KAUNAS UNIVERSITY OF TECHNOLOGY
MECHNICAL ENGINEERING AND DESIGN FACULTY

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Natural Fiber Reinforced Composites with Moringa and Vinyl Ester Matrix

Final project for Master degree

Supervisor
Assoc. Prof. Paulius Griskevicius

KAUNAS, 2015

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Study programme: Mechanical Engineering (621H30001)

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KAUNAS, 2015

KAUNAS UNIVERSITY OF TECHNOLOGY

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Master’s in Mechanical Engineering (621H30001)

(Title and code of study programme)

Natural Fiber Reinforced Composites with Moringa and Vinyl Ester Matrix

DECLARATION OF ACADEMIC HONESTY

04 06 2015

Kaunas

I confirm that a final project by me, **Jagannathan Sundarababu**, on the subject ". Natural Fiber Reinforced Composites with Moringa and Vinyl Ester Matrix "is written completely by myself; all provided data and research results are correct and obtained honestly. None of the parts of this thesis have been plagiarized from any printed or Internet sources, all direct and indirect quotations from other resources are indicated in literature references. No monetary amounts not provided for by law have been paid to anyone for this thesis.

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Jagannathan Sundarababu, Natural Fiber Reinforced Composites with Moringa and Vinyl Ester Matrix, Masters in mechanical engineering and Design final project supervisor Assoc. Prof. Paulius Griskevicius, Kaunas University of Technology, Mechanical Engineering and Design faculty, Mechanical Engineering department.

Kaunas, 2015. 72 p.

SUMMARY

In this research work an attempt is carried out for producing a Natural Plant Based fiber Reinforced Composites using the Moringa Resins and Vinyl Ester by utilizing the wastage of natural plant based fiber as Reinforcement material and Matrix material as Natural Resin and Vinyl Ester. The objective of the work is Utilization of Natural Plant Based Bio- degardable wastage into an alternative materials in the industrial applications by analyzing, Various Manufacturing and testing. Initially the fabrication work is also carried out with the natural plant based fiber and Natural Resin and secondly by using synthetic resin as a matrix material. The natural plant fibers like Coconut Shells Powder (CSP), Rice Husk Powder (RHP), and Linen fiber. The filler material as Sugarcane-Bagasse-Ash (SBA) Fungi. The matrix material such as Moringa (natural resin) and Vinyl Ester (synthetic resin). The Reinforcements with a particle size of 45.5 micron (µm) and density of 1.20 g/cm^3. The different composition for the manufacturing of specimens are carried out in constant proportion of 40% reinforcement and 60% of matrix material by manufacturing with Moringa and on the other hand by Vinyl Ester. The manufacturing is done by hand lay-up method. The mechanical properties of the natural based fiber composite materials is illustrated. Such as Tensile Testing. The hardness of the material is carried out by using the Brinell hardness testing. The behavior of the materials and the surface morphology are carried out by using the optical microscope and USB electron microscope. Finally the potential of the natural composites and synthetic composites is explored and investigated.

Key words: Coconut Shells Powder (CSP), Rice Husk Powder (RHP), Sugarcane-Bagasse-Ash (SBA), Fungi, Linen Fiber, Moringa Resin, Vinyl Ester, Tensile Testing, Hardness Testing.

Jagannathan Sundarababu, Natūraliomis medžiagomis armuoti kompozitai su moringos ir vinilesterio derva, Mechanikos inžinerijos magistro baigiamasis darbas / vadovas Assoc. Prof. Dr. Paulius Griškevičius; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas, Mechanikos inžinerijos katedra.

Kaunas, 2015. 72 p.

SANTRAUKA

Darbe atlikti kompozitinių struktūrų gamybos iš natūralių medžiagų tyrimai t.y. armuojančios medžiagos kokoso riešutų kevalų milteliai, ryžių lukštų milteliai, cukranendrių milteliai, lelijos lapų milteliai, natūralios medžiagos moringos derva ir sintetinė vinilesterio derva. Darbo tikslas eksperimentiškai ištirti galimybes panaudoti augalinės kilmės biologiškai skaidžių natūralių medžiagų atliekų priemaišas gaminant alternatyvias kompozitines medžiagas tinkančias pramonei. Pirmiausia iš natūralių augalinės kilmės atliekinių medžaigų paruoštas užpildas ir derva, vėliau natūrali derva pakeista į sintetinę. Užpildo medžiagos (kokoso riešutų kevalų milteliai, ryžių lukštų milteliai, cukranendrių milteliai, lelijos lapų milteliai) sumaltos iki 45,5 μm dalelių dydžio, kurių tankis apie 1.20 g/cm^{3}*. Bandiniai buvo gaminami varijuojant užpildo santykines dalis siekiant nustatyti, priemaišų įtaką kompozitinės medžiagos mechaninėms savybėms. Užpildo ir dervos masės santykis buvo 40% ir 60%. Bandiniai buvo gaminami rankinio formavimo metodu. Darbe pateikiamos medžiagų mechaninės savybės, nustatytos tempimo kietumo bandymais pagal Brinelį. Naudojant optinį ir USB elektroninį mikroskopus buvo analizuojamos medžiagos struktūros. Galiausiai išanalizuotos kompozitinių struktūrų iš natūralių ir sintetinių medžiagų perspektyvos.*

Key words: Kokoso riešutų kevalų milteliai, Ryžių lukštų milteliai, Cukranendrių milteliai, lelijos lapų milteliai, Lino pluoštas, Moringos derva, Vinilesterio derva, Tempimo bandymas, Kietumo bandymas.

KAUNAS UN IVERSITY OF TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Approved:
Head of Mechanical Engineering Department

_______________________ *(Signature, date)*

Vytautas Grigas
(Name, Surname)

MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme MECHANICAL ENGINERING

The final project of Master studies to gain the master qualification degree, is research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

NATURAL FIBER REINFORCED COMPOSITES WITH MORINGA AND VINYL ESTER MATRIX

Approved by the Dean 2015 y. May m.11d. __ Order No. ST17-F-11-2

2. Aim of the project

Analyse the Mechanical Property of Natural Plant Based Reinfored compsoites with Moringa and Vinyl Ester

3. Structure of the project

Collection of Materials, Planetary Milling – Individual milling, Homogenous milling, Identification of particle size and density by using the Hydraulic Compacting Machine and Optical Microscopy, Manufacturing of Specimens firstly with 100% Natural like reinforcements (40%) and matrix (Natural) (60%) and secondly with reinforcements (40%) and matrix (Polymer) (60%), Different case study is done for manufacturing, results are evaluated and the potential use has been identified by carrying out various Mechanical Testing such as Tensile testing, Brinell Hardness, Young Modulus, Theoretical with experimental Values are evaluated.

4. Requirements and conditions

General Requirements for Master Thesis

5. This task assignment is an integral part of the final project

6. Project submission deadline: 2015 June 1st.

Given to the student

Task Assignment received Jagannathan Sundara babu
(*Name, Surname of the Student*) (*Signature, date*)

Supervisor Assoc. Prof.Paulius Griskevicius
(*Position, Name, Surname*) (*Signature, date*)

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Abbreviations

1. Coconut Shell Powder (CSP)

2. Rice Husk Powder (RHP)

3. Sugarcane Baggase Ash (SCBA)

4. Response Surface Modelling (RSM)

ACKNOWLEGEMENT

My Sincere thanks to **Assoc. Prof. Paulius Griskevicius** from department of mechanical engineering at **Kaunas University of Technology** who has been a great Motivator and Supervisor for my Research work. My Sincere thanks to **Dr. Cabrere Marrero Jose Maria** from Department of Materials Engineering at **Universitat Politecnica de Catalunya · BarcelonaTech (Erasmus Study)** for helping out to carry out my research work in the UPC Materials Engineering Laboratory. My Sincere thanks to **Mr. Lluis Rodriguez Jose Maria** General Manager and **Marc Crescenti** Research and Development Manager at **Center of Technology of composites** (CETECOM) for providing me an great oppturnity to Successfully Complete my Research work by carrying out an Erasmus Traineeship at **“Associació Centre Tecnològic del Compòsit”** (la "Compañía"), (CETECOM) at Amposta. Spain.

1. Introduction

The composite materials is the combination of reinforcements and the matrix, where the reinforcements such as fiber from plants like coconut shell, rice husk, sugar-cane baggase ash, which is mainly the wastage from the plant based natural fibers. The matrix is the lum of moringa plant which is crystal structured and hard materials which act as binding material for the composite material. The reinforcement phase are discontinuous whereas the matrix is in continuous phase. The matrix acts as a load bearing materials which can transfer the stress to the reinforcement. The reinforcement is the dispersed phase which is basically stronger than the matrix. Reinforcement material are such as fibers like, sisal, areca, hemp, flax, kenaf, coir, baggase, jute, cotton, bamboo, Roselle, coconut shell, rice husk, banana, pineapple, these are the fibers that are not manmade or synthetic. Hence, these fibers are actually plentiful stock all around the world.

The natural fiber composites are completely natural and biodegradable, the wastage from the plants are collected and dumped as a ground waste. These dumped wastage are extracted and used for the production of several applications. The challenge in working with natural fiber composites has a large variation on the properties and characteristics. The properties of natural fibers are mostly impacted by the type of fiber, environmental conditions, where the plant fiber are obtained and also the treatments to the fiber.

Aim: The objective of the research work is to analyze the mechanical property of the natural plant based fiber with Moringa and Vinyl Ester Matrix.

Task

1. The extraction of the Natural Fiber is to be done and measurement of the particle size and density of the fiber is determined by using the Hydraulic Compacting Machine and Optical Microscopy.

2. Manufacturing of composites is to be done such as Composites of Natural plant fiber with Moringa Resin, Composites of Natural plant fiber with Vinyl Ester Resin, Composites of Vinyl Ester with Coarse and Fine, Composites of Vinyl Ester with Linen fiber, Composites of Pure Vinyl Ester

3. Analyzing of the Manufactured Specimen by Tensile Testing, Hardness Testing and comparing the experimental results with Theoretical results.

2. Literature survey

The natural fibers and the fillers reinforced thermoplastic composite have successfully proven their quality in various fields of technical application due to their lower density, good thermal expansion, mechanical properties, reduced tool wear, unlimited availability from the environment, low price and avoidance of disposal problem due to their biocompability. The investigation of the better comfort ability of natural fiber composites in structural and infrastructural applications where moderate strength, lower cost and environmental friendly features are required. LOC Composites Pty Ltd has developed and produced a fiber composites sandwich panel which uses plant based polymers that can be used in several applications such as balcony construction, walls, roofs, floors, fire doors. The natural fiber composites panel is suitable for the housing construction materials, furniture and automotive parts has been developed [1].

Natural Wood fibers / particles gives much sufficient as a reinforcement at lower cost than the synthetic and mineral filled thermoplastic. Whenever there is a usage of synthetic and mineral fibers there has been damage on processing is more than the wood filler and in the machine wear. Utilization of wood gently reduced the fibers from damage during processing, which allows for recycling the waste production without compromising the quality [2]. Natural fiber composites are light in weight and ease of carrying and it's a biodegradable materials so as these comes from the eco- friendly material. These can be used in the industrial application as an engineered materials due to their high strength to weight ratio, as well as low cost, eventually it's abundance in the environment.

Various studies have shown that the use of epoxy resins for the improvement of the composite materials as well as the combination to the reinforcements materials like fiber and filler pineapple, sisal, jute, coir, bamboo and wood have been studied by Luo and Netravali Studied the tensile and flexural properties of the green composites with different pineapple fiber Content and compared with the virgin resin. Sisal fiber is fairly coarse and inflexible. It has good strength, durability, Ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in seawater. Sisal ropes and twines are widely used for marine, agricultural, shipping, and general industrial use [3].

B.H. Manjunath, Dr. K Prahlada Rao [4] has investigated the study on influence of fiber / filler particles Reinforcement on epoxy composites and showed the tensile properties of the composites are increased by adding the fiber and the filler content whereas the moisture absorption is high if the filler content is added with the fiber. The results shown that tensile and flexural properties of the composites increased with increase of filler particle content and fiber content.

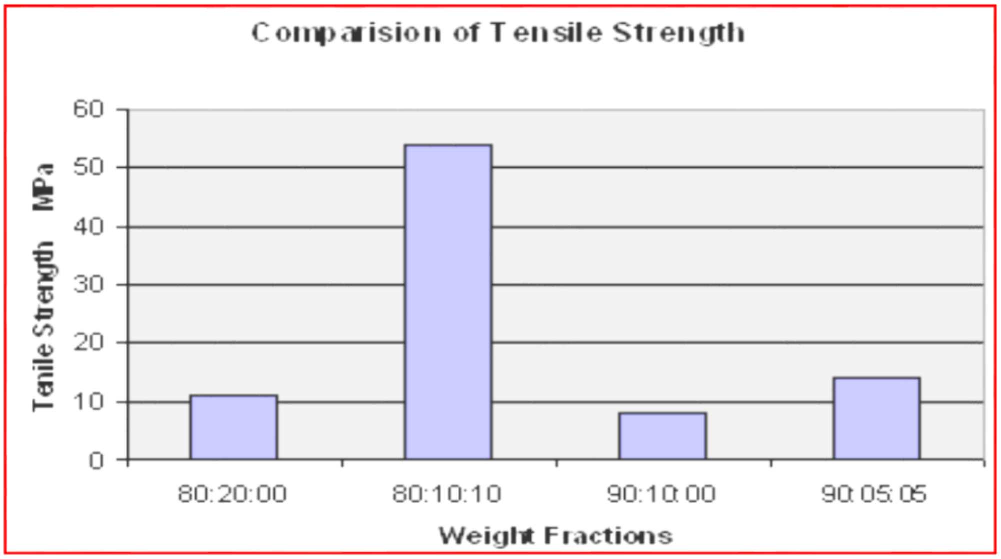


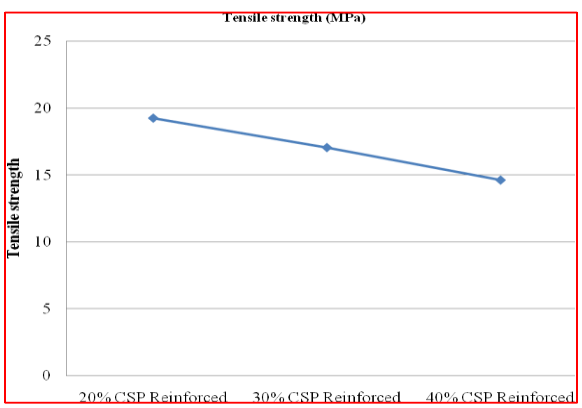
Figure – 1 Comparison of Tensile strength of composite specimen with fiber reinforcement and without fiber reinforcement [4].

J.Sahari and S.M.Sapuan [5] evaluated the development and properties of natural fiber reinforced Biodegradable polymer composites. The tensile and flexural properties of composites made from coconut shell filler particles and epoxy resin. The tensile and flexural tests of composites based on coconut shell filler particles at three different filler contents *viz*. 5%, 10%, and 15%, were carried out using universal tensile testing machine. Experimental results showed that tensile properties of the composites increased with the increase of the filler particle content. The composite materials demonstrate somewhat linear behavior and sharp fracture for tensile the relation between stress and percentage of filler for tensile and flexural tests were found to be linear with correlation factors of 0.9929 and 0.9973 respectively.

In late 1980s, the development of bio composites had been intensified and polymer matrices reinforced with natural fibers had gained more attention among the researchers [6]. Bio-composite with starch used as a matrix is one of the most popular biodegradable bio composite and is highly investigated by researchers [7, 8]. Biodegradable matrices were reinforced with natural fibers to improve the composites properties and these composites provide positive environmental advantages, good mechanical properties and light weight. Luo and Netravali studied the tensile and flexural properties of the green composites with different pineapple fiber Content and compared with the virgin resin. Sisal fiber is fairly coarse and inflexible. It has good strength, durability, Ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in seawater. Sisal ropes and twines are widely used for marine, agricultural, shipping, and general industrial use. [9], Schneider [10], Faud [11], Ahmed [12], have studied pineapple, cotton fiber wounded by filament, oil palm wood flour, kenaf and jute fiber based on the composite respectively.

In general, their result stated that the particles had not shown extreme effective in improving the fracture resistance but they enhanced the stiffness of the composites to a limited extent. The fillers are extensively used to improve the properties of the matrix materials such as to modify the thermal and electrical conductive and the major importance is to reduce the cost and also it is used to reduce the matrix content. The nature composites usage has been drastically increased due to their lower density, light weight, ecological advances over the conventional composites.

Alok Singh, S.Muthukumar, [13-14] developed a polymer matrix composite (Epoxy- resin) using coconut shell powder (CSP) in different particle size and reinforcing in different volume and evaluate its tensile strength, flexural property and hydrophilic behavior along with engineering application of resulting composites.



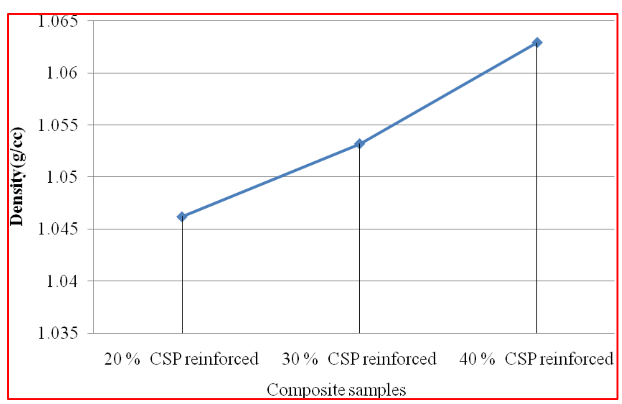


Figure -2 Tensile Strength Curve and Density Curve [13-14].

The experimental investigation on mechanical properties viz. density, tensile strength and flexural strength of CSP epoxy composite material is greatly influenced by the CSP filled volume fraction. The density of the composite having 20% CSP filled is less compared to others. That an increase of filler volume from 20% to 30% the density increases gradually while an increase in filler Volume from 30% to 40% the density increases rapidly. Thus, the rate of increase in density is maximum from 30% to 40%CSP filled composites. The maximum tensile strength is obtained for the composite prepared with 20% CSP volume fraction. The tensile strength increase of filler volume the tensile strength goes on decreasing. The maximum flexural strength is obtained for the composite prepared with 30% CSP filled while; the flexural Strength is minimum for the composite prepared with 40% CSP filled.

The flexural strength that an increase of filler volume flexural strength increases from 20% to 30%, while, the flexural strength decreases on increasing filler volume from 30% to 40%. Thus, the rate of decrease of flexural strength from 30% to 40% is greater than the rate of increase from 20% to 30% CSP filled composite. The less water absorption is obtained for the composite prepared with 20% CSP volume fraction. An Increase of reinforcing volume the water absorption goes on increasing. Consequently, the composite prepared with 20% to 30% CSP filled volume fraction is suitable for the application in the interior part of an aircraft, motor car and automobile where materials with good tensile strength, low density and low hydrophilic characteristic are required.

T. Balarami Reddy [15] conducted experiments on the mechanical performance of green coconut shell fiber / high density polymer fiber composites. The main objectives he resulted is to develop a new class of fiber based polymer the potential of green coconut shell fiber. He studied the effects of fiber length and fiber volume fraction on mechanical behavior of green coconut fiber reinforced HDPE based composites. Evaluation of mechanical properties such as Tensile Testing (TS). Developed and analyzed mathematical model to predict mechanical properties of green coconut fiber reinforced HDPE composites like Tensile Testing (TS) from experimental results using response surface methodology (RSM).

The response function has been determined in un-coded units as

$$\mathbf{T.S = 8.93 + 0.474 * V_f - 0.084 * f_1 - 0.00587 * (v_f)^2 + 0.012\,(f_1)^2 + 0.00058 * V_f * f_1 \ldots(1)}$$

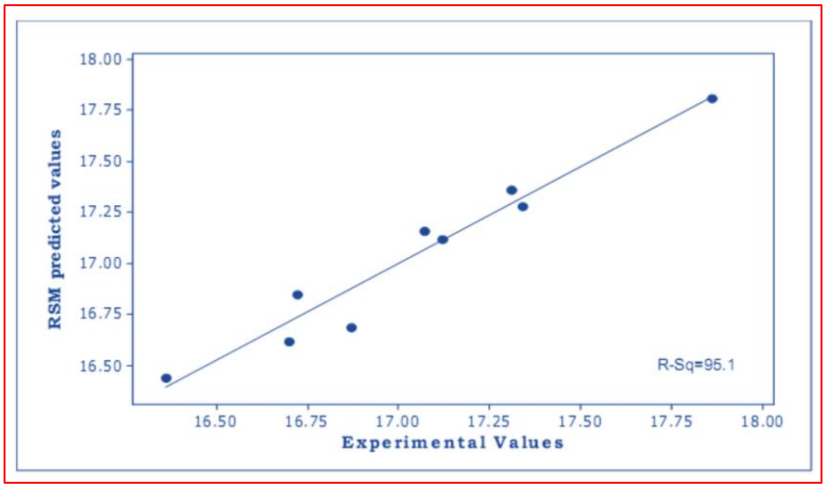


Figure - 3 Comparison plot for Tensile strength [15].

D. Chandramohan [16] conducted hardness test in the Natural fiber reinforced polymer composites such as (*Agave sisalana*), Banana (*Musa sepientum*) & Roselle (*Hibiscus sabdariffa*) , Sisal and banana (hybrid) , Roselle and banana (hybrid) and Roselle and sisal (hybrid) are fabricated with bio epoxy resin using molding method. The hardness of Sisal and banana (hybrid), Roselle and banana (hybridand Roselle and sisal (hybrid) composite at dry and wet conditions were studied. Hardness test were conducted using Brinell hardness testing machine.

Table -1 Material comparison for hardness test [16]

MATERIAL	BHN
Banana	323
Sisal	442.5
Roselle	767
Banana and Sisal (hybrid) reinforced composites	338.2
Banana and Roselle(hybrid) reinforced composites	409.5
Sisal and Roselle(hybrid) reinforced composites	522

J. Olumuyiwa Agunsoye*, Talabi S. Isaac, Sanni O. Samuel [17], The morphology and mechanical properties of coconut shell reinforced polyethylene composite have been evaluated to establish the possibility of using it as a new material for engineering applications. Coconut shell reinforced composite was prepared by compacting low density polyethylene matrix with 5% - 25% volume fraction coconut shell particles and the effect of the particles on the mechanical properties of the composite produced was investigated. The result shows that the hardness of the composite increases with increase in coconut shell content though the tensile strength, modulus of elasticity, impact energy and ductility of the composite decreases with increase in the particle content. Scanning Electron Microscopy (SEM) of the composites (with 0% - 25% particles) surfaces indicates poor interfacial interaction between the coconut shell particle and the low density polyethylene matrix.

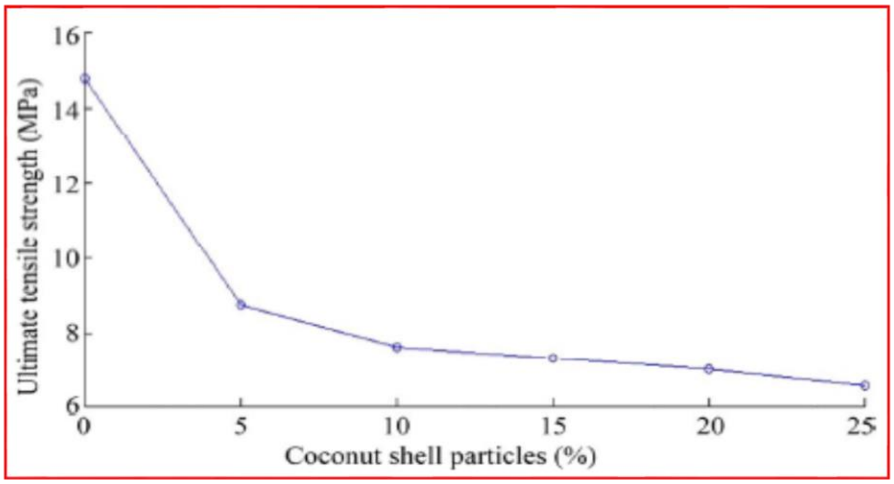


Figure- 4 Effect of coconut shell particles addition [17].

The non-uniform distribution of coconut shell particle in the microstructure of the coconut shell reinforced polyethylene composite is the major factor responsible for the decrease in strength when compared with the control sample having 0% coconut shell particles. As the percentage of particle increases, there was a corresponding decrease in porosity. This property makes the composite suitable for the application in the interior part of a motor car where materials with good hydrophobic characteristic are required. Coconut shell particles improve the hardness property of the polyethylene matrix composite. This property is an added requirement for automobile interior.

3. Methodology

3.1 Materials for the fabrication

The natural fibers for the research work are sourced from the environment which is biodegradable

<u>The Reinforcement's materials</u>

Fibers

a) Coconut shell powder

b) Rice husk ash

Filler

c) Fungi (extracted from the lakeshore)

d) Sugarcane baggase ash

<u>The matrix materials</u>

Bio resin

e) Moringa resin

Synthetic resin

f) Vinyl Ester

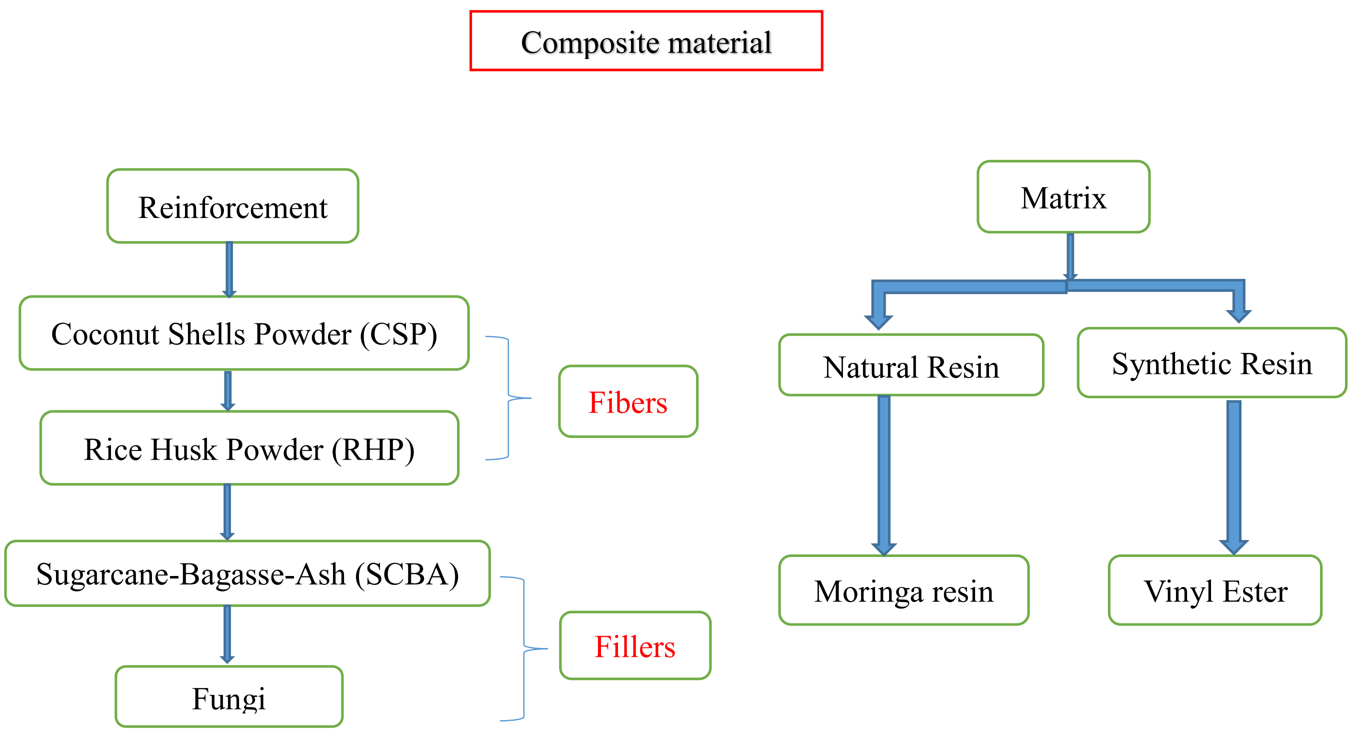


Figure – 5 Materials for the fabrication

a) Coconut Shells Powder (CSP)

The coconut shell is the one of the most abundant plant fiber all the world, it is cultivated more than 80 countries mainly in the tropical and subtropical countries like Philippines, Malaysia, Indonesia, Brazil, Srilanka, Thailand, Mexico, Vietnam, Papua New Guinea, Tanzania and India after the consumption of coconut water, oil and meal the shell of the coconut is thrown away as a wastage and also certainly these plentiful wastage as dumped as a wastage, these can be avoided by using as a reinforcements for the production of composites as an engineering material. Several authors have investigated to develop the composites by using the coconut shell as a filler and the reinforcement materials using the epoxy resins as a matrix with difference in the particle size and reinforcing it with different volume. They have evaluated the tensile and flexural properties of the materials along with engineering application.

The mechanical properties and dynamic characteristic of the coconut shell fiber reinforced composites have conducted by I.Z.Bujang, M.K.Awang and A.E.Ismail [18] and also they have evaluated the influence of the fibers volume, where they proved by their work that the increase in the fiber content increased the dynamic characteristics, however the stress between the matrix and fiber is effective due to the matrix which is polyester matrix causes the deformation due to high strain values and reduction on the high resonant amplitude.

(Coconut shell collected from farm) (Coconut shell pulverizing) Coconut shell powder (milled)

Figure -6 Coconut shell Processing

The morphology and mechanical properties of coconut shell particles reinforced natural composite have been evaluated to establish the possibility of using it as an alternative material for engineering and its applications, Vignesh.K, Natarajan, and Vijayasekar.A [19]. In our research the coconut shell is extracted from the coconut farm where the coconut shells which is free from the contaminations from the coir, pith, are broken into small pieces and fed into the a pulverizer machine. The coconut shell powder obtained from the pulverizer is further feed into the cyclone.

Eventually, the parallel products obtained is collected in a bag filters. The coconut shell powder is then feed into the vibrating sieving machine which can be recycled in the pulverizer for further size reduction to attain the fine and coarse grain size of the particles. Initially, the CSP particles size is measured by using the optical microscopy, where the size of the particles is about 200-800µm. The density is about 1.60 g/cm^3. Further the CSP is taken for planetary millings to reduce the grain size for achieving the good mechanical properties of the materials. As the grain or particle size decreases the strength increase as the density also decrease it reduces the porosity of the fiber. Eventually the materials load bearing capacity will be increased by using this technique D G.Morris [20].

b) Rice Husk Powder (RHP)

Rice husk is the one of the most widely available agricultural wastes in many rice producing countries around the world. Globally, approximately 600 million tons of the rice paddy is produced each year. On an average of 20 % of the rice paddy is husk, certainly producing an annual total production of 120 million tones [21]. In most of rice producing countries the husk which is considered as a wastage are dumped on the ground or either been burnt [22]. Burning of rice husk in ambient atmospheric leaves a residue called as rice husk ash, for every 1000 Kilograms of paddy milled, about 20 % of rice husk is produced and this husk is burnt in the boilers, about 55 kilograms (25 %) of RHA is generated [23]. The removal of rice husk during rice refining creates problems in disposal due to less commercial interest.

Rice husk from agriculture Rice husk ash Rice husk (milled)

Figure –7 Rice Husk Processing

Eventually, of its less density it is a tedious process for transportation and handling. It can cause problem on the surrounding where the rice husk has been dumped. Certainly use of rice husk in an alternative process has been take over in the research works for the avoidance of such a great damage to the environment. Rice husk contains 75-90 % organic matter such as cellulose, lignin etc. and also the minerals like silica, alkalis and trace elements [24]. The content of the organic matters depend on the rice variety, soil density, climate conditions, and even the geographic localization of the culture [25].

Basically, rice husk contains high is ash compared to other biomass fuels in the range of 10-20 %. The ash is about 87-97% of silica [26], highly porous and light weight with a high surface external area. Due to the extreme content of silica it’s been a valuable materials for the industrial applications. Certainly, there is various factors which can influence on the rice husk ash properties such as temperature, duration of the crop, rate of heating, burning techniques, crop variety, fertilizer used [27]. Rice husk as also used for the construction industries and cement like binding materials for bricks, concretes. Blended cement has fulfilled the mechanical properties of the cements which can be stronger and durable materials for the cement, nowadays blending of rice husk in the cement has been a common recommendation for international building codes. Some of the reports indicate that the rice husk ash as a highly reactive pozzolanic [28-29]. The rice husk ash can be added in manufacturing of low cost concrete block. The usage of this mineral can give to a new industrial sector of rice husk.

c) Sugarcane bagasse ash (SCBA)

The sugarcane bagasse ash wastage is the one of the most abundant waste from the industry producing the sugarcane. Mainly it is one the major wastage which is drawn out from the industries and dumped as a wastage in the earth. Eventually, Sugarcane baggase ash is an industrial waste which is used worldwide as a fuel in the some sugarcane industry. Nowadays, the rescue of waste materials for concrete production is a worldwide in practice.

Raw SCBA SCBA for milling Milled SCBA

Figure - 8 Sugarcane Baggase Ash Processing

In addition these can be added to the rice husk for the concrete and act as good binder materials [30]. The bagasse is produced as a fibrous residue after crushing and juice extraction in water media in sugar industries, and it is reused as a fuel in boilers in the same industry for heat generation and vapour. Eventually, the ash, sugarcane bagasse ash, SCBS usually bottom ash and in a smaller proportion, fly ash, are valuable material for cement and concrete production due to the presence of high amount of silicon and aluminum oxides. For each 10 tones' of sugarcane crushed, a sugar factory produces nearly 3 tones' of wet bagasse. Sugarcane crushed out from the machine and it's removed from the conveyor belt as a wastage. Since bagasse is a by-product of the sugar - cane sugar industry, the quantity of production in each country is in line with the quantity of sugarcane produced. The high moisture content of bagasse, typically 40 to 50%, are used as a fuel. In general, bagasse is stored prior to further processing. For electricity production, it is stored under moist conditions, and the mild in exothermic reaction that results from the degradation of residual sugars which dries the bagasse pile slightly. For paper and pulp production, it is normally stored wet in order to assist in removal of the short pith fibers, which impede the papermaking process, as well as to remove any remaining sugar. SCBA from factories has a more amount of carbon content (higher than 15%) and is can be used in the concrete production. Certainly it can also be used as a replacement materials for cement. Due to the high carbon content it can used to increase the strength when used a hydraulic binder [31].

d) Fungi

Fungi is the one the most abundant wastage from the seashore, lakes and ponds. Basically, the colour of fungi is green, also a soft material. Initially the fungi is extracted from the lake which contains water molecules and it's like a Jelly materials. The water molecules from the fungi is dried out in a sunlight for 24hours, the water molecules from the fungi has been partially absorbed by the sunlight. Further to obtain a complete dryness once again the fungi is dried in the sunlight for 24hours. After all the water molecules is removed from the fungi eventually, it is taken for the grinding process. The grinding of the fungi takes place in the room temperature, eventually to make the dried fungi into powder. Once the grinding process has been completed it is taken to the mechanical milling to reduce the size by using the milling process as well compacting of the samples with different load in tones by using an hydraulic compacting machine and the size of the fungi and density of the fungi is measured using the optical microscopy through individually (fungi) and also with the other reinforcement materials such as coconut shell powder, rice husk ash, sugarcane baggase ash, and the data are measured and evaluated.

Fungi at the lake shore | Fungi collected for the process | Fungi dried and powdered

Figure – 9 Fungi

In the milling process the planetary milling is considered for the milling of fiber to attain the reduction of particle size as well as even distribution of size. The milling process has done in an ambient temperature with an ionic vial containing 10 millimeter (mm) steel ball acting as a grinding medium and the rotation speed 200 rpm for a milling time is about 30 minutes. The evaluated values shown that the when it is individually milled and compacted with different load in tones the average value of the particle size obtained is about 27.2 µm (microns) and whereas the density is of about 1.60g/cm^3. When it is milled with the reinforcement material such as coconut shell powder, rice husk ash, sugarcane baggase ash, the density of the particle and the particle size of the homogenous milling has been obtained as about 45.5 µm (microns) whereas the density of the homogenous materials has 1.19-1.25 g/cm^3 has been obtained.

e) Moringa resin

The moringa resin is plant based bio resin which is obtained from the moringa plant and one of the major wastage of the moringa plant. The name is derived from Murungai/Muringa, from the scientific family Moringa Oleifera. It is crystal like structure with purple reddish color with uneven distribution of size secreted from the moringa plant. The resin from moringa is like a lump of material which perhaps have a behavior like Polylactic acid (PLA). Namely the other parts of the plant are used as a vegetables and as well as in medicinal field. The lump like materials is present across the plant which is sticky as shown in the figure below. The resin is melted in a furnace for about 135˚C in the ambient temperature for attaining solid moringa resin material which can be coupled with the reinforcement and the filler. Certainly the reinforcement's materials such as fiber from the plants cannot be heated due to the dryness and it may get burnt out easily for this avoidance the resin is melted individually.

Basically, for this reason the moringa is heated for the formation of solid like material and also the main consideration is that the resin extracted from the moringa plant is crystal like structure so to bind with the reinforcements it must be melted to attain a specific condition which is known as solid state.

Moringa plant Resin extracted from plant Milled Moringa

Figure -10 Moringa Resin

As from the nature the moringa resin has a jelly like property has been a good resistance to corrosion as well as the avoidance of water molecules. The crystal naturally has high stiffness and strength also has a light in weight, harmless to human beings to work with because of its naturally occurring property. According to Kelly [32] he states that clearly the composite materials cannot be simply a combination of two materials. In a wide consequence, the combination has its own unique properties. The moringa resin a thermoplastic polymer matrices which is natural extracted from the plant as a wastage from the plant. The moringa resin is a biodegradable material, light in weight and it's readily available from the environment as a waste material. The usage of moringa resin in engineering applications can be given birth to the moringa plant. These resins can be a substitute to the synthetic polymer in the composite materials and the resin is an extracted from the plant is the main advantage that it a biodegradable materials.

f).Vinyl Ester

Vinