciously yield equal results. The ratio of resin and catalyst right into a straight-sided container and the usage of a suitable blending stick begins to mix the resin and catalyst to combine them completely (Easy Composites Ltd, 2019). Mixed properly in any other case shown in Figure 3.2a. (S Arun Prasath, 2018).

Fig. 3.2 (a). Mixing the resin and catalyst (b) Stir the mixture of resin and catalyst

III. **Wax:** After preparing the mold and clean with the brush; Maguire’s Maximum Mold Release Wax (M-08 v 2.0) shown in Figure 3.3 was used for easy release of mold from the composite material. Applying a thin coat of wax and wipe off or polish the haze/obscure/ part using a cloth towel is recommended for better performance of the material.

Fig. 3.3.Maximum Mold Release Wax

IV.**Fiber** is the reinforcing segment of a composite material. In this research work, false banana, jute, and E-Glass hybrid fiber have been taken as the reinforcement within the unsaturated polyester matrix to fabricate composites.

Glass fiber is light in weight, extraordinarily strong, and robust. Its bulk strength, stiffness, and weight properties are also very favorable when in comparison to metals. The E-glass fiber with the random orientation shown in Figure 3.4 below. This sort of glass combines the characteristics of E -glass with very good insulation to electricity.

Fig. 3.4. Chopped Strand Mat E-glass fiber

Jute fiber has some precise bodily properties like excessive tenacity, bulkiness, sound & warmness insulation property, low thermal conductivity, antistatic property, etc. Due to those qualities, jute fiber is a greater desire for the manufacture of technical textiles in certain precise areas. Jute is 100% bio-degradable and thus environment- friendly. It is to be had in India at aggressive prices. Now it isn't just a first-rate fabric fiber, but also a raw fabric for non- fabric products, which facilitates to guard the surroundings, which is an integral part of any development planning (Wang et al., 2011).

Jute fibers have one of long fiber type natural fiber as shown in Figure 3.5. and also known as strong, coarse, surroundings friendly, and organic. The use of jute was mainly constrained to marginal and small producers and growers, however now it's far used as an important raw cloth for numerous industries. Jute is termed as a favorite material for packaging substances and furnishings. Jute fibers are used for making mats, gunny cloth, cordage, hangings, paper, and decorative articles.

Fig. 3.5.Jute fiber

False Banana fiber is likewise called enset which growing within the areas of southwest highlands Ethiopia. This does not mean that false banan is cultivated and used the simplest in these regions as meals. It is standard meals within the southwest, central, towns, and cities with the Ethiopian delicious food, kitfo. False banana (Enset) is a member of the same botanical circle of relatives because the banana, however which isn't always producing its fruit like a banana.

The fundamental edible elements of the enset plant are the stiff stem and pseudostem. It is also the main food warranty for greater than 15 million people in the southwestern part of Ethiopia. The fiber, having a hair-like structure, locally called “kancha” is gathered after scarping of the leaf sheath and leaf bases around the pseudostem as shown in Fig 3.6 below. The internal a part of the pseudostem is without a doubt discarded as waste. These residues are abundant natural sources and can be a capability source of cellulosic fiber.

The extraction technique is manually by a hand and its primary goal is to get food ‘kocho’ and the byproduct of this manner is banana fiber material. this can be collected from the southern components of a country and markets promote different functions in markets (Admasu, 2002).

Fig. 3.6.False banana fiber

V.**Sodium Hydroxide (NaOH)** Also called lye or caustic soda has the molecular formula NaOH and is an incredibly caustic base and alkali salt. Pure sodium hydroxide is a faded solid, which is accessible in pellets, flakes, granules, in this work NaOH became used in pellets form as illustrated in Figure.3.7.

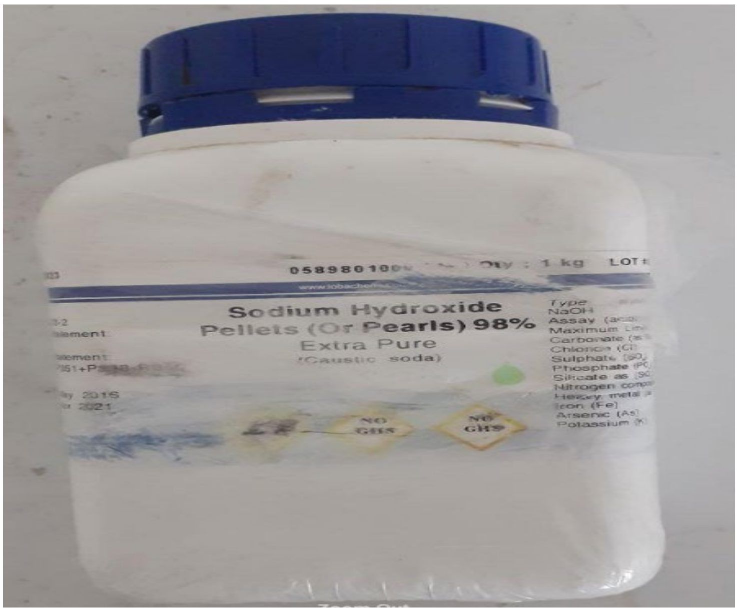

Fig. 3.7.Sodium hydroxide pellet

3.3. UTM Test Machines

UTM test machines were used in this work to find different mechanical properties of prepared composite material. Compression, bending tests, and Tensile test, respectively were tested in Defence University college of engineering, Bishoftu. department of metallurgy and material engineering, workshop with a machine set up shown in Figure.3.8.

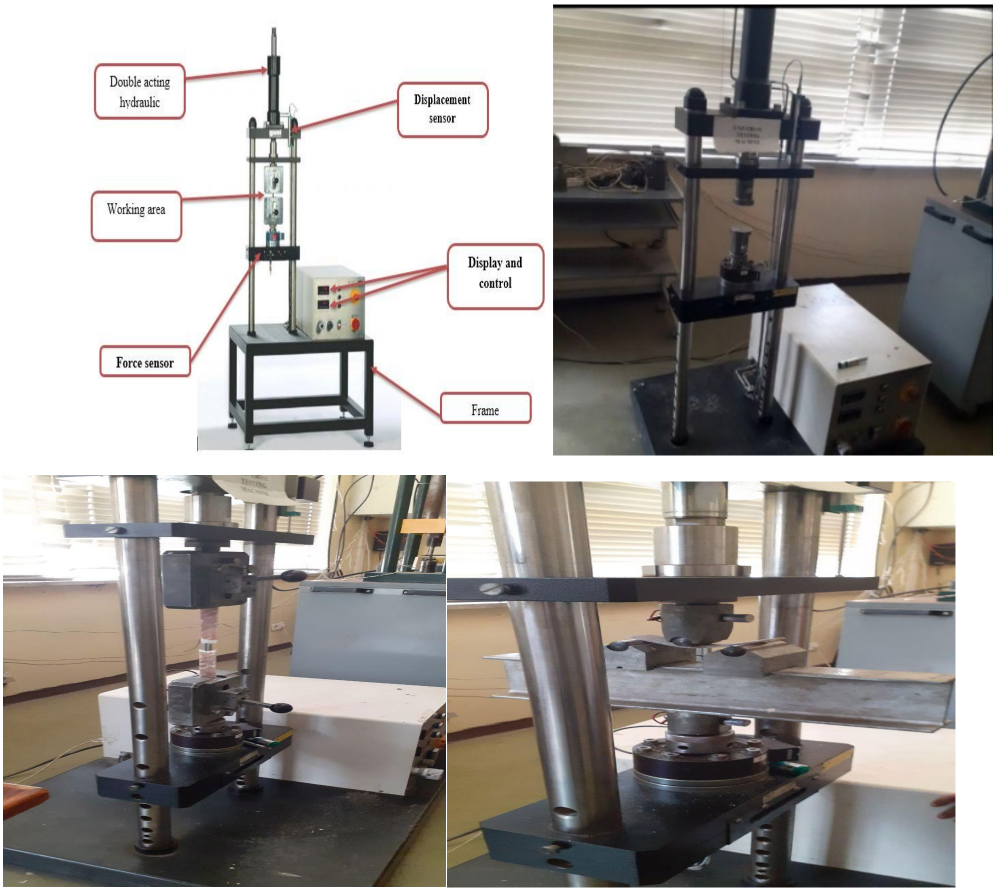

Fig. 3.8.Universal Test Machines

The next properties that were found in this work were impact tests examined in Debrebirhen university with the test setup shown in Figure 3.9.

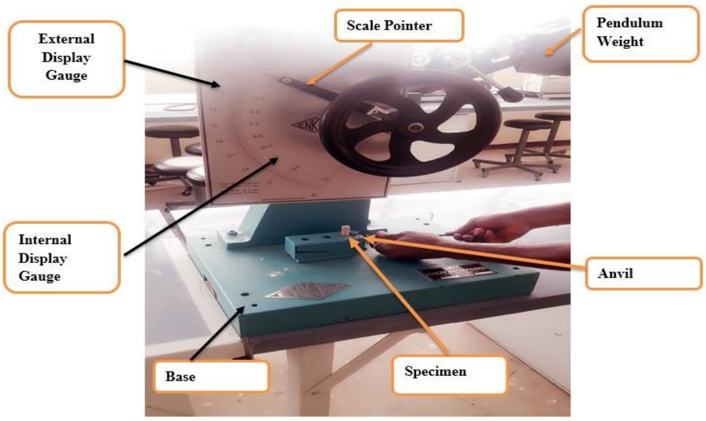

Fig. 3.9.Impact test machine

3.4. Methods

Various steps followed in methodology of the thesis work were shown in the form of flowchart shown in the Figure 3.10.

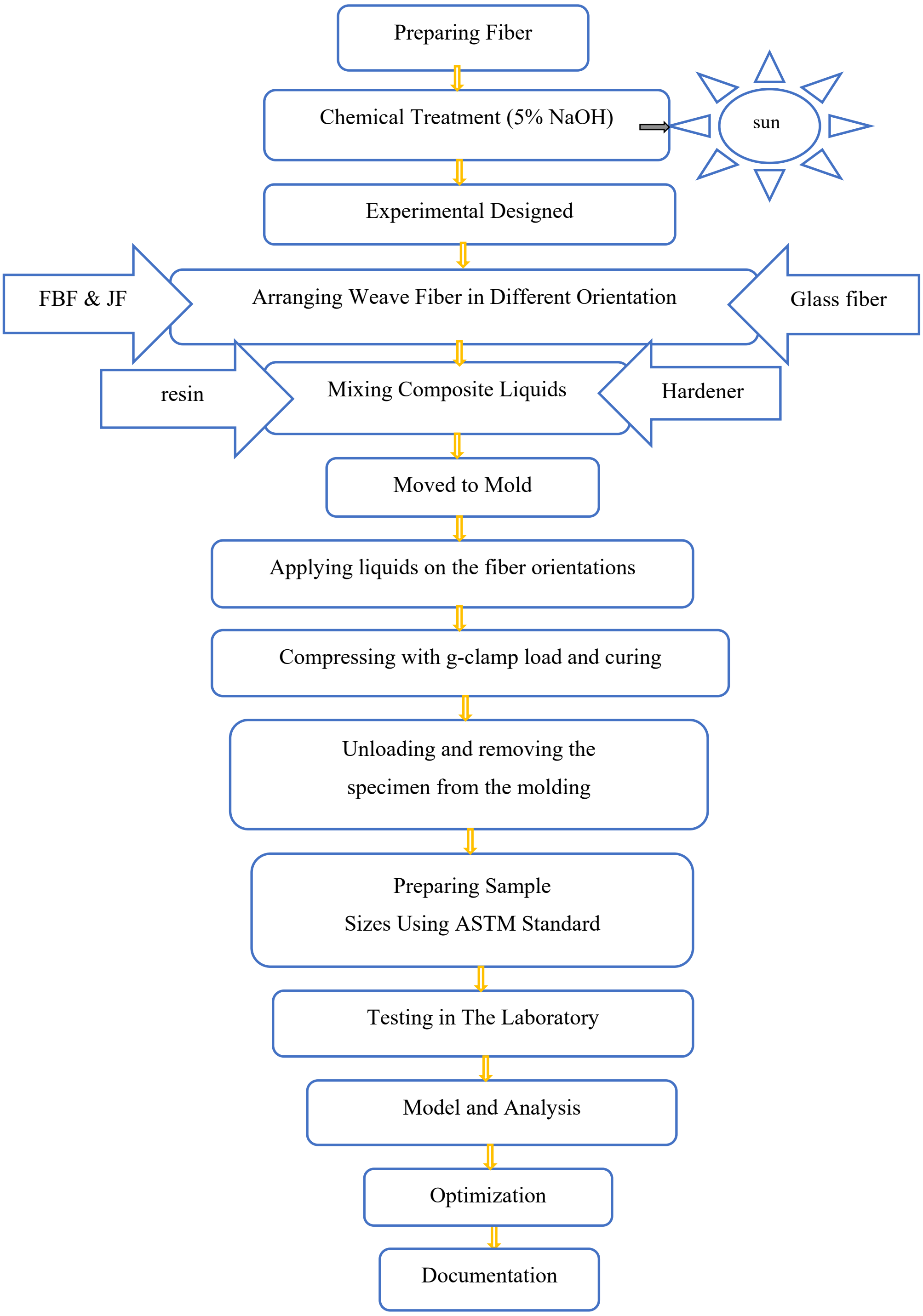

Fig. 3.10. Flow chart of methodology

3.4.1. Visits

Automotive maintenance companies are visited to have knowledge about different components and structure of the trunk lid. Even if it is difficult to replace the whole component in private garages, they try to modify and maintain the deformed part only and reinstall. In large companies like MOENCO they replace with its importable component designed for its own model. So visiting those companies gave information how trunk lid failures are look like, what action are they are taking and what its internal structure contains using sectional view, finaly information aboute the cost also.

3.4.2. Experimental Design

The primary influential factors in determining the tensile, compression, flexural, and hardness strength of the composite on the proportion of the fiber and matrix. Hence, the test changed into planned to be conducted with various weight possibilities of fiber, diverse composite mixing ratio, and various orientation of reinforcement with unique values of polyester resins. Most of the literature found that the weight percentage of natural fibers are in the range of 40-60%. Thus, 40% of fiber weight fraction and 60% of matrix weight fraction are taken.

3.4.2.1. Taguchi Design of Experiment

The following steps are followed in Taguchi design test procedure

Step 1: Define the problem and noise factors

Analysis of the influence during the preparation of molding for tensile, compression, bending, and impact strength of hybrid fibers reinforced polyester resin composite material are: weight percentages of false banana-jute-glass fibers, fiber orientation, and the effect of mixing ratio of polyster resin and catalyst.

Step 2: Identify design parameters that influence product properties

The composite product performances are mainly affected by the composition of material variants and proportions. Hence, the fiber orientation, fibers weight percentage, and mixing ratio during hand lay-up molding are considered as design factors that affect the characters of composite material.

Step 3: Determine Control Parameters, Response Variables, and Their Levels

The response variable is the parameter that performs the product or process. Hence, the tensile, compression, bending or flexural and impact strength was chosen as a response variable for the investigation. Control parameters are the variables that influence the output of the process or the product. Based on the literature survey, reinforcement, and matrix factors listed in Table 3.1 were chosen as the control parameter and their levels.

Step 4: Select Orthogonal Array taguchi uses the following convention for naming the orthogonal arrays: L_a (b^c), where a is the experimental runs, b is the levels of each factor, and c is variables. Several levels of factors are used in orthogonal arrays. In this investigation, three factors two levels selected by considering the number of factors and levels possible to determine the orthogonal arrays on MINITAB 18.1 software. finally *L4* (level two factor three) orthogonal arrays. feeding the number of control factors and level on MINITAB 18.1 software then displays the combination of level and factors are shown in Table 3.2 and 3.3 were used.

Table 3.1 Control factors and their level.

Item	Control factor	Level 1	Level 2
A	Orientation	0^0 Jf with 90^0 FBF	0^0FBF with 45^0JF
B	Mixing ratio	1:1	3:1
C	Weight % of FBF with JF	20%FBF with 10%JF	10%FBF with 20%JF

Table 3.2. L4 Orthogonal Array

Expt.no.	A	B	C
1	1	1	1
2	1	2	2
3	2	1	1
4	2	2	1

Table 3.3.Substituted Matrix

Expt.no.	Orientation	Mixing ratio	The weight percentage of FBF with JF
1	0^0 Jf with 90^0 FBF	1:1	20%FBF with 10%Jf
2	0^0 Jf with 90^0 FBF	3:1	10% FBF with 20%Jf
3	0^0 Fbf with 45^0 JF	1:1	10% FBF with 20%Jf
4	0^0 Fbf with 45^0 JF	3:1	20% FBF with 10%Jf

3.4.3. Fiber Matrix Weight and Volume Fraction Content of the Composite

In the research, the ratio of the polyester resin and false banana- jute-glass fiber used in the sample preparation was based on the weight ratio. This means the weight of both polyester resin and fiber was measured using an electronic balance. In design, fabrication, and analysis of composite materials, the first and critical task is the determination of ingredient percentages such as false banana- jute-glass fiber and polyester matrix fraction presenced in laminate (Mohd et al. 2015). These components are microstructural elements of the composite laminate in which composites' strength and properties are determined and limited by these values. In generals, results obtained from the equations presented below are mandatory for:

- ✓ Composite laminate preparation

- ✓ To use the ASTM standard to determine the size of laminates that meets the ASTM requirements before laminate fabrication, these values are necessary.
- ✓ The improvement of fabricating laminated for the future by varying these values.
- ✓ These values can be used as a design manual in collaboration with composite laminate's different experimental results, which are fabricated, by this content.

3.4.3.1. Fiber and Matrix Volume Fraction (VF, VM)

Consider a composite material that consists of fibers and matrix material. The volume of the fiber is equal to the ratio of the weight of the fibers to the density of the fibers (Mallick, 1993). Therefore,

$$Vf = \frac{Wf}{\rho f} \tag{3.1}$$

Where Vf is a volume of fiber; Wf is the weight of fiber; ρf density of fiber

The volume of the matrix is also equal to the ratio of the weight of the matrix to the density of the matrix.

$$Vm = \frac{Wm}{\rho m} \tag{3.2}$$

Where Vm is a volume of the matrix; Wm is the weight of matrix; ρm density of the matrix.

The volume of the composite material is equal to the sum of the volume of the fibers and the volume of the matrix.

$$Vc = Vf + Vm \tag{3.3}$$

Where Vc is the total volume of composite; Vf is the volume of fiber; Vm is the volume of the matrix. The fiber volume fraction of composite is described by the ratio of the volume of fiber to the volume of the composite.

$$VF = \frac{Vf}{Vc} = \frac{Vf}{Vf+Vm} \tag{3.4}$$

Where VF is fiber volume fraction.

The matrix volume fraction of composite also described by:

$$VM = \frac{Vm}{Vc} = \frac{Vm}{Vm+Vf} \tag{3.5}$$

Where VM is the matrix volume fraction

The sum of fiber volume fraction and matrix volume fraction equals the unit.

$$VF + VM = 1 \tag{3.6}$$

From this volume fraction of fiber and volume fraction of matrix can be described;

$$VF = \frac{Wf*\rho m}{Wf*\rho m+Wm*\rho f} \tag{3.7}$$

$$VM = \frac{Wm*\rho f}{Wm*\rho f+Wf*\rho m} \tag{3.8}$$

3.4.3.2. Fiber and Matrix Weight Fraction (WF, WM)

Assuming that the composite material consists of fibers and matrix material, the weight of the composite material is equal to the sum of the weight of the fibers and the weight of the matrix (Mallick, 1993). Therefore,

$$Wc = Wf + Wm \tag{3.9}$$

Where Wc is the total weight of the composite

The weight fractions (mass fractions) of the fiber and the matrix are defined as

$$WF = \frac{Wf}{WC} = \frac{Wf}{Wf+Wm} \tag{3.10}$$

Where WF is fiber weight fraction, and

$$WM = \frac{Wm}{Wc} = \frac{Wm}{Wm+Wf} \tag{3.11}$$

Where WM is the matrix weight fraction

$$WM + WF = 1 \tag{3.12}$$

3.4.3.3. The Density of the Composite

The density of composite material can be defined as the ratio of the weight of the composite material to the volume of the composite material (Mallick, 1993). and expressed as:

$$\rho c = \frac{Wc}{Vc} \tag{3.13}$$

Where ρc is the total density of the composite.

but, $Vc = Vf + Vm$, and $V = \frac{W}{\rho}$, therefore equation (3.13) can be rewritten as:

$$\frac{Wc}{\rho c} = \frac{Wf}{\rho f} + \frac{Wm}{\rho m} \tag{3.14}$$

By multiplying with a ratio of one by weight of composite both sides get

$$\frac{1}{\rho c} = \frac{1}{\rho f}\left(\frac{Wf}{Wc}\right) + \frac{1}{\rho m}\left(\frac{Wm}{Wc}\right) \tag{3.15}$$

3.4.3.4. Calculation of the Weight of Fiber and Matrix for Specimen Preparation

The volume of the composite was calculated by multiplying the length, width, and breadth of the mold prepared for molding the composite material. The dimension of the mold for this research is taken based on the literature.

Volume of the mold (VC) $= 300 * 350 * 4 = 420{,}000$ mm^3 $= 420$ cm^3

From literature, the density of polyester resin, false banana fiber, jute fiber, and E-glass fiber is 1.2g/cm^3, 1.31 g/cm^3, 1.5 g/cm^3 and 2.54 g/cm^3 respectively.

$$V\,\text{Composite} = V\,\text{fiber} + V\,\text{polyester}$$

To calculate the density of the composite

The predominant influential factors in figuring out the tensile, compression, flexural, and hardness energy of the composite depend on the percentage of the fiber and matrix. Depending on several literature evaluations this has a look at considers 40% and 60% of fiber to matrix volume fraction. The quantity fraction of every composite sample for 40% of fiber; 20% false banana, 10% jute, and 10% E-glass fiber, and the closing 60% of polyester resin is used. By using equation (3.15) the density of the composite sample is calculated:

$$\frac{1}{\rho c} = \frac{1}{\rho f}\left(\frac{Wf}{Wc}\right) + \frac{1}{\rho m}\left(\frac{Wm}{Wc}\right)$$

$$\frac{1}{\rho c} = \frac{1}{(1.31 + 1.5 + 2.54)}\left(\frac{0.4}{1}\right) + \frac{1}{1.2}\left(\frac{0.6}{1}\right)$$

$$\frac{1}{\rho c} = 0.574767$$

$$\rho c = 1.74 \text{ g/cm}^3$$

From equation (3.13) we have

$$Wc = Vc \times \rho c$$

$$Wc = 420\text{cm}^3 * 1.74 \text{ g/cm}^3 = 730\text{g}$$

$$Wm = 60\% \text{ of } Wc = 0.6 * 730\text{g} = 438\text{g}$$

$$Wf = 40\% \text{ of } Wc = 0.4 * 730\text{g} = 292\text{g}$$

$$Wfbf = 20\% \text{ of } Wc = 146\text{g}$$

$$WJf = 10\% \text{ of } Wc = 0.1 * 730 = 73\text{g} = WGf$$

Where, W_{fbf}; wight of false banana fiber, W_{Jf}; wight of jute fiber, W_{Gf}; weight of glass fiber.From the above calculation Table 3.4 shows the weight of renforcement and matrix.

Table 3.4. Weight of renforcement and matrix

Level	Weight of JF in (gram)	Weight of FBF in (gram)	Weight of GF in (gram)	Weight of matrix in (gram)	Total weight in (gram)
1	73	146	73	438	730
2	146	73	73	438	730

Based on the above table data Finally, measure the weight of reinforcement and matrix component of the false banana- jute-glass fiber polyester matrix reinforcement composite in the electronic balance as shown below in Figure 3.11.

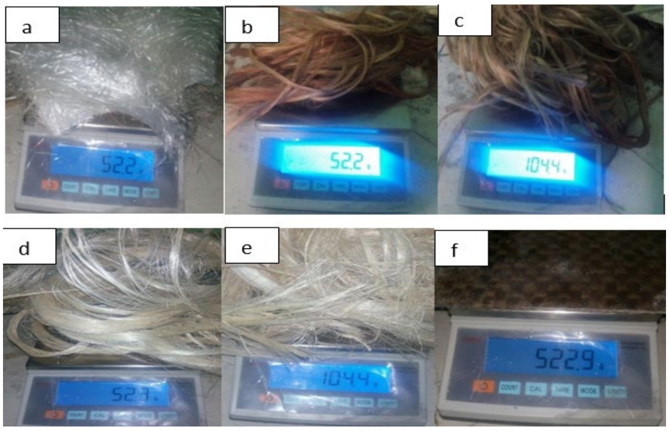

Fig. 3.11 Wight of measured fiber and composite (a)weight of glass fiber (b&c) weight of jute fiber (d & e) weight of false banana fiber (f) weight of finally made composite

3.4.4. Preparation of Composite Specimen or Sample Preparation Methods

The specimens were prepared as per Taguchi DOE and as per ASTM – D790 standared dimension. An overall of four experiments were carried out with in the orientation of fibers for two-level of Taguchi experimental design. Thus,two level of experiment focus on [0^0 Jf with 90^0 FBF,] and [0^0 Fbf with 45^0 JF]. So in this paper not considered glass fiber orientation on Taguchi experimental design. The composite materials used for the present research are fabricated through the hand layup process. Prepare Weave from false banana and jute fibers by making 300 cm length. This pattern guidance has extra similarities with the preparations of other natural and artificial composite materials that apply to specific engineering aspects.

3.4.4.1. Preparation of False Banana Fibers, Jute Fiber, and Glass Fiber

The fiber was organized in unique lengths for chopped and other orientations.For instance, for chopped specimens the length of jute and false banana fiber is cut into 20 mm length and 400 mm length for the woven strand orientations. This sample preparation has greater similarities with the arrangements of different natural and artificial composite substances that are relevant to distinctive engineering aspects.

The procedure to prepare the false banana, jute fiber, and glass fiber.

- ✓ Chopped Strand Mat fiberglass is purchased from the fiberglass market in Addis Ababa and cut into the mold size of 400 mm by 300 mm to lay up into the specimen molding prepared MDF.
- ✓ Collecting the jute fiber from the G-7 (G-seven trading and Industry P.L.C) and false banana fiber from the southern part of Ethiopia where it grows mostly. Figure 3.12 shows the collected jute fiber and false banana fiber respectively.

Fig. 3.12 Collected jute and false banana fiber respectively.

✓ Preparing the solution by mixing NaOH in distilled water inside the plastic container. The NaOH treatment also gets rid of the waxy and fatty acids from the cellular walls that are also answerable for the enhancement of the houses

Composite and Test Specimen Preparation (Venkatachalam N. and Navaneethakrishnan P., 2016). The EOSN fibers were treated with alkaline treatment the use of 5% NaOH in order to eliminate wax, lignin, oils, and different fiber parts that reduce adhesion between the matrix and fibers constituting a weak boundary layer (Ishidi, 2015). The time requirement to soak jute and false banana fiber with an awareness of a 5% base in distilled water.

✓ As unwanted components of the fiber are removed, it's miles washed with distilled and freshwater again and again until the base/NaOH concentration is removed. Finally, the PH value of the water used to wash may be tested. Distilled water is used from Adama Science and Technology University, the material science department with a distiller device has the potential of producing 15 liters within hrs. Figure 3.13 shows the set up for the distillation process.

Fig. 3.13. NaOH and water distiller setup respectively

✓ The jute and false banana fiber are soaked in the solution for 24 hours to resolve dirt, impurities, and increase thermal resistance roughness and mechanical properties.

Socking a false banana fiber into this distilled solution container more than this hour, it tends to damage and decreases the overall advantages.

✓ After soaking for 24 hours, the jute and false banana fiber were washed thoroughly with more amount of water to remove the base solution from the fiber completely.

✓ The jute and false banana fiber were dried for one day in sunlight.

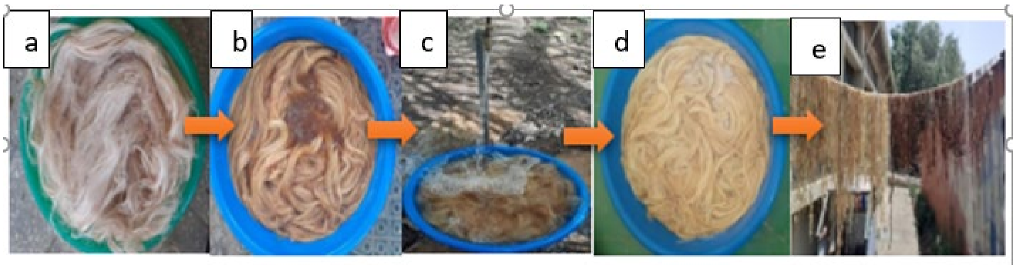

Fig. 3.14. Steps for Soaking fiber in NaOH solution and drying

Figure 3.14 shows steps for Soaking fiber in NaOH solution and drying. The alkali-treated natural fiber had been dried in sunlight at least for one day to remove the moisture completely. This helps the fiber to absorb more resin and enhance the mechanical properties of composites. The dried and pure fiber was used for the preparation of the composite by mixing with the glass fiber and a matrix of resin epoxy. After the composite plate is formed; based on the international standard (ASTM) test specimen was prepared and tested for different properties like tensile, compression, bending, and water absorption; which are required for vehicle body design.

3.4.5. Making Plain Weave

Plain weave is the simplest weave form. It is made via interlocking hybrid fiber in an irregular over-and-beneath pattern. There is one twist fiber for one fill fiber without skipping. The maximum fabric balance and inflexibility with minimum fiber slippage (failing to hold) result from this weave. The pattern offers uniform electricity in two directions when fiber length and matter are comparable in a twist and fill. This weave kind is the maximum resistance in shear and is also considered to be an alternative stiff weave. because simple weave fabric is stable, they're used for flat laminates. Making hybrid fiber weave with the orientation of 0^0 with 90^0 and $0^0/90^0$ with 45^0 (i.e. 0^0 FBF making weave with 90^0 JF and $0^0/ 90^0$ FBF making weave with 45^0 JF) as shown in Figure. 3.15 below.

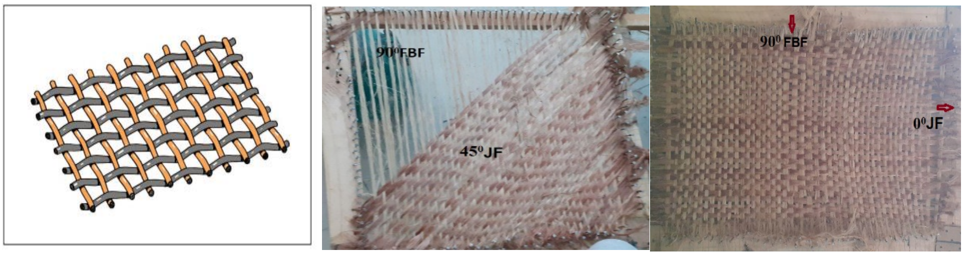

Fig. 3.15 Model and prepared bidirectional plain weave

3.4.6. Hand Lay-Up Technique

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 a better surface finish over the side that is in contact with the mold. The hand lay-up technique is the simplest method of composite processing.

Materials requirements of Hand-lay-up method

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

Mold: the wood plate surfaces are made up of HDF of 300mm 'x'350mm 'x' 4mm

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 for this work is Mold Release Wax 8.2 is chosen because of its excellent release properties, easy application, and exceptional mirror finish shine.

3.4.6.1. Hand Lay-up Process Set up

Molding The processing steps are quite simple. Jute, false banana, and glass fiber reinforced hybrid composite are fabricated using hand lay up method. Polyethylene Plastic was used at the top and bottom of the mold plate to get a good surface finish of the product. Reinforcement in the form of woven or bidirectional fiber was set as per the mold size and placed at the surface of mold after a transparent thermoplastic sheet.

Steps which were followed during fabricate false banana, jute fiber and glass fiber reinforced epoxy composite specimen

- First of all, Clean the HDF wood plat surface and the mold surface were polished by applying release gel/wax to avoid the sticking of polyester resin to the surface as shown in Figure 3.16.

Fig. 3.16. Applying release gel/wax to the surface

- Apply the fiber on the mold since the composite specimen includes 3 layers in which glass fiber layers are fixed in the bottom and pinnacle of the specimen. The second or the middle layers are stuffed with herbal fibers. Making hybrid simple weave sisal and jute fiber on 0^0 JF with 90^0 FBF and 0^0 FBF with 45^0 JF fiber orientation based totally on the Taguchi design of the experiment.
- Cut the fiberglass a little more than mold surface size and put this glass fiber as the first layer on a base surface plate then add mixed resin on the surface area of glass fiber.
- Use normal and roller brush to distribute the chemical solution uniformly and to remove out air bubbles from a glass fiber plus resin surface. the glass fiber reinforced polymer is filled with polyester resin. The resin got mixed with glass fiber reinforced polymer as shown in the Figure.3.17 and it tends to dry up within 15–20 min.

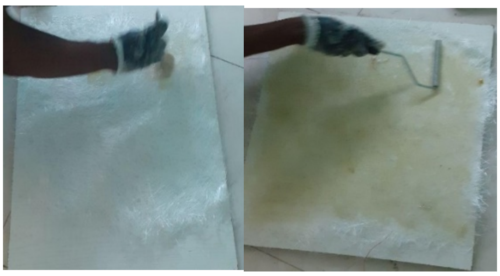

Fig. 3.17. Distributing the chemical solution uniformly and to remove out air bubbles

- Before the resin gets dried, the second layer of natural fiber is mounted over the glass fiber reinforced polymer applying resin on woven fabric jute, false banana natural fiber material(Plain weave), and the fiberglass. The same procedures are repeated for Weave fabric jute and false banana natural fiber too as shown in Figure 3.18.

Fig. 3.18. Applied resin on Weave fabric jute and false banana natural fiber

- Apply the final top E- glass fiber on the Weave fabric jute and false banana natural fiber material. repeated the same procedures here also. The final stage was Post curing of the mold to trap the air bubbles, the laminate was pressed in the weight press. Sufficient weight was placed on the mold of the laminate surface uniformly by Appling G-clamp vice on each corner of the mold as shown in Figure 3.19 and kept for 24 hours. after curing for 24 hours remove the pressed load.

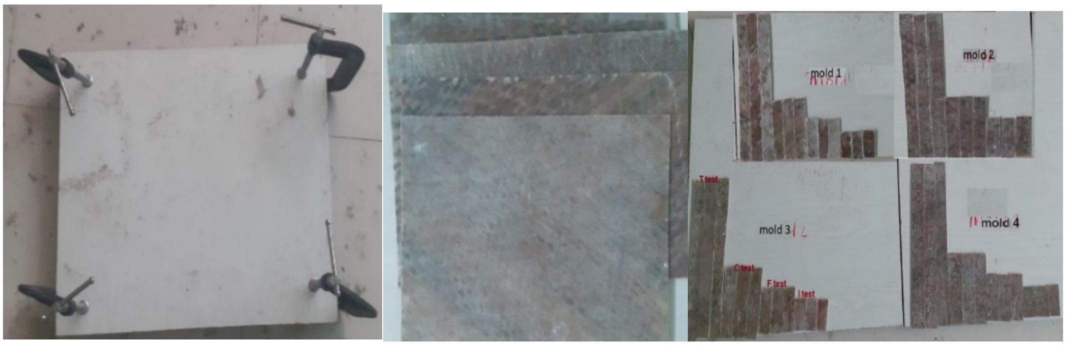

Fig. 3.19. G-clamp vice, release spaceman and specimen into the test piece respectively.

3.4.7. The Dimension of Test Piece

ASTM was used to prepare and conduct a test of this false banana -jute -glass fiber reinforced hybrid composite. All the test pieces for tensile, compressive, and Flexural testing based on ASTM standard and their value as shown below in Figure 3.20, whereas for impact test based on (ISO 9001:20001, 2010).

Fig. 3.20. Tensile test specimen

Fig. 3.21. Compression test specimen dimension

Fig. 3.22. Flexural test specimen dimension

3.4.8. Experimental Test

The composites were 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. So, specimens were prepared in the Eyosiyas Nikodimos wood workshop in Addis Ababa using a grinder as shown in Figure 3.24.

Fig. 3.23. Grinding The specimens

Each test is verified with an average of samples for the case of fiber orientations. (0^0 FBF making weave with 90^0 JF and 0^0/ 90^0 FBF making weave with 45^0 JF)

3.4.8.1. 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 failure. The specimen used for the tensile test is the flat type. During the test, a uniaxial load is applied through both the ends of the specimen. The dimension of the specimen is (300 x 350 x 4) mm. The specimen 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 for load and displacement for jute Fiber, false banana fiber, and glass fiber 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 a composite sample.

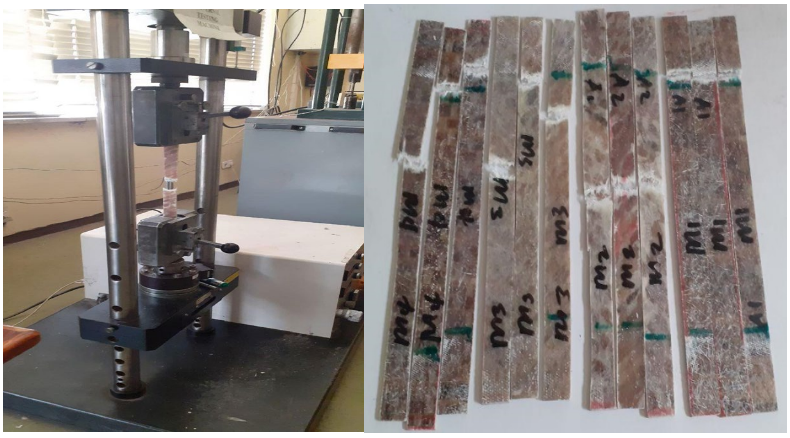

Fig. 3.24. Specimen fractured by UTM tensile force

The testing process involves fixing the test specimen in the testing machine and slowly extending by applying load until it fractures as shown in Figure 3.24. 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.

3.4.8.2. 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 3.25.

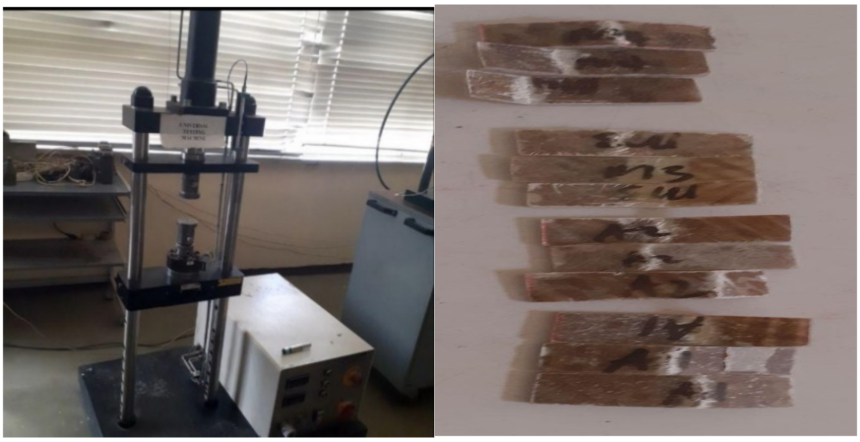

Fig. 3.25. UTM machine Sample a) loaded condition for compressive testing b) fracture of the compressed specimen

3.4.8.3. 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 the ASTM standard using UTM. The loading arrangement is shown in Figure 3.26. 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.

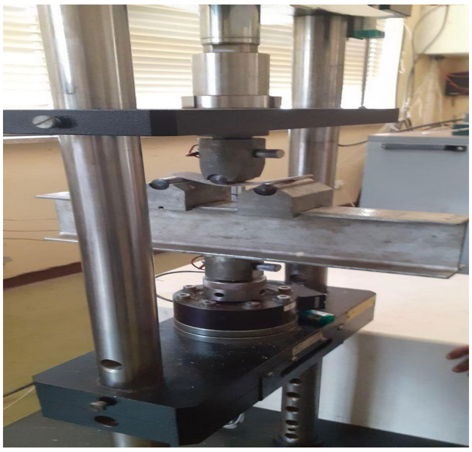

Fig. 3.26. The specimen under flexural testing

3.4.8.4. 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 Figure 3.27. The impact speed of the hammer is 3.8 meters per second having a 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 tests the energy needed to fracture material and can be used to measure the toughness of the material.

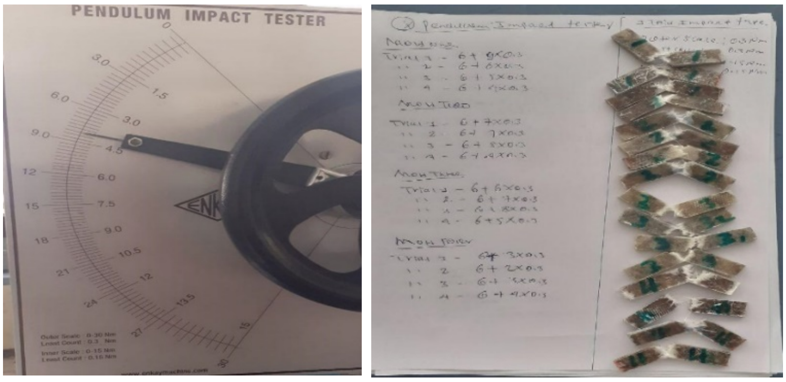

Fig. 3.27. Fixing of test conditions

3.4.9. 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.

The 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 to get the best structure. Due to the high cost of prototypes when developing new vehicle models, computer simulations of vehicle dynamics become more and more important in the product development process.

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).

The 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 a 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. To start of the problem, only parameters of the calculation regime should be added to the input file.

3.4.9.1. Finite Element Analysis of Trunk Lid Panel

Geometrical modeling of the trunk lid 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 research, the 3D modeling of the trunk lid panel done by using solid work software as shown in Figure 3.28 below. This is done by taking the actual data from a selected type of vehicle The corolla 1996 model vehicle is selected for this purpose. This vehicle is selected due to some reasons; such as corolla 1996 model vehicles are old enough to need spare parts for the replacement of their parts; such as trunk lid panel. Thus it will be feasible to implement the findings of this research on the selected vehicle Large number of this car available in the transport sector and easy to take data.

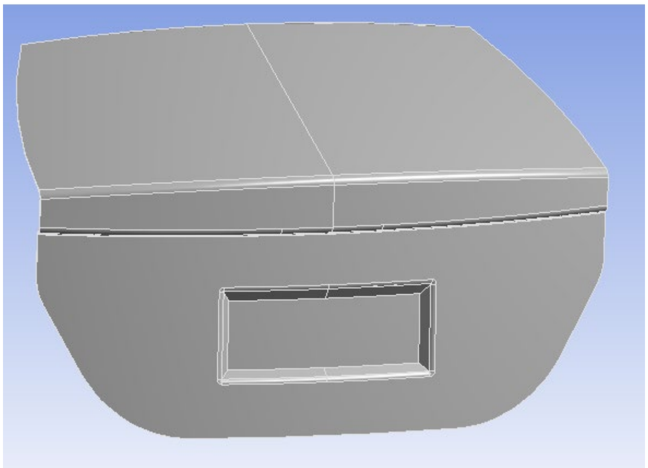

Fig. 3.28 Solid work modeling of the trunk lid

3.4.9.2. Assumptions and Declaration

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

The stress and strain character of the boot lid panel by applying a load on the surface, but not consider the full scale, Vehicle geometry, and the passage damage. the properties of the material of the boot lid panels were made of steel (outer part) and composite materials but the project would consider the simulation of boot lid panel composite materials. Table 3.5 below shows the mass of steel trunk lid (Jacobsson, 2013).

Table 3.5. Torsional stiffness and mass of boot lid

Boot lid configuration	Torsional stiffness[Nm/rad]	Mass [kg]
Original steel component	~9800 (estimated)	13.0
Monocoque design: 6MF slabs with 0°/±45° skin and 3.6mm stiffener wall thickness. (stiffness matched with steel component)	9740 (11% MF)	10.1

3.4.9.3. Importing the Model Geometry

The mechanical geometry model of the panel is done by space claim software. The finite element analysis, it should be imported to the ANSYS Workbench as shown in Figure 3.29.

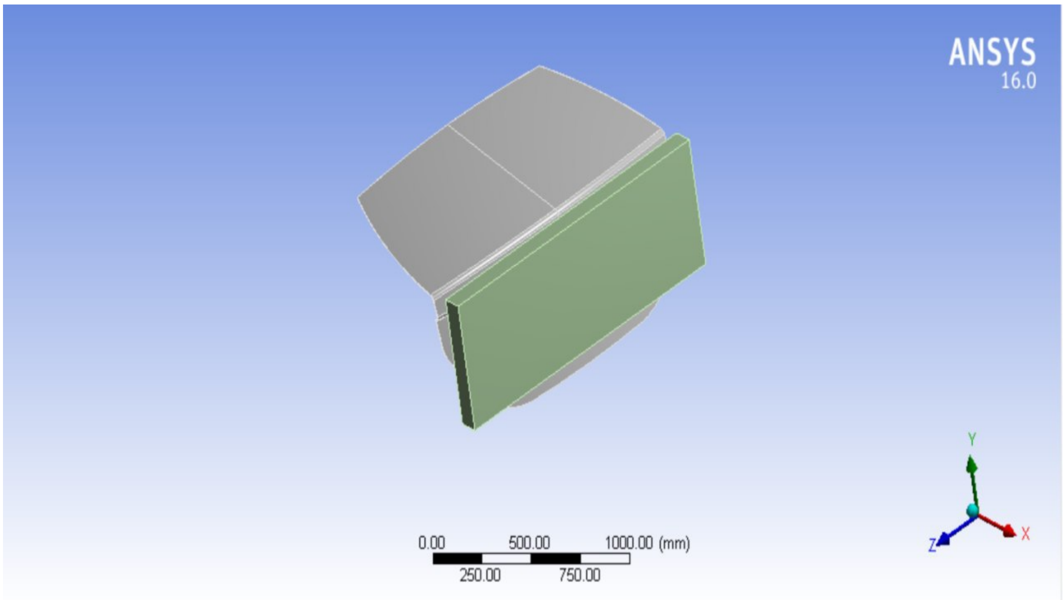

Fig. 3.29. Impactor and boot lid panel in Ansys workbench

3.4.9.4. 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 false banana-jute -glass fiber reinforced hybrid composite important material properties are taken from the experimental test result of composite in Table 3.6

Table 3.6. Mechanical properties of FBJGFRHC for mold 3

Property	Jute false banana glass fiber reinforced composite
Density (ρ)	1.74 g/cm^3
Tensile Strength	66.73 MPa
Flexural Strength	350 MPa
Compressive Strength	34.86 MPa
Young's Modulus	1809 MPa
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 that are connected 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 generated 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 the 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 upon 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. As shown in Fig 3.30 below.

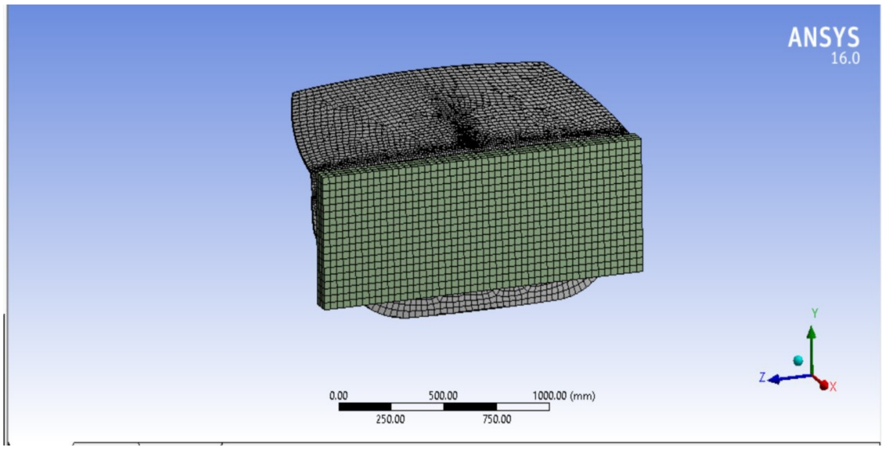

Fig. 3.30. Geometric meshing of the model on ANSYS Workbench

3.4.9.5. Generate Solutions

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

3.4.9.6. Application of Boundary Conditions and External Loads

The next step of finite element analysis involves applying appropriate boundary conditions and the proper loading mechanism.

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 to the model in a variety of ways in the ANSYS program.

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. Experimental Test Results

4.1.1. Tensile Strength

False banana, Jute fiber, and glass fiber reinforced hybrid composite were fabricated with 40 % fiber quantity fraction and 60 % matrix volume fraction in an (0^0 FBF making weave with 90^0 JF and 0^0/ 90^0 FBF making weave with 45^0 JF) orientation Weave cloth jute and false banana herbal fiber. Based on mass 20%false banana fiber, 10 % jute fiber with 10% of glass fiber and 10% false banana fiber, 20 % jute fiber with 10% of glass fiber used for the coaching of the composite. An overall of three specimens for every orientation has been used for repeatability. The variation inside the recorded take a look at results some of the three specimens in each of the orientations aren't significant. After checking out of the tensile test in a universal testing machine, the following are the graphs obtained as the load increases.

The graphs are followed as shown below.

- Force Vs elongation

Typical Force Vs elongation and Stress Vs elongation curves of FBJGFHC under tensile loading for different fiber orientation is presented in figures below.

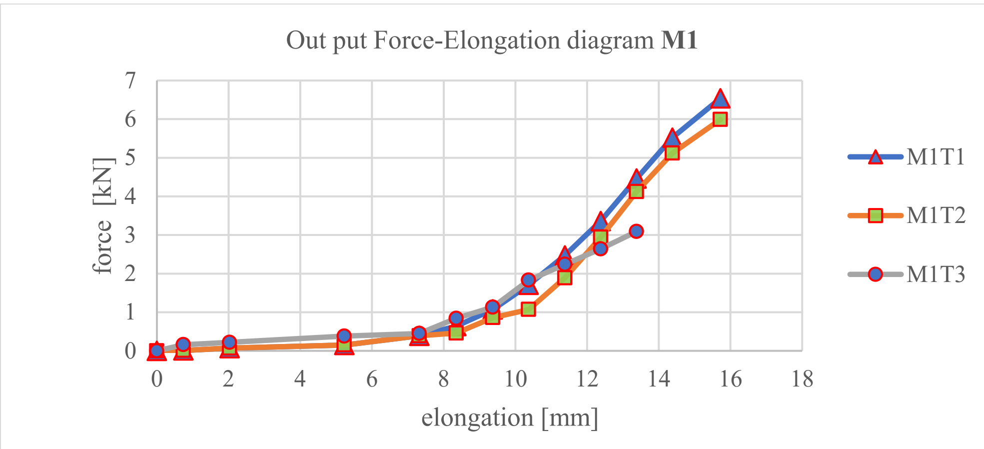

Fig. 4.1. Force Vs Elongation for three fiber orientation tensile test of mold 1

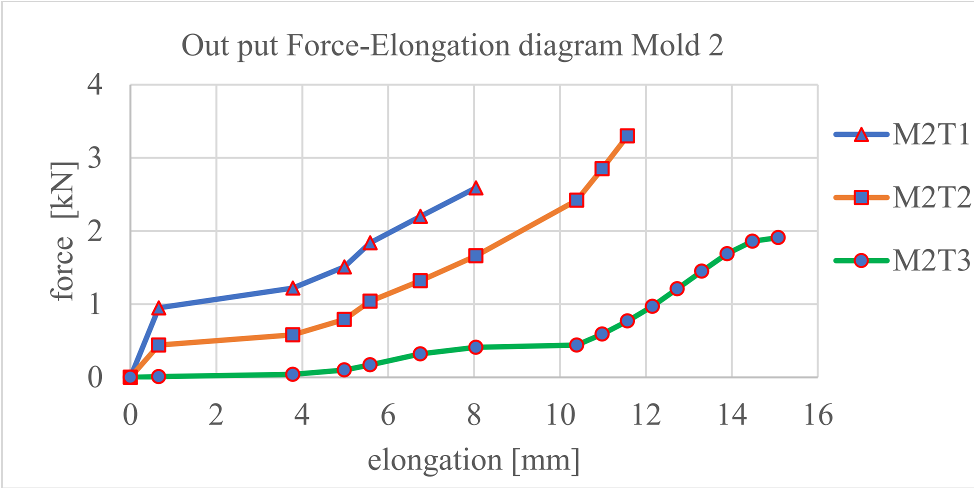

Fig. 4.2. Force Vs Elongation for three fiber orientation tensile test of mold 2

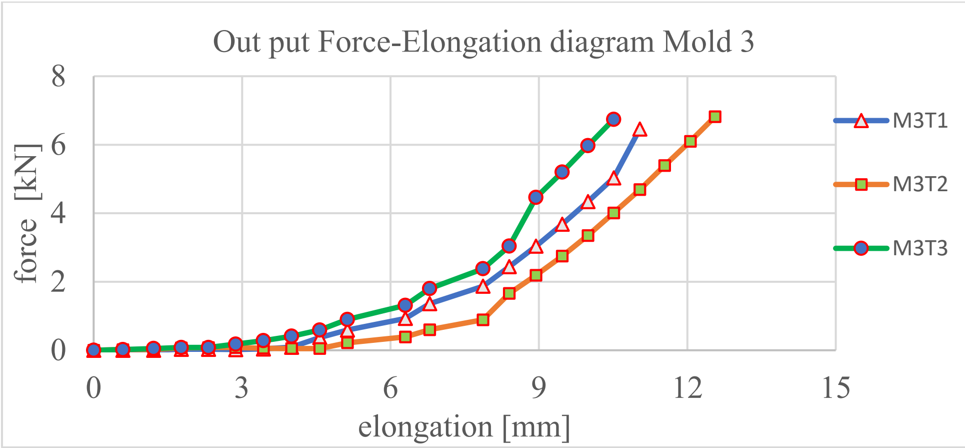

Fig.4.3. Force Vs Elongation for three fiber orientation tensile test of mold 3

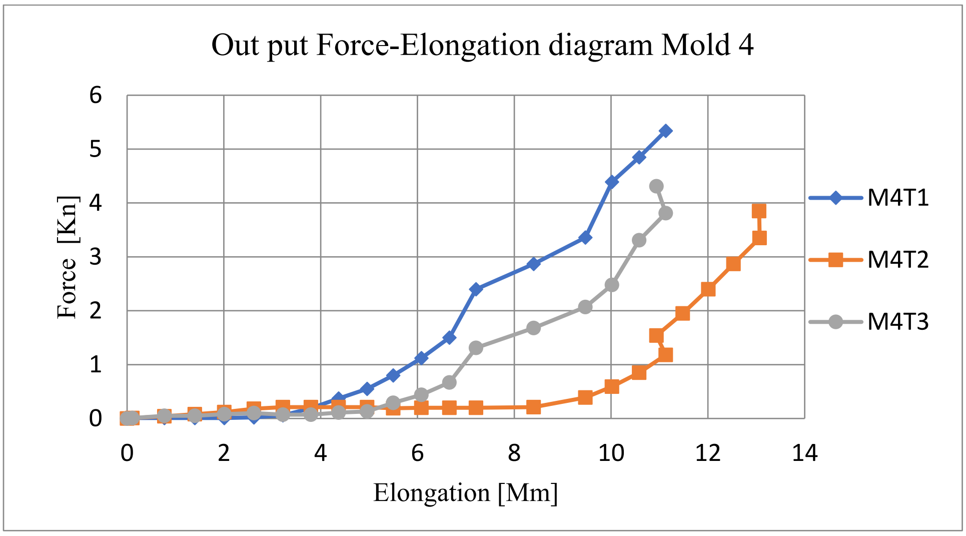

Fig. 4.4. Force vs elongation for three fiber orientation tensile test of mold 4

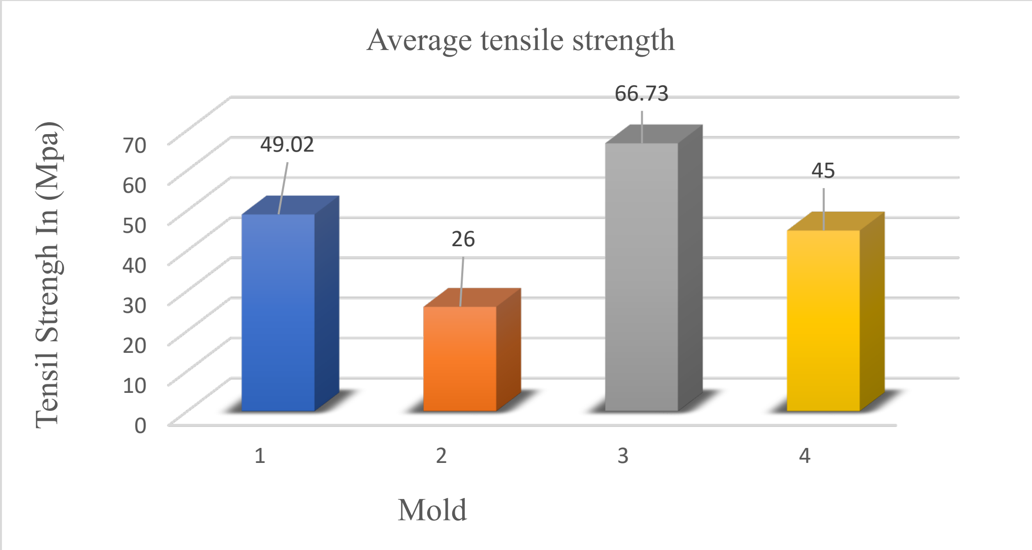

Fig. 4.5. Comparison of tensile strength for average test result

Discussion

The tensile strength of false banana-jute-glass fiber reinforced hybrid composites is presented in Figure. 4.3. It is observed that the hybrid composite mold 3 (fiber orientation (45^0 JF with 0^0 FBF), mixing ratio (1:1), and the weight ratio of fiber (10%Fbf 20%Jf 10% GF)) is exhibiting higher tensile strength than another hybrid composite mold.

From Figure 4.2, Force Vs Elongation diagram for three fiber orientations, the percent elongation as well as force varies in a different number of mold. the maximum 6.82 kN force is with 12.56% E for mold 3 false banana-jute-glass fiber reinforced hybrid composites is observed. Whereas 4.9 kN with 12.12% E, 2.61kN with 11.96 E and 4.5kN with 11.72% E for Mold; 1, 2, and 4 hybrid composites respectively. The maximum tensile strength is 66.73 MPa for mold 3 hybrid composite and the maximum percent elongation is 12.56% with 6.82 kN.

In general, it is observed that as varying control variables like mixing ratio, the weight ratio of fiber, and fiber orientation, the tensile strength varies. The higher tensile strength is observed on mold number three with; fiber orientation (45^0 JF with 0^0 FBF), mixing ratio (1:1) and the weight ratio of fiber (10%Fbf 20%Jf 10% GF) have Tensile Strength Rm: 66.73 Mpa.

After observing the above-listed graph quantitative data of tensile test exhibits the resalt as prepared in the form of a Table as shown below.

Table 4.1 Tensile strength of test result

Mold	Tensile strength test 1(N/mm²)	Tensile strength test 2 (N/mm²)	Tensile strength test 3 (N/mm²)	Average (N/mm²)	Rank
1	65.40	50.75	30.90	49.02	2
2	25.90	33.00	19.10	26.00	4
3	64.60	68.20	67.40	66.73	1
4	53.40	38.50	43.10	45.00	3

Finally from the above Table mold 3 have maximum tensile strength with 66.73 Mpa

4.1.2. Compression Strength Test

Typical Force Vs elongation and Stress Vs elongation curves of FBJGFHC under Compression loading for different fiber orientation is presented in the figure listed below.

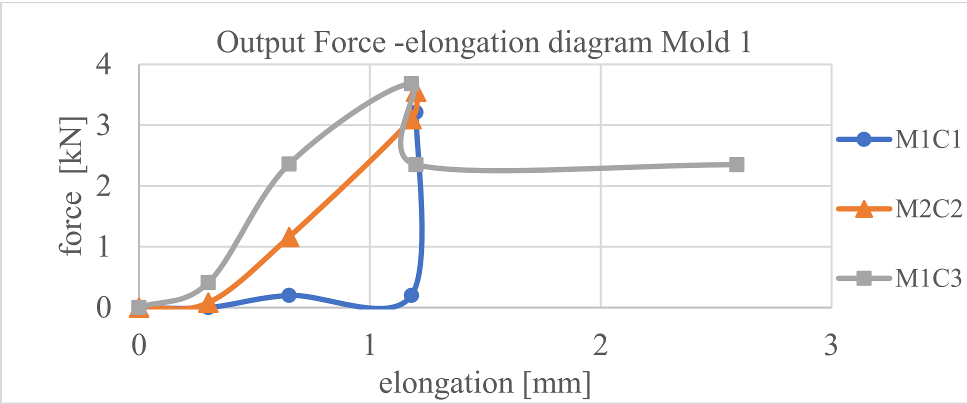

Fig. 4.6. Force Vs Elongation for three fiber orientation compression test of mold 1

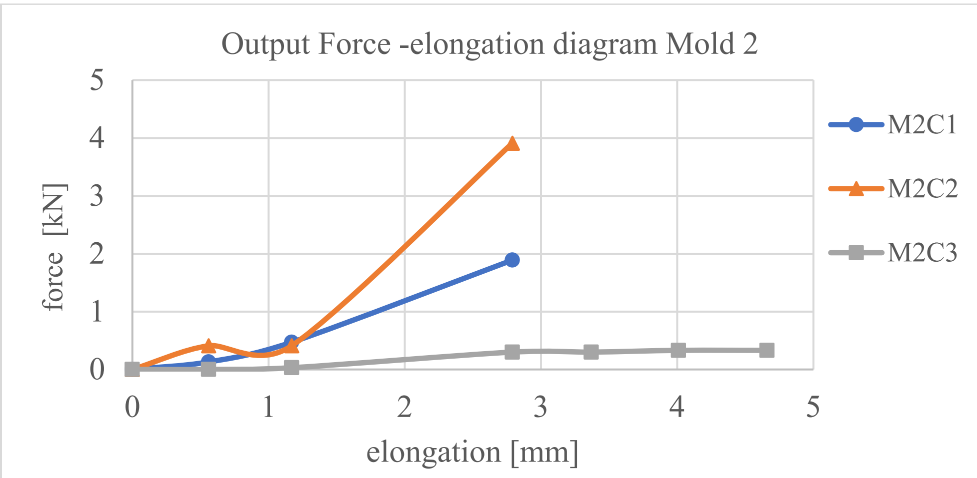

Fig. 4.7. Force Vs Elongation for three fiber orientation compression test of mold 2

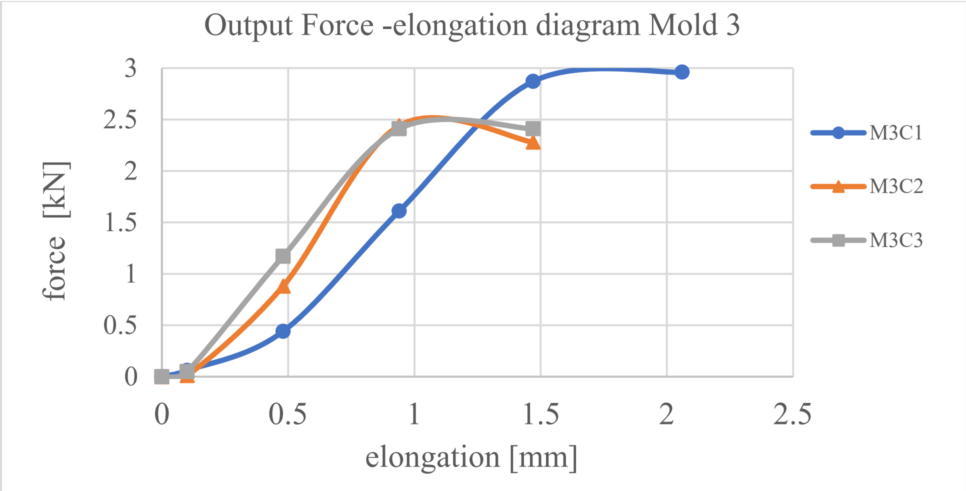

Fig. 4.8. Force Vs Elongation for three fiber orientation compression test of mold 3

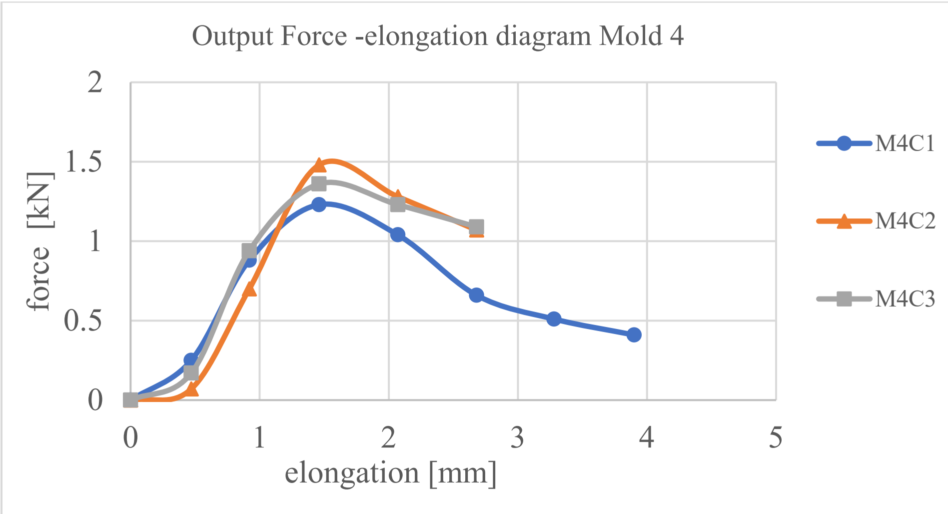

Fig. 4.9. Force Vs Elongation for three fiber orientation compression test of mold 4

After observing the above-listed graph the quantitative data of the compression test exhibits the resalt as prepared in the form of a table as shown below in Table 4.2.

Table 4.2 Compression strength test result

Mold	compression strength test 1(Mpa)	compression strength test 2 (Mpa)	compression strength test 3 (Mpa)	Average (Mpa)	Rank
1	32.3	35.50	36.80	34.86	1
2	18.90	19.20	11.67	16.59	3
3	29.60	24.40	24.10	26.03	2
4	12.30	14.80	13.60	13.56	4

The test results are tabulated and presented in Fig 4.37. based on the maximum values of the three specimens for each test condition.

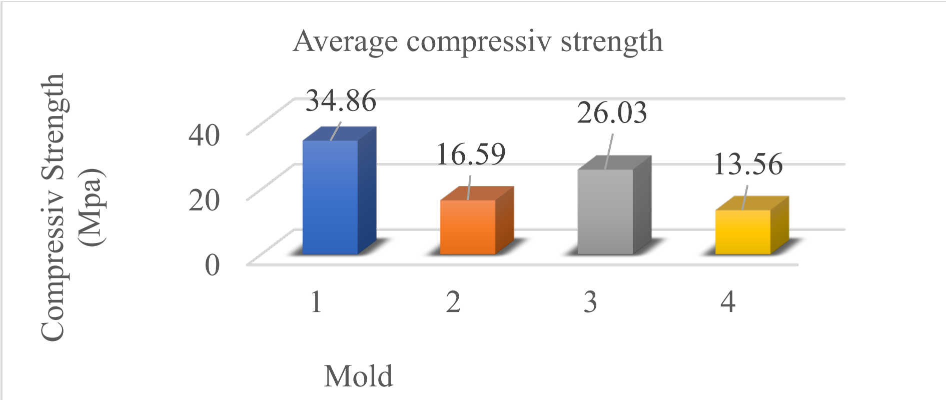

Fig. 4.10. Comparison of compression strength for average test result

Discussion

The compression strength of false banana-jute-glass fiber reinforced hybrid composites is presented in Figure.4.6. It is observed that the hybrid composite of mold 1 (orientation (0^0 Jf with 90^0 FBF), mixing ratio (1:1), and a weight ratio of fiber (20%Fbf 10%Jf 10% GF)) is exhibiting higher compression strength than other hybrid composite molds.

From Figure 4.9, Force Vs Elongation diagram for number 4 mold, the percent elongation as well as force varies in a different number of mold. the maximum 3.55 kN force is with 3.24% E for mold 1 false banana-jute-glass fiber reinforced hybrid composites is observed. Whereas 1.07 kN with 2.33 % E, 2.96 kN with 2.06 %E and 1.92 kN with 1.35 % E for Mold; 2, 3, and 4 hybrid composites respectively. The maximum compression strength is 34.86 MPa for mold 3 hybrid composite and the maximum percent elongation is 3.24% with 3.55 kN.

In general, the higher compression strength is observed on mold number one with; fiber orientation (0^0 Jf with 90^0 FBF), mixing ratio (1:1), and a weight ratio of fiber (20%Fbf 10%Jf 10% GF) have compression Strength Rm: 34.86 Mpa.

4.1.3. Flexural Strength Test

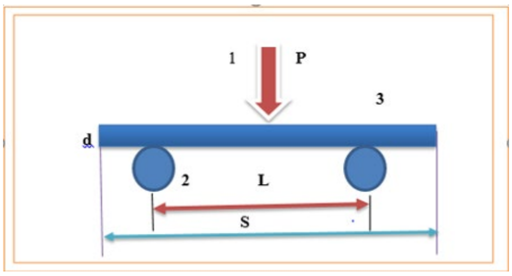

Fig. 4.11. Three-point bending

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

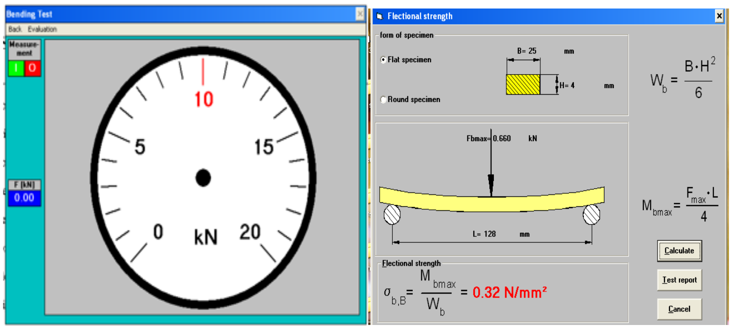

Fig. 4.12.Loading in control system

Section modulus (wb) $$Wb = \frac{(w\times H^2)}{6} \quad (4.1)$$

Maximum bending moment $$Mbmax = \frac{Fmax\ L}{4} \quad (4.2)$$

Under three-point bending in Figure 4.11 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 ………… $$\delta bmax = \frac{Mb\ max}{wb} \quad (4.3)$$

Table 4.3. Test results of flexural test

No	Orientation	Designation	Width (mm)	Thickness (mm)	Initial measurement (mm)	Maximum test force (kN)	Flexural Strength (MPa)
1	0^0 Jf with 90^0 FBF	M1T1-FS	25	4	128	0.660	320
		M1T2-FS	25	4	128	0.650	310
		M1T3-FS	25	4	128	0.630	300
		Average					310
2	0^0 Jf with 90^0 FBF	M2T1-FS	25	4	128	0.340	180
		M2T2-FS	25	4	128	0.480	230
		M2T3-FS	25	4	128	0.280	130
		Average					180
3	45^0 JF with 0^0 FBF	M3T1-FS	25	4	128	0.800	380
		M3T2-FS	25	4	128	0.640	310
		M3T3-FS	25	4	128	0.740	360
		Average					350
4	45^0 JF with 0^0 FBF	M4T1-FS	25	4	128	0.360	170
		M4T2-FS	25	4	128	0.390	190
		M4T3	25	4	128	0.490	240
		Average					200

The test results are tabulated and presented in Table 4.3 based on the maximum values of the three specimens for each test condition. within this result, the overall test result with rank is shown in Table 4.4 below.

Table 4.4 Flexural strength test result

Mold	flexural strength test 1(N/mm²)	flexural strength test 2 (N/mm²)	flexural strength test 3 N/mm²)	Average (N/mm²)	Rank
1	320	310	300	310	2
2	180	230	130	180	4
3	380	310	360	350	1
4	170	190	240	200	3

The results obtained during flexural tests on composite specimens of different fiber orientations are summarized in Figure.4.13.

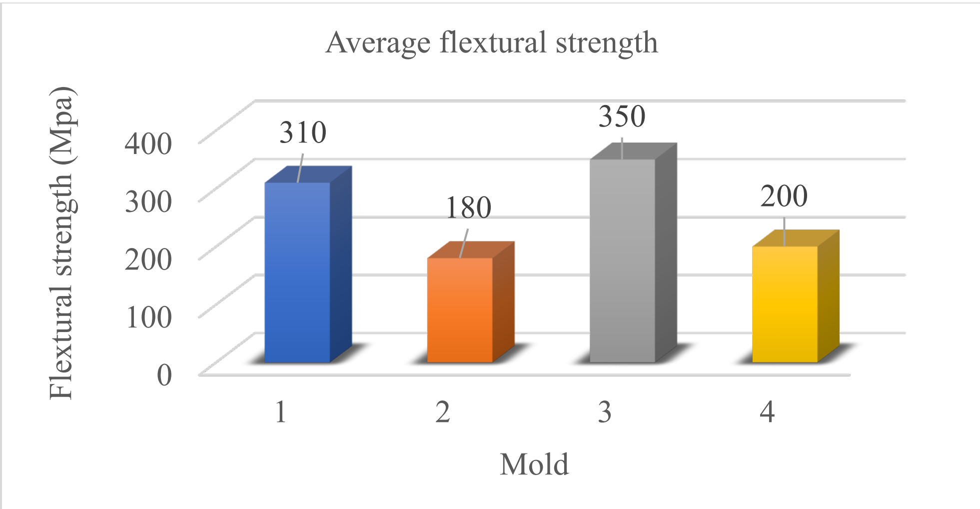

Fig. 4.13. Comparison of flexural strength for average test resalt

Discussion

From Figure 4.13 comparing three different false banana-jute-glass fiber reinforced hybrid composites the highest flexural strength is observed on mold three (350 MPa) and lowest in the case of on mold two reinforced hybrid composites have (180 MPa). flexural strength is less than other three hybrid composites mold Maximum bending moment is observed and maximum bending stress observed on mold number three with; fiber orientation (45^0 JF with 0^0 FBF), mixing ratio (1:1) and a weight ratio of fiber (10%Fbf 20%Jf 10% GF) has 350 MPa.

4.1.4. Impact Strength Test

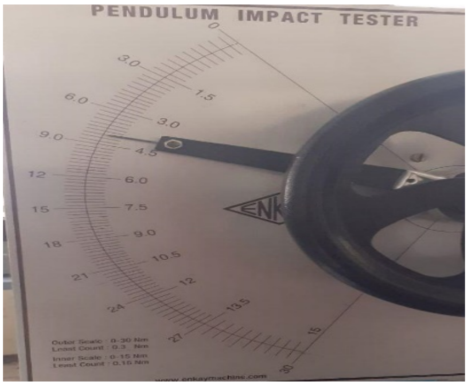

Fig. 4.14. Pendulum impact test scale

The pendulum impact test has two scales which is the outer scale: 0.30 Nm and inner scale:0.15 Nm example in Figure.4.14 the scale pointer indicates at 6.7 this means $6 + 7 * 0.3$ Nm=8.1 Nm, finally the total test result of impact test are shown in Table 4.5 below.

Table 4.5.Test results of the impact test

Orientation	Designation	reading	Calculation	Impact energy (Nm)
0^0 Jf with 90^0 FBF	M1T1-IS	6.9	$8 + 9 * 0.3$	10.7
	M1T2-IS	6.6	$6 + 6 * 0.3$	7.8
	M1T3-IS	6.5	$6 + 5 * 0.3$	7.5
	M1T4-IS	6.3	$6 + 3 * 0.3$	6.9
	Average			8.225
0^0 Jf with 90^0 FBF	M2T1-IS	6.7	$6 + 7 * 0.3$	8.1
	M2T2-IS	6.7	$6 + 7 * 0.3$	8.1
	M2T3-IS	6.5	$6 + 5 * 0.3$	7.5
	M2T4-IS	6.4	$6 + 4 * 0.3$	7.2
	Average			7.725
0^0 Fbf with 45^0 JF	M3T1-IS	6.6	$6 + 6 * 0.3$	7.8
	M3T2-IS	6.7	$6 + 7 * 0.3$	8.1
	M3T3-IS	6.8	$6 + 8 * 0.3$	8.4
	M3T4-IS	6.3	$6 + 3 * 0.3$	6.9
	Average			7.8
0^0 Fbf with 45^0 JF	M4T1-IS	6.3	$6 + 3 * 0.3$	6.9
	M4T2-IS	6.2	$6 + 2 * 0.3$	6.6
	M4T3-IS	6.3	$6 + 3 * 0.3$	6.9
	M4T4-IS	6.4	$6 + 4 * 0.3$	7.2
	Average			6.9

Discussion

The impact test was carried out with Charpy machine, results are presented in Table 4.5 and the corresponding graphs have been plotted.

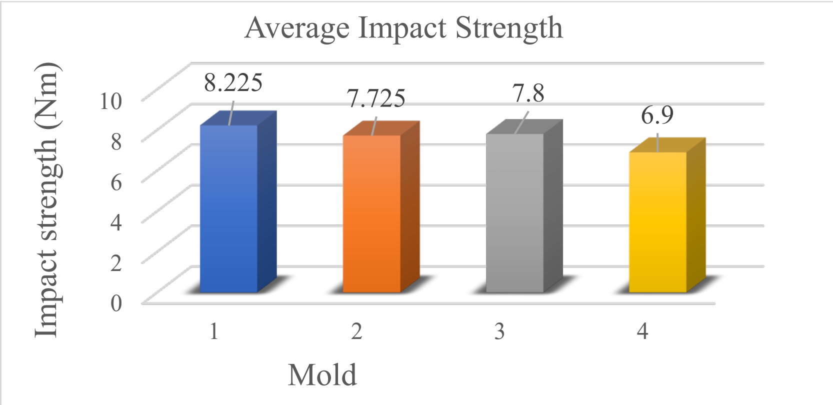

Fig. 4.15. Comparison of impact strength for average test result

In the graphs in Figure 4.15 plotted for the energy absorbed in Nm, It has been observed that mold 1 reinforced hybrid composites of false banana-jute-glass fiber reinforced hybrid composites have higher impact strength 8.25 Nm when compared to other types of hybrid composite mold.

4.2. Discussions of Results on Taguchi Analysis

4.2.1. Tensile Results

The fabricated composite samples were tested for its tensile strength. The tensile test was carried out on a three-point or specimen tensile test machine as per ASTM – D790 standard. The tested composite specimen is shown in Figure.4.16. The tensile strength of the tested composite specimen is shown in Table 4.6.

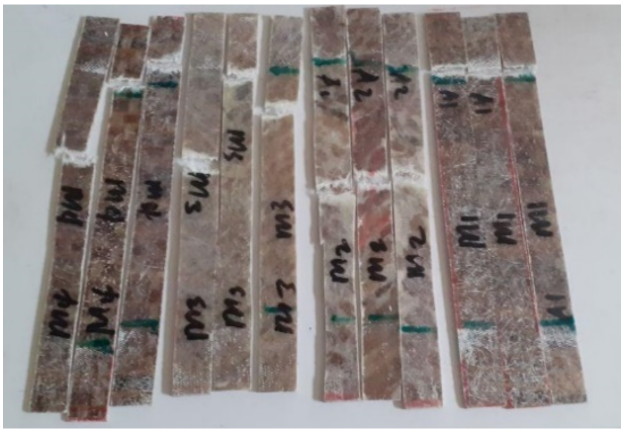

Fig. 4.16. Composite sample tested for tensile strength

Table 4.6. Tensile strength of the tested composite specimens

Expt .no.	Orientation	Mixing ratio	The weight percentage of FBF with JF	Tensile strength (N/mm²)			
				Trial-1	Trial-2	Trial-3	mean
1	0^0 Jf with 90^0 FBF	1:1	20%Fbf with 10%Jf	65.40	50.75	30.90	49.02
2	0^0 Jf with 90^0 FBF	3:1	10%Fbf with 20%Jf	25.90	33.00	19.10	26.00
3	0^0 Fbf with 45^0 JF	1:1	10%Fbf with 20%Jf	64.60	68.20	67.40	66.73
4	0^0 Fbf with 45^0 JF	3:1	20% Fbf with 10%Jf	53.40	38.50	43.10	45.00

Based on the tensile strength obtained, the Signal to Noise ratio has to be computed. Taguchi has postulated three types of objective functions. They are:

1. Larger the better type objective function.
2. Nominal the best type of objective function.
3. Smaller the better type objective function.

In the present work, the aim is to determine the best tensile strength among the various composite samples fabricated, and therefore the tensile strength of the composite sample should be higher. Hence Larger the better type objective function is chosen. The formula for computing the S/N ratio for Larger the better type is given below:

$$\eta = -10\log_{10}\left(\frac{1}{y^2}\right)$$

The S/N ratio for each experiment can be computed by using the MINITAB version 18.1 software. The computed S/N ratio from MINITAB software is shown in Table 4.7.

Table 4.7. Computed S/N Ratios

Orientation	Mixing ratio	The weight percentage of FBF with JF	Tensile strength (N/mm²)	S/N Ratio
0^0 Jf with 90^0 FBF	1:1	20%Fbf with 10%Jf	49.02	32.54
0^0 Jf with 90^0 FBF	3:1	10%Fbf with 20%Jf	26.00	27.65
0^0 Fbf with 45^0 JF	1:1	10%Fbf with 20%Jf	66.73	36.47
0^0Fbf with 45^0JF	3:1	20%Fbf with 10%Jf	45.00	32.82

Table 4.8. Response Table for Signal to Noise Ratios

Level	Orientation	Mixing ratio	The weight percentage of FBF with JF
1	30.10	34.51	32.69
2	34.65	30.24	32.07
Delta	4.56	4.27	0.62
Rank	1	2	3

The main effects plot for S/N Ratio is shown in Fig.4.17

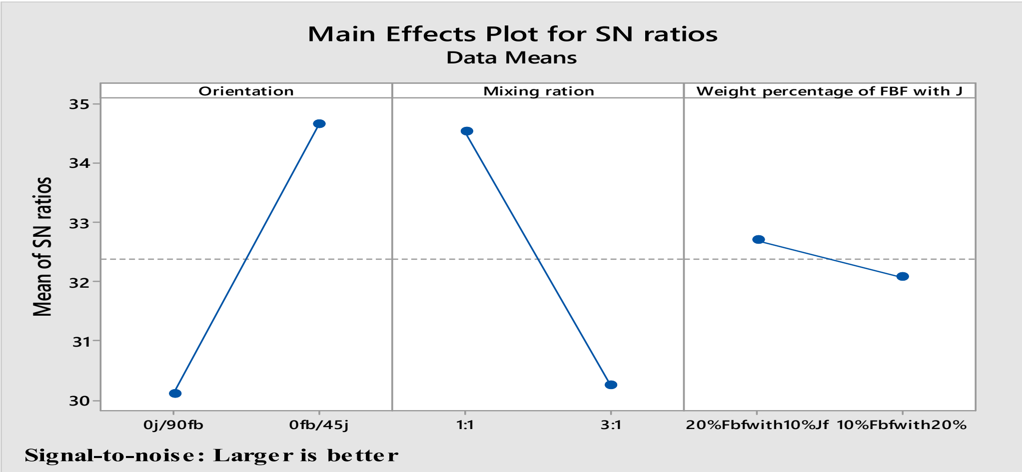

Fig. 4.17.Main effects plot for S/N ratios

From the main effects plot for S/N ratios, it is clear and obvious that the combination A2 (orientation of [0^0 Fbf with 45^0 JF]), B1 (mixing ratio of 1:1) and C1 (20% Fbf with 10% Jf) would give the best Tensile strength. Based on the results obtained, the following decisions are drawn:

- The combination A2, B1, C1 would provide the best tensile strength.
- It is to be noted that fiber orientation and the mixing ratio play a significant role in predicting the tensile strength of the composite material.

4.2.2. Compressive Results

The fabricated composite samples were tested for their compressive strength. The compressive test was carried out on the UTM or specimen compressive test machine as per ASTM - D3410 standard. The tested composite specimen is shown in Figure.4.18. The compressive strength of the tested composite specimens is shown in Table 4.9.

Fig. 4.18. Composite sample tested for compressive strength

Table 4.9 Experimental values of compression Strength

Expt. no.	Orientation	Mixing ratio	The weight percentage of FBF with JF	compression strength (N/mm²)			
				Trial-1	Trial-2	Trial-3	mean
1	0^0 JF with 90^0 FBF	1:1	20% FBF with 10% JF	32.3	35.50	36.80	34.86
2	0^0 JF with 90^0 FBF	3:1	10% FBF with 20% JF	18.90	19.20	11.67	16.59
3	0^0 FBF with 45^0 JF	1:1	10% FBF with 20% JF	29.60	24.40	24.10	26.03
4	0^0 FBF with 45^0 JF	3:1	20% FBF with 10% JF	12.30	14.80	13.60	13.56

The computed S/N ratio of Compression Strength from MINITAB software is shown in Table 4.10.

Table 4.10. Computed S/N Ratios

Orientation	Mixing Ration	Weight Percentage of FBF with JF	Compression Strength (N/Mm²)	S/N Ratio
0^0 Jf with 90^0 FBF	1:1	20% FBF with 10% JF	34.8667	30.808
0^0 Jf with 90^0 FBF	3:1	10% FBF with 20% JF	16.5900	23.680
0^0 Fbf with 45^0 JF	1:1	10% FBF with 20% JF	26.0333	28.198
0^0 Fbf with 45^0 JF	3:1	20% FBF with 10% JF	13.5667	22.574

The response values of the control factors are shown in Table 4.11 & 4.12

Taguchi Analysis: result 1, result 2, result 3 versus ..., weight % of fiber

Larger is better

Table 4.11. Response Table for Signal to Noise Ratio

Level	Orientation	Mixing ratio	weight % of fiber
1	27.24	29.50	26.69
2	25.39	23.13	25.94
Delta	1.86	6.38	0.75
Rank	2	1	3

Table 4.12. Response Table for Means

Level	Orientation	Mixing ratio	weight % of fiber
1	25.73	30.45	24.22
2	19.80	15.08	21.31
Delta	5.93	15.37	2.91
Rank	2	1	3

The main effects plot for S/N Ratio is shown in Figure.4.19

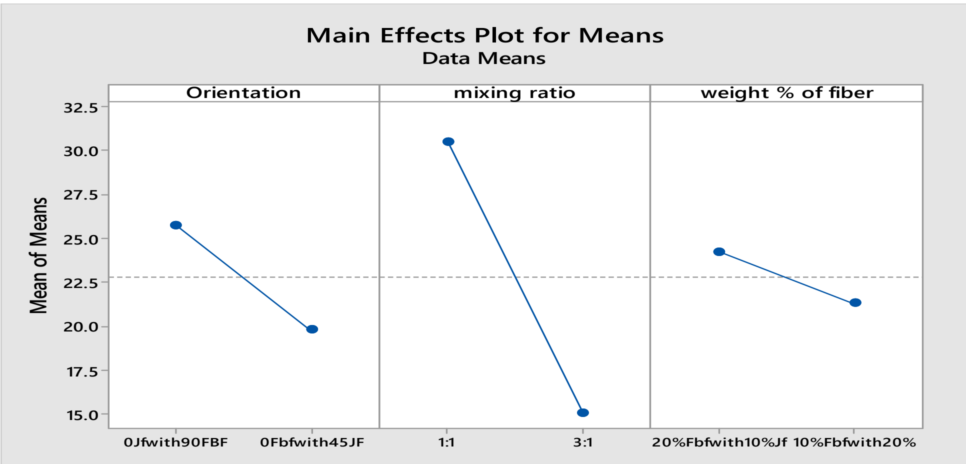

Fig. 4.19. Main effects plot for means

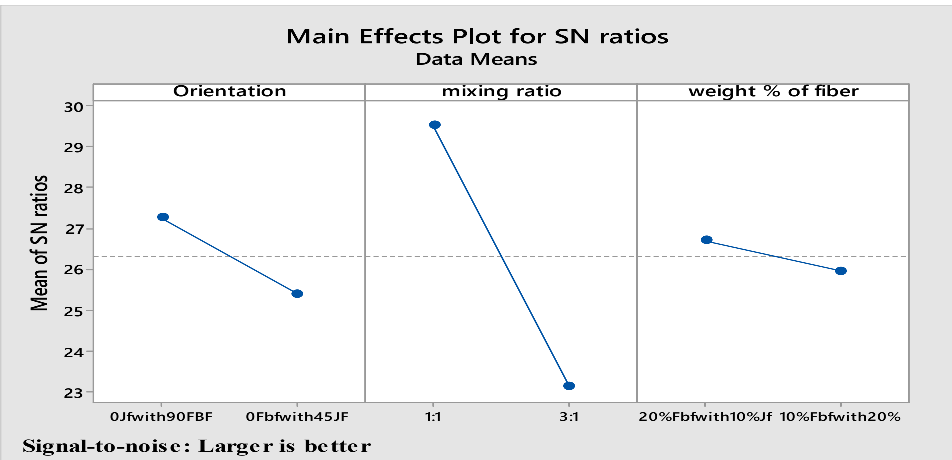

Fig. 4.20. Main effects plot for S/N ratios

From the main effects plot for S/N ratios, it is clear and obvious that the combination A1 (orientation of [0^0 JF with 90^0 Fbf), B1 (mixing ratio of 1:1) and C1 (20%Fbf with 10%Jf & 10%GF) would give the best compressive strength. Based on the results obtained, the following decisions are drawn:

- The combination A1, B1, C1 would provide the best compressive strength.
- It is to be noted that fiber orientation and the mixing ratio play a significant role in predicting the compressive strength of the composite material.

4.2.3. Flexural Results

The fabricated composite samples were tested for its flexural strength. The Flexural test was carried out on a three-point or specimen Flexural test machine as per the ASTM D790-2010 standard. The tested composite specimen is shown in Figure.4.21. The Flexural strength of the tested composite specimens is shown in Table 4.13.

Fig. 4.21. Composite sample tested for Flexural strength

Table 4.13. Experimental values of Flexural Strength on Taguchi design

Expt .no.	Orientation	Mixing ratio	The weight percentage of FBF with JF	Flexural strength (MPa)			
				Trial-1	Trial-2	Trial-3	mean
1	0^0 Jf with 90^0 FBF	1:1	20%Fbf with 10%Jf	320	310	300	310
2	0^0 Jf with 90^0 FBF	3:1	10%Fbf with 20%Jf	180	230	130	180
3	0^0 Fbf with 45^0 JF	1:1	10%Fbf with 20%Jf	380	310	360	350
4	0^0 Fbf with 45^0 JF	3:1	20% Fbf with 10%Jf	170	190	240	200

The computed S/N ratio of Flexural strength from MINITAB software is shown in Table 4.14.

Table 4.14. Computed S/N Ratios

Orientation	Mixing ratio	The weight percentage of FBF with JF	Flexural strength (Mpa)	S/N Ratio
0^0Jf with 90^0 FBF	1:1	20%Fbf with 10%Jf	310	49.81
0^0Jf with 90^0 FBF	3:1	10%Fbf with 20%Jf	180	44.39
0^0 Fbf with 45^0 JF	1:1	10%Fbf with 20%Jf	350	50.78
0^0Fbf with 45^0JF	3:1	20%Fbf with 10%Jf	200	45.75

Taguchi Analysis: result 1, result 2, result 3 versus ..., weight % of fiber

Larger is better

Table 4.15. Response Table for Signal to Noise Ratio

Level	Orientation	Mixing ratio	weight % of fiber
1	47.11	50.30	47.79
2	48.27	45.08	47.59
Delta	1.16	5.22	0.20
Rank	2	1	3

Table 4.16. Response Table for Means

Level	Orientation	Mixing ratio	Weight % of fiber
1	245.0	330.0	255.0
2	275.0	190.0	265.0
Delta	30.0	140.0	10.0
Rank	2	1	3

The main effects plot for Means is shown in Figure.4.22

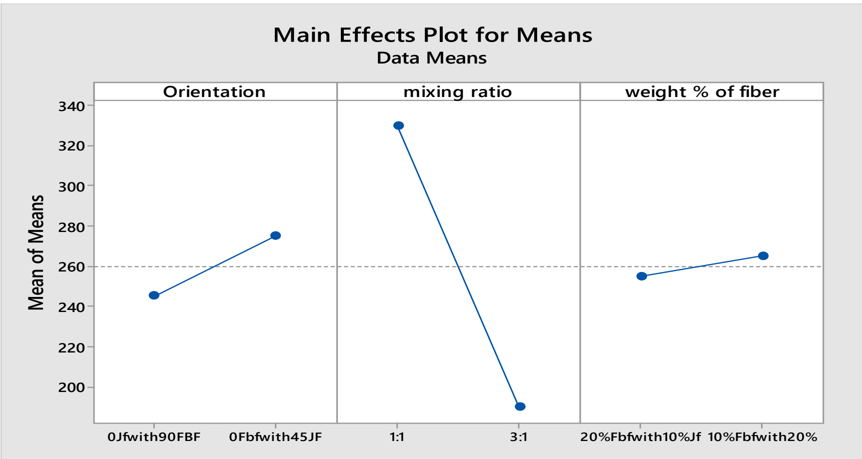

Fig. 4.22. Main effects plot for Means

The main effects plot for S/N Ratio is shown in Figure.4.23

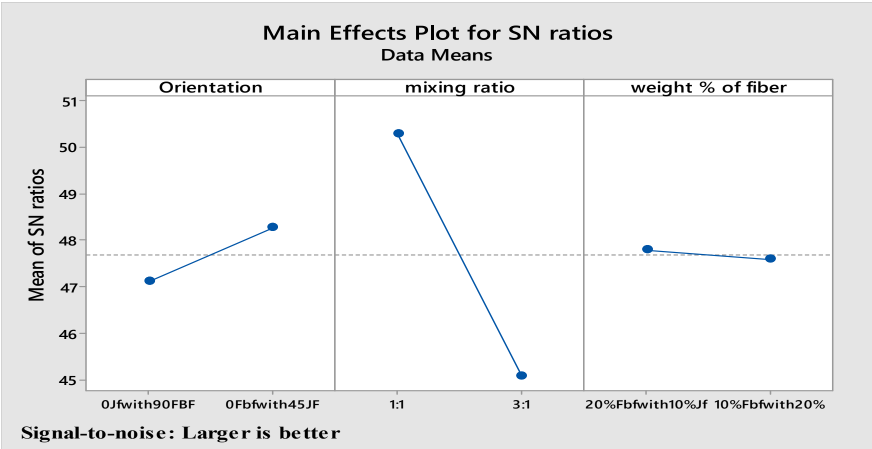

Fig. 4.23. Main effects plot for S/N ratios

From the main effects plot for S/N ratios, it is clear and obvious that the combination A2 (orientation of [0^0 Fbf with 45^0 JF]), B1 (mixing ratio of (1:1) and C1 (20%Fbf with 10% GF & 10%Jf) would give the best flexural strength. Based on the results obtained, the following decisions are drawn:

- The combination A_2, B_1, C_1 would provide the best flexural strength.
- It is to be noted that fiber orientation and the mixing ratio play a significant role in predicting the flexural strength of the composite material.

4.2.4. Impact Results

The fabricated composite samples were tested for their impact strength. The impact test was carried out on the pendulum impact machine ISO 9001:2001 standard. The computed S/N ratio from MINITAB software is shown in Table 4.17.

Table 4.17. Computed S/N ratio from MINITAB software

Orientation	Mixing ratio	The weight percentage of FBF with JF	Flexural strength (MPa)	S/N Ratio
0^0Jf with 90^0 FBF	1:1	20% FBF with 10% JF	8.46	17.59
0^0Jf with 90^0 FBF	3:1	10% FBF with 20% JF	7.90	18.16
0^0 Fbf with 45^0 JF	1:1	10% FBF with 20% JF	8.10	17.62
0^0Fbf with 45^0JF	3:1	20% FBF with 10% JF	7.00	18.13

Taguchi Analysis: for results 1, 2, 3 versus ..., weight % of fiber and table of signal to noise ratio and response table for mean computed from MINITAB software as shown below table 4.18 and 4.19.

Larger is better

Table 4.18. Response Table for Signal to Noise Ratios

Level	Orientation	Mixing ratio	Weight % of fiber
1	17.86	17.89	17.51
2	17.27	17.24	17.61
Delta	0.59	0.64	0.10
Rank	2	1	3

Table 4.19. Response Table for Means

Level	Orientation	Mixing ratio	Weight % of fiber
1	8.033	8.083	7.733
2	7.350	7.300	7.650
Delta	0.683	0.783	0.083
Rank	2	1	3

The main effects plot for S/N Ratio is shown in Figure.4.24

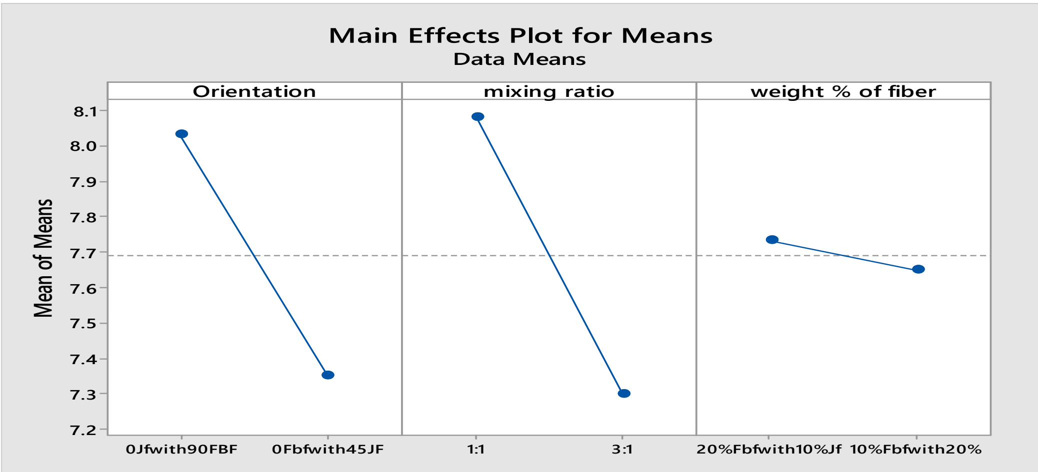

Fig. 4.24. Main effects plot for means

The main effects plot for S/N Ratio is shown in Figure.4.25

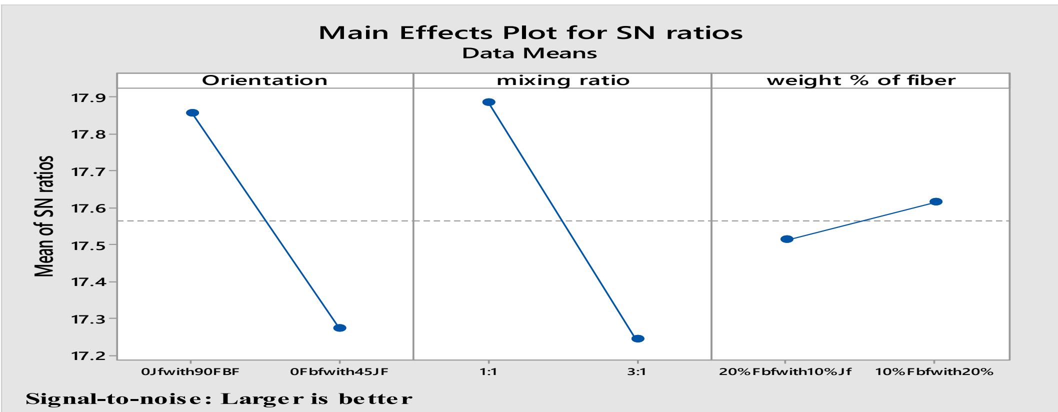

Fig. 4.25.Main effects plot for S/N ratios

From the main effects plot for S/N ratios, it is clear and obvious that the combination A1 (orientation of [0^0 Fbf with 45^0 JF]), B1 (mixing ratio of (1:1) and C2 (20%Fbf with 10% GF & 10%Jf) would give the best impact strength. Based on the results obtained, the following decisions are drawn:

- The combination A2, B1, C1 would provide the best impact strength.
- It is to be noted that fiber orientation and the mixing ratio play a significant role in predicting the impact strength of the composite material.

4.3. Results and Discussion of FEA

Table 4.20. Properties of FBJGFRHC boot lid outer panel

Assignment	Structural steel	FBJGFRHC
Properties		
Volume	2.2353e+007mm^3	2.2353e+007mm^3
Mass	13.8 kg	7.3kg
Centroid x	100.42mm	-207mm
Centroid y	-150.mm	19.711mm
Centroid z	20.237mm	7.2434e+002mm
Moment of inertia Ip 1	3.8711e+007 kg.mm^2	7.6431e+006kg.mm^2
Moment of inertia Ip 2	3.4068e+007kg.mm^2	1.1406e+007kg.mm^2
Moment of inertia Ip 3	4.8806e+007kg.mm^2	4.9064e+006kg.mm^2
Surface area	4.4706+006mm^2	
Statistics		
Nodes	20051	4080
Element	120158	2850
Mesh metric	None	

The above Table 4.20 observed from (ANSYS 16.0 material)

4.3.1. FBJGFHC Fiber Composites Boot Lid Analysis

For an object of mass m, moving at a speed of v, its kinetic energy (KE) can be determined by using the relation,

$$\mathrm{kE} = \frac{1}{2}\mathrm{mv}^2 \tag{4.1}$$

So the boot lid panel will have collision energy due to its mass for those two different materials at a constant speed of 50 kmph can be determined using Eq. 1. From table 4.20 mass of FBJGFRHC boot lid is 7.3 kg.

$$\text{Collision Energy} \quad = \frac{1}{2} m_T v_I$$

$$\mathrm{KE} = \frac{1}{2} * (7 \cdot 3\mathrm{kg} * (13.889\ {}^{\mathrm{m}}/_{s})^2)$$

$$= 704.1\mathrm{J}$$

Here also the collision energy of the boot lid can be determined similarly as done for FBJGFRHC material. Mass of boot lid panel is determined in Table 3.4 of the literature review mass of steel boot lid panel = 13.0 kg. Collision energy only due to its mass and specified speed is can be determined mathematically as KE,

$$\mathrm{KE} = \frac{1}{2} * (13\mathrm{kg} * (13.889\ ^{\mathrm{m}}/_{s})^2)$$

$$1250.8\ \mathrm{J}$$

The energy analysis can be done by considering the vehicle as a whole and toughness property of boot lid panel can be stated. For the case of Toyota corolla, executive sedan car collides with moving deformable barrier, its total mass is considered, at a collision speed of 50 kmph to analyze energy absorbed by boot lid component for FBJGFRHC and steel. So total energy to be applied on the panel means the kinetic energy of the vehicle (KEvehicle). Therefore the kinetic energy of the vehicle with the steel boot lid and mass of Mv = 1155kg from the specification.

$$\mathrm{KE}_{\mathrm{vehicle,steel}} = \frac{1}{2}\mathrm{m}_{\mathrm{vs}}\mathrm{v}^2 \qquad (4.2)$$

$$0.5 * 1155\mathrm{kg} * (13.889\ ^{\mathrm{m}}/_{s})^2$$

$$= 111{,}402.24\mathrm{J} = 111.4\mathrm{kJ}$$

And kinetic energy of the vehicle with FBJGFRHC composite boot lid for the corresponding mass of Mv = 1149.3 Kg

$$\mathrm{KE}_{\mathrm{vehicle,comp}} = \frac{1}{2}\mathrm{m}_{\mathrm{VC}}\mathrm{v}^2 \qquad (4.3)$$

$$0.5 * 1149.3\mathrm{kg} * (13.889\ ^{\mathrm{m}}/_{s})^2$$

$$= 110{,}852.46\mathrm{J} = 110.85\mathrm{kJ}$$

So the crashing energy of the steel boot lid panel and composite boot lid of the vehicle moving at a speed of 50 kmph is 111.402kJ and 110.85kJ respectively.

The capacity of energy absorption per unit volume of the boot lid during a collision (strain energy/toughness) can be determined using Eq. 4.4 below. but before that have to be calculated youngs modules by referring stress-strain and ultimate tensile strength from Appendix table A.2., 0.909333, 0.5024, and Rm: 68.20 MPa respectively.

youngs modulus (modulus of elasticity) = $\mathrm{E} = \frac{\sigma}{\varepsilon}$ (4.4)

$$= \frac{0.90933}{0.5024} = 1.809979\ GPa$$

$$\mathrm{Umax} = \frac{\sigma^2_{\mathrm{ULt}}}{2\mathrm{E}} \qquad (4.5)$$

- Umax /Elastic strain energy/ is internal work done in deforming the body by the action of externally applied forces
- σult is the ultimate tensile strength of the materials
- E is modules of elasticity

Table 4.21. Different properties of steel and FBJGFRHC of the boot lid

	Mass(kg)	Volume(mm^3)	E(MPa)	KE vehicle (kJ)	σult (MPa)	Umax (MPa) (MN-m/m3)
FBJGFRHC Panel	7.3	2.2353e+007	1809.97	110.85	68.2	1.18315
Steel Panel	13.8	2.2353e+007	200000	111.402	400	0.4

After substituting values into eq.4.5, strain energy

$$\mathrm{Umax} = \frac{\sigma^2_{\mathrm{ULt_{comp}}}}{2\mathrm{E}} = \frac{(68.20\ \mathrm{MPa})^2}{2 * 1809.979\mathrm{MPa}} = 1.18315\ \mathrm{MNm/m^3}$$

modules of material elasticity of the steel according to AS1397 (1993) have 200 GPa. According to ASTM international ultimate tensile strength of the steel, materials have from (400 – 550) MPa. Therefore substitute in eq.(4.5).

$$\mathrm{Umax} = \frac{\sigma^2_{\mathrm{ULt_{steel}}}}{2\mathrm{E}} = \frac{(400\ \mathrm{MPa})^2}{2 * 200000\ \mathrm{MPa}} = 0.4\frac{\mathrm{MN.m}}{\mathrm{m^3}}$$

Total strain energy (toughness) U Total, that a trunk lid can absorb can be determined as follows by multiplying maximum strain energy with its volume listed in Table 4.21 for composite material and steel respectively.

For FBJGFRH composite;

$$\mathrm{UtotaL} = \mathrm{U\,max}^* \mathrm{TL_{Volume}} \qquad (4.6)$$

$$= 1.1831\mathrm{MPa} * 0.022353\mathrm{m^3}$$

$$0.04093\mathrm{MN.m} = 14.93\mathrm{kJ}$$

For steel component;

$$\mathrm{UtotaL} = \mathrm{U\,max}^* \mathrm{TL_{Volum}}$$

$0.4\mathrm{MPa} * 0.022353\mathrm{m^3}$= 0.0089412 MN.m = 8.9412kJ

4.3.2. Equivalent (Von-Mises) Stress

Maximum Von-Mises Stress of the FBJGFRHC boot lid due to the rear impact is 369.24 MPa. the stress distribution is displayed in Fig 4.26.

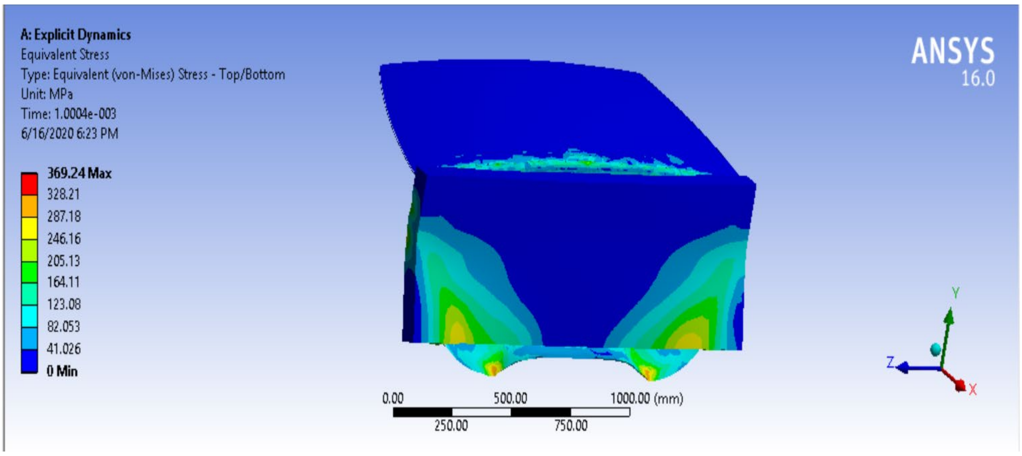

Fig. 4.26. Equivalent (Von Mises) stress values of the rear boot lid panel

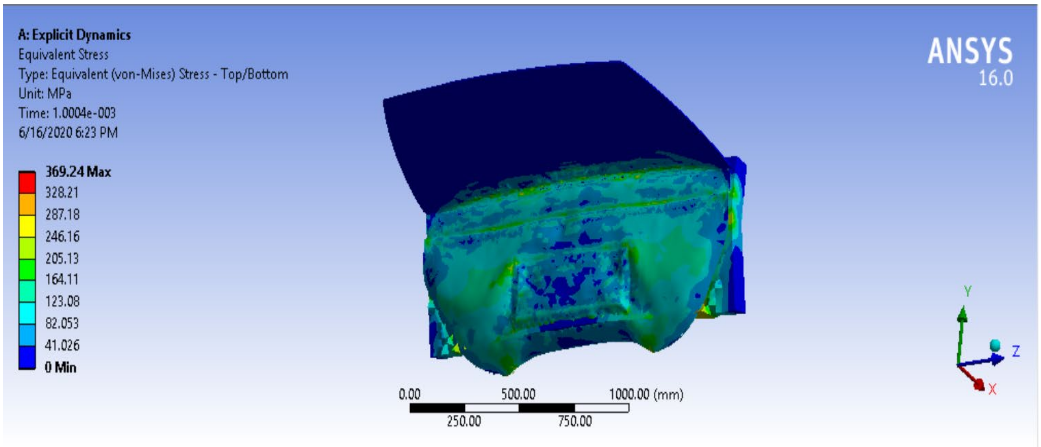

Fig. 4.27. Equivalent (Von Mises) stress

4.3.3. Displacement

Fig 4.28 shows the place where maximum deformation takes place thought the component.

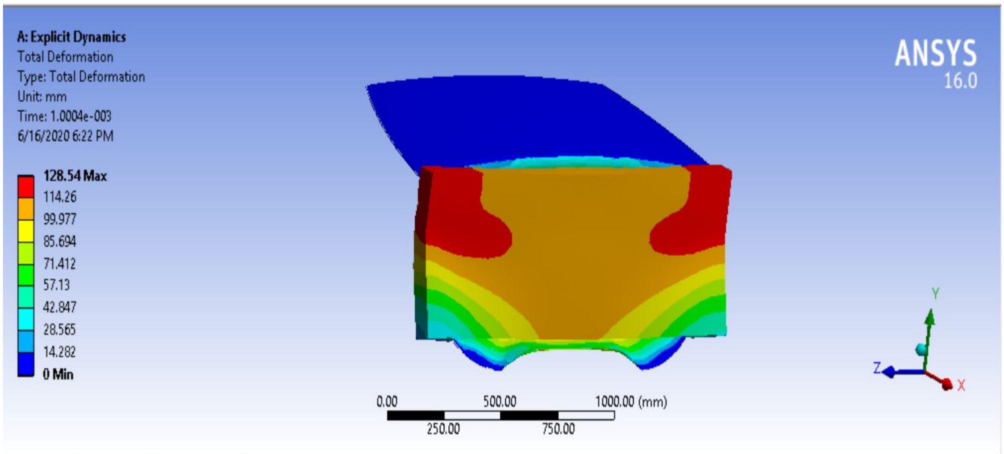

Fig. 4.28. Maximum deformation

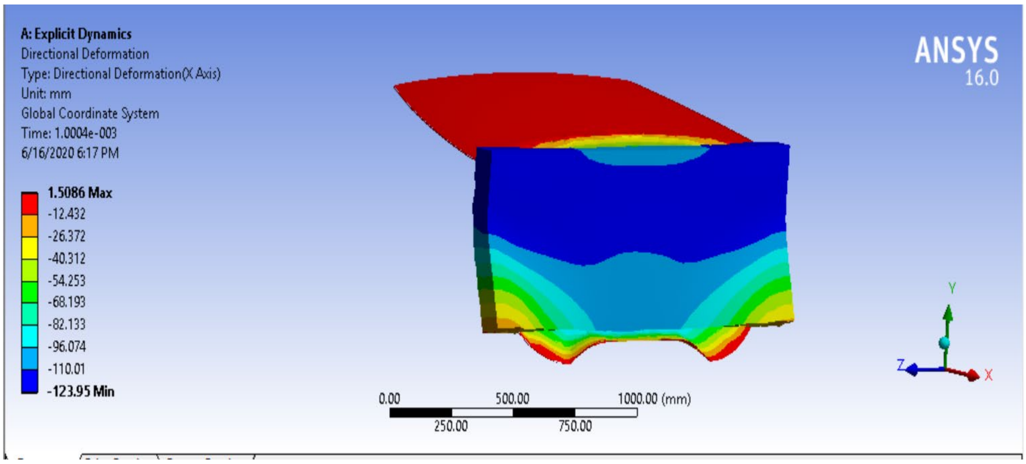

Fig. 4.29. directional deformation

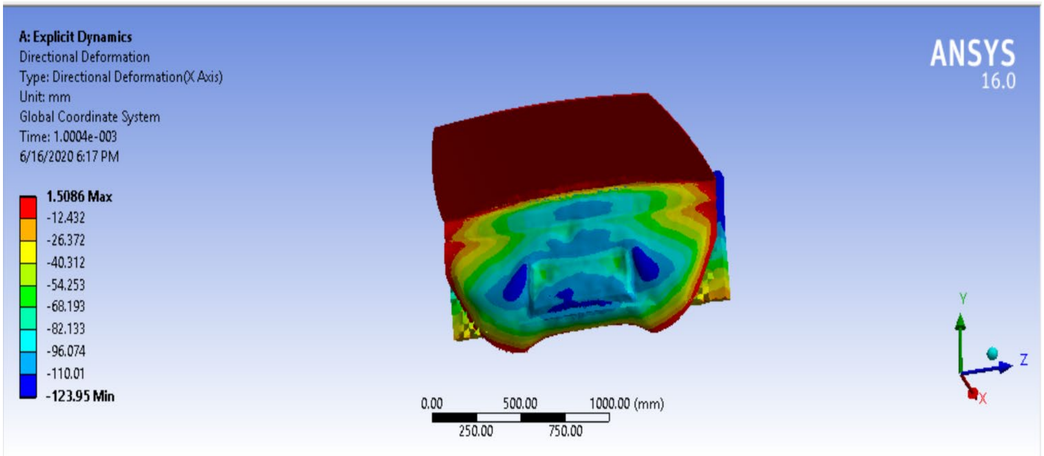

Fig. 4.30. Final display directional diformation

Discussions

This explicit dynamic analysis of the internal door panel of a vehicle using BSFRHC was performed for rear impact analysis of boot lid panel the impact produced while the impactor moves 50km/hr. Comparing the results obtained by FEA of the false banana, jute and glass fiber reinforced hybrid composite panel with the panels of other previously recommended materials (steel) 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. The results of the FEM analysis for FBJGFHC material and previous work of the steel boot lid displayed in the Tables 4.22 and 4.33.

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 16.0 software, along with the given boundary conditions and applied loads we got value for this load, the equivalent of the value (Von-

Mises) stress. Then the maximum equivalent (Von-Mises) stress values are noted. The results of this analysis show that the equivalent (Von-Mises) stress of the FBJGFRHC panel has 369.2 MPa.

4.4. Comparison with the Previous works on Experimental Lab Test

4.4.1. Tensile Strength

The tensile properties of samples are compared and given in Table 4.22. The tensile strength is found to be higher 66.7 MPa for composites with [45^0 JF with 0^0 FBF] fiber orientation of composite. The tensile strength mold 3 recorded in intermediate with the values of 66.74 MPa. Some other researchers working regarding tensile properties of natural fiber composites are compared with the current work.

From Table 4.22 The tensile strength which is found in the current work is more similar abaca – jute – glass fiber 45^0 fiber orientation.

Table 4.22. Comparison previous works on tensile properties of hybrid composites

Matrix Material	Fiber	Fiber orientation	Fiber/matrix ratio	Method of fabrication	Tensile Strength(MPa)	Reference
polyester	False banana-jute-glass fiber	Woven	40/60	Hand lay	66.73	Current work
Epoxy resin	Sisal /Coir	Random	40/60	Hand lay	30.00	(G.Velmurugan, 2014)
epoxy resin	Banana/Pin apple	________	40/60	Hand lay-up	60	(Madhuriran,2013)
epoxy resin	flax and banana with glass fiber	Chopped	40/60	Hand lay-up	39	(V.S. Srinivasan a, 2014)
Polyester	Glass fiber/ Banana	Chopped	35/65	Hand lay-up	45	(G.Gupta. 2016)
epoxy resin	Abaca –jute – glass fiber	Woven	40/60	Hand lay-up	66.21	(B. Vijaya Ramnath a, 2014)

4.4.2. Flexural Strength

Flexural Properties of the current work compared with that of some of the other researchers' work in table 4.23.

Table 4.23. Comparison of previous work on Flexural properties of hybrid composites

Matrix Material	Fiber	Fiber orientation	Fiber/matrix ratio(w/w)	Method of fabrication	Flexural Strength (MPa)	References
polyester	False banana-jute-glass fiber	woven	40/60	Hand lay	350	Current work
polyester	Bamboo/sisal	chopped	50/50	Hand lay	149.1.	(Dawit getu 2019)
Epoxy resin	Sisal /Coir	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)
Polyesterr	Glass fiber/banana	chopped	35/65	Hand lay up	89	(G.Gupta. 2016)
Epoxy resin	SISAL/Jute	Woven	…….	Hand lay	46	(Madhu Van ,2016)
epoxy resin	abaca–jute–glass fiber	woven	40/60	Hand lay-up	66.21	(B. Vijaya Ramnath a, 2014)
epoxy resin	flax and banana with glass fiber	chopped	40/60	Hand lay-up	13.54	(V.S. Srinivasana, 2014)
epoxy resin	Banana – Bamboo – Glass fiber	--------	--------	Hand lay-up	135.21	(Ashwin Sailesh1, 2015)

4.4.3. Impact Strength

The impact strength of the current work compared with that of some of the other researchers' work. From Table 4.24.

Table 4.24. Comparison previous works on impact properties of hybrid composites

Matrix Material	Fiber	Fiber orientation	Fiber/matrix ratio	Method of fabrication	Impact Strength Nm	References
polyester	False banana-jute-glass fiber	woven	40/60	Hand lay	8.225	Current work
Polyester	fiber/Ria 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	Random	40/60	Hand lay	4.42	(G.Velouragan, 2014

From ANSYS analysis result from false banana – jute – glass fiber reinforced hybrid composite boot lid outer panel has better energy absorbing property /toughness/ while deforming than of steel panel. Generally, FBJGFHC composite newly designed trunk lid outer panel can absorb 14.93 kJ of energy out of vehicles colliding energy of 110.85kJ whereas the existing outer panel absorbs 8.9412 kJ energy out of 111.4kJ colliding energy due to its speed and mass.

Other parameters like fuel consumption and CO_2 emission due to weight variation can be compared through table 4.25 (M. N. M. Ansari et al, 2015).

Table 4.25. Comparison of steel and FBJGFHC boot lid outer panel

	All steel body	All aluminum body	Δ	Δ New
Gross vehicle weight	2500kg	2075kg	425kg	6.5 kg
Average energy consumption	11.8L/100km	9.9L/100km	1.9L/100km	29.05ml/100km
CO2 emissions	220g/km	199g/km	21g/km	321.2g/km

Let us consider a vehicle with a composite boot lid outer panel, which can be traveled 50km per day for 1 years. Fuel to be saved can be determined as follows:

Fuel save = 29.05ml/100km × 50km/day × 365day/year × 1year = 5.3016L. Therefore within one years it is possible to save approximately 5.3L fuel from one vehicle. CO2 reduced = 126.64g/km × 50km/day × 365day/year × 1year = 2311.18kg. So it can be possible to reduce CO_2 by 58,619 kg in one years per a vehicle.

Table 4.26 Cost comparison

material	Cost in birr	Source
Existing trunk lid	25727.36	MOENCO
New developed	5689	Appendix table.A.1

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Summary

Boot or trunk lid of the rear part of the sedan car in the luggage compartment of outer panel structural member. The outer panel of the trunk lid was replaced with natural fiber composite material to enhance vehicle performance. false banana -jute fiber was used with E-glass fiber as reinforcement and polyester resin was a matrix. Cost, fuel, and emission-related problems are reasons to conduct this thesis work. Even researchers are trying to develop different mechanisms to minimize this problem, it is not as effective as working with body materials replacement. In this thesis composite material from false banana jute glass fiber was manufactured. Composite development started from plant collection and followed by its fiber extraction. The fiber was treated with NaOH to increase its surface roughness to have better bonding capability with a matrix. Different properties like tensile strength, compressive strength, bending strength, and impact strength of the developed composite was tested as per ASTM standard and optimize the best combination by Taguchi L4 orthogonal array in Minitab software. Toyota Corolla sedan car's trunk lid outer panel was modeled in solid work and analyzed in Ansys. To accomplish this thesis standards, literature findings, and MOENCO Adama branches were referred. in FBJGFHC the combination A2 (orientation of [0^0 Fbf with 45^0 JF]), B1 (mixing ratio of 1:1), and C1 (20% Fbf with 10% Jf) preferable with an average of 66.73 MPa tensile strength and 34.8 MPa. compression strength to design the panel. The software analysis was done based on these values. The energy absorption of composite material trunk lid outer panel can absorb 14.93kJ of energy out of vehicles collision energy of 110.85kJ whereas the existing outer panel absorbs 8.9412kJ energy out of 111.402 kJ collision energy due to its speed and mass.

5.2. Conclusion

False banana, jute, and glass fiber reinforced hybrid composite were 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 its usage in the automotive outer panel body application. After determining the material properties of False banana, jute and glass fiber reinforced hybrid composites with Taguchi experimental design and Ansys result of the composite material the following conclusions can be drawn

1. Successful fabrication of the hybrid composite using False banana- jute - glass fiber reinforced polyester has been done by the hand layup technique.
2. Different mechanical properties of FBJFRHC were determined from 4 number of mold or experimental setup.
3. mold 3 fiber orientation of False banana- jute - glass fiber hybrid composite samples possess good tensile strength and can withstand the strength up to 66.73 MPa
4. The mold 3 fiber orientation of False banana- jute - glass fiber hybrid composite samples maximum compression strength of 34.8 MPa.
5. The mold 1 fiber orientation of False banana- jute - glass fiber hybrid composite samples maximum flexural strength of 350 MPa
6. From the impact Experimental test results it is found that impact energy of mold 1 fiber composite higher compared to others which are about 8.22 Joules.
7. Now a day's most of the 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 the advantage to replace synthetic fibers.
8. As the analysis shows that trunk lid panel from newly developed composite material has better energy absorption property than steel material during impact.
9. This work also demonstrates the potential of the hybrid natural fiber composites can be regarded as a useful material in lightweight applications.
10. From all the results and comparisons conclude that the fabricated FBJFRHC can be used in automobile parts that do not need a very high mechanical performance but need lightweight and recyclability such as an interior panel.
11. Final properties optimization was also done in this research by Taguchi orthogonal array design of experiment
    - ✓ The combination A2, B1, C1 would provide the best tensile strength
    - ✓ The combination A1, B1, C1 would provide the best compression strength
    - ✓ The combination A2, B1, C1 would provide the best flexural strength.
    - ✓ The combination A2, B1, C1 would provide the best impact strength
12. The role of control factor also determine:-

- ✓ It is to be noted that fiber orientation and the mixing ratio play a significant role in predicting the tensile, compressive, flexural, and impact strength of the composite material.

5.3. Recommendation

It is also recommended to use false banana, jute and glass fiber hybrid composite to fabricate the non structural body parts of the vehicle to reduce the weight of the vehicle.

- ➢ Using more accurate composite manufacturing technics may increase the performance of output like resin transfer method, Vacuum Bagging, vacuum-assisted hand layup, etc.
- ➢ Developing EOSN natural fiber composite material property can be enhanced by using a matrix having better strength like epoxy resin.

It is recommended that the university has to develop the necessary facilities for preparation and testing of composite materials.

It is recommended to use false banana hybrid fiber composites in other parts of vehicle to reduce the weight of the vehicle.

5.4. Future Work

From different aspects, working on natural materials as composite has several advantages. From this point of view, regarding false banana, jute, and glass fiber reinforced hybrid composite 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 false banana, jute, and glass fiber reinforced hybrid composite.
- ✓ Design of natural fibers extraction processing machine.
- ✓ Applying false banana, jute, and glass fiber reinforced hybrid composite for the production of other internal parts of the vehicle such as dashboards. Roof, floor, Door, etc
- ✓ Making Toguchi analysis L9 and above array for further improvement or increasing the control factor and level of the design.

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APPENDIX

In this appendix, all the data that have been collected during the laboratory specimens testing were Provided. Data collected during the laboratory tensile specimens testing those are not in use on the main body of the thesis.

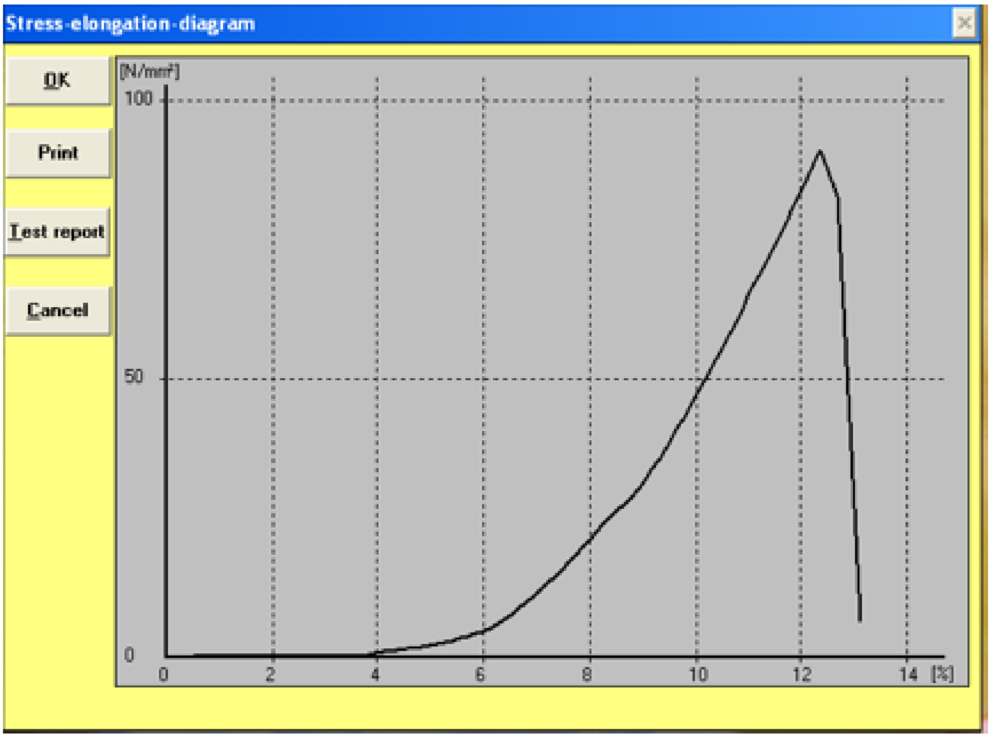

Fig. A. 1. Stress elongation diagram for mold1

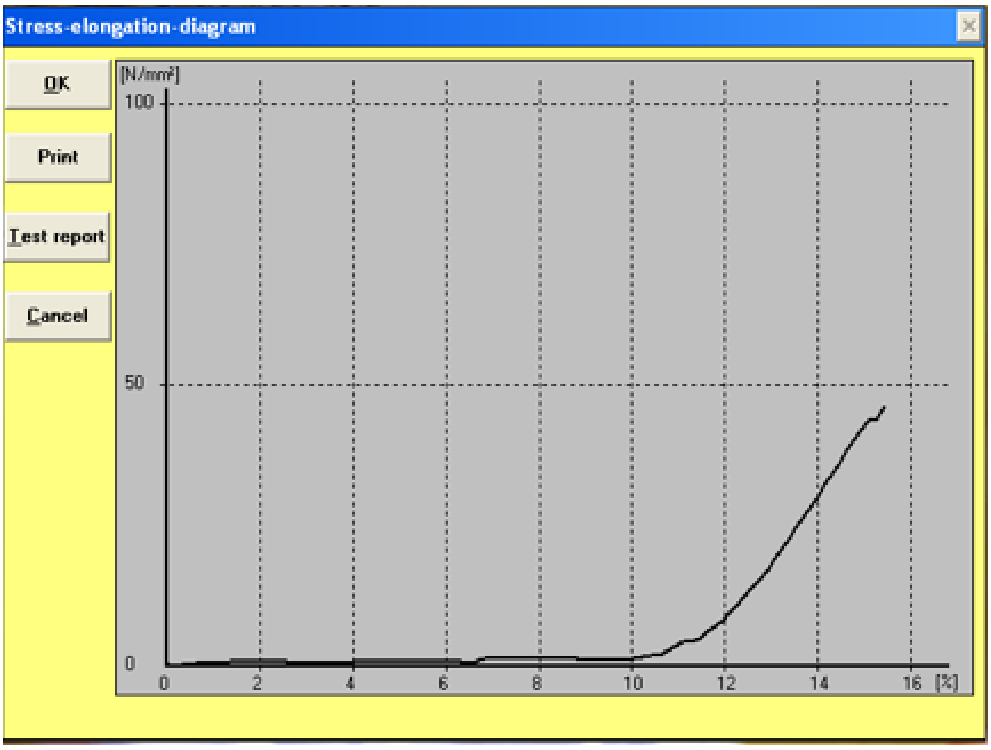

Fig. A. 2. Stress elongation diagram for mold 2

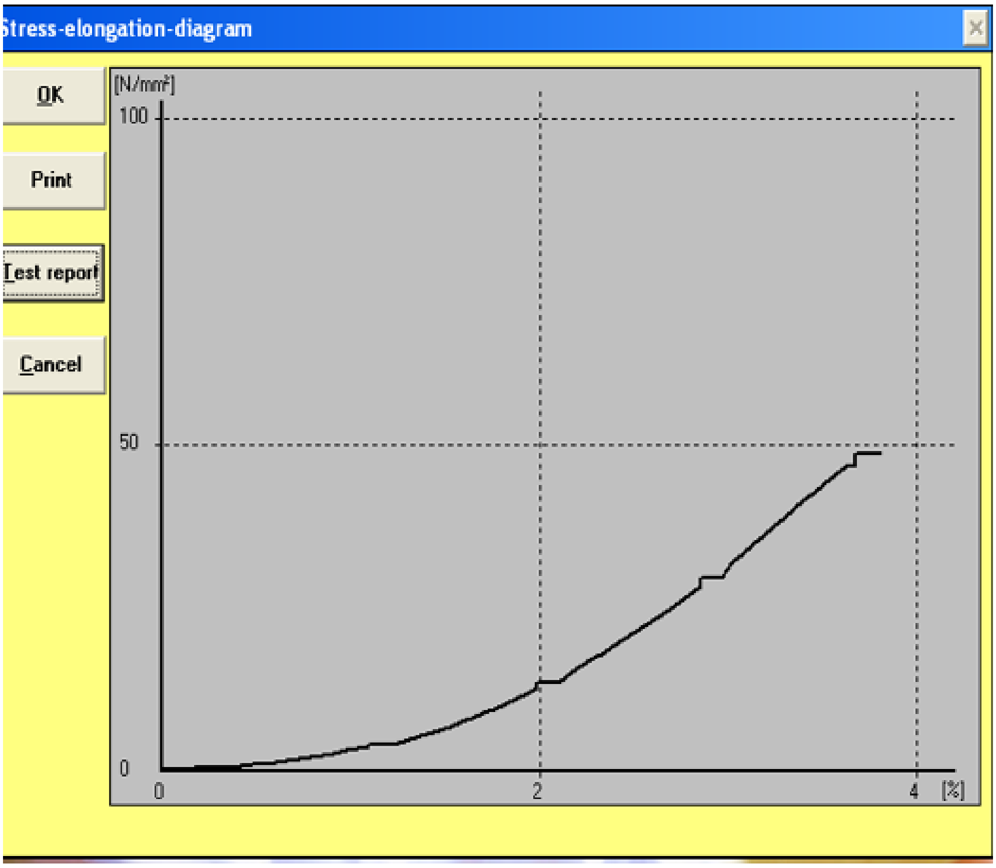

Fig. A. 3. Stress elongation diagram for mold 3

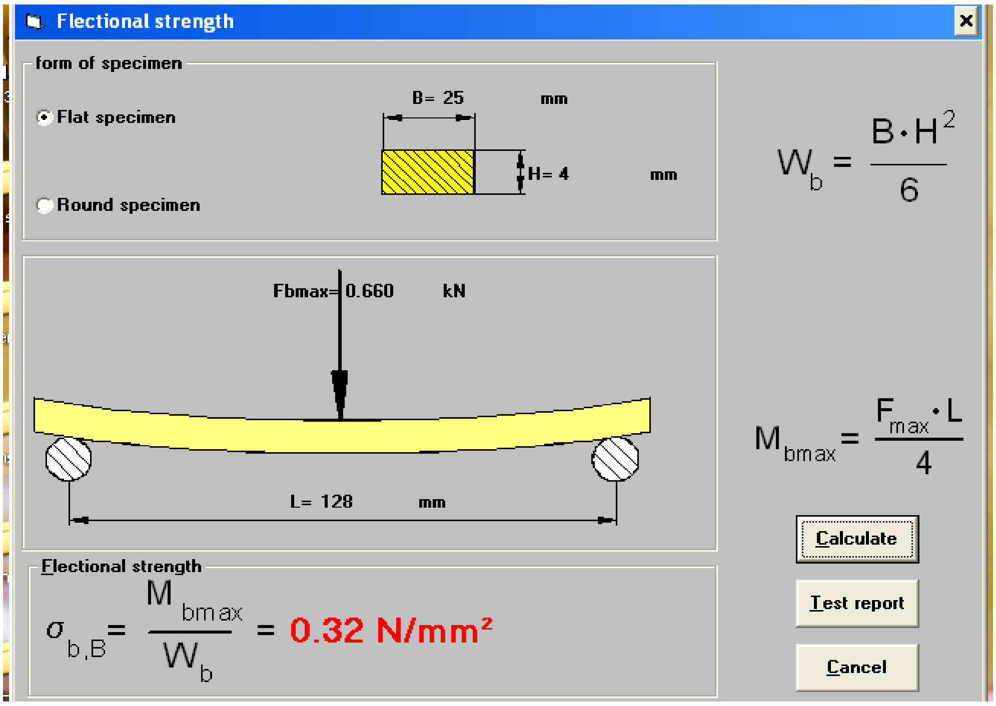

Fig. A. 4. Flexural test result on UTM machine

Table A. 1 Material cost

No	Item	Unit	Quantity	Price (birr)
1	False banana fiber	gram	1000	35
2	jute fiber	gram	1000	50
3	Glass fiber	gram	500	75
4	Hardener	Kg	10ml	60
5	Sodium hydroxide	Ml	330ml	54
6	Polyester Resin	Litter	1	135
7	Wax	gram	10	80
The total material cost of the boot lid panel				489
Labor cost				2000
Painting				1200
Finishing				1000
Contingency cost				1000
The total cost of the boot lid panel				5689

Table A. 2. The max elongation for max tensile strength 45^0 JF with 0^0 FBF Tensile Strength Rm: 68.20 N/mm²

stress	strain	Elongation [%]
0	0	0
0.0236	0.002667	0.112994
0.0484	0.002667	0.055096
0.0708	0.009333	0.131827
0.0928	0.010667	0.114943
0.1148	0.010667	0.092915
0.1372	0.008	0.058309
0.16	0.006667	0.041667
0.1828	0.006667	0.03647
0.2052	0.029333	0.14295
0.252	0.052	0.206349
0.2716	0.08	0.294551
0.3148	0.118667	0.376959
0.336	0.221333	0.65873
0.3576	0.292	0.816555
0.3788	0.366667	0.967969
0.3996	0.446667	1.117784
0.4204	0.534667	1.271805
0.4416	0.625333	1.416063
0.4616	0.718667	1.556904
0.4824	0.813333	1.686014
0.5024	0.909333	1.809979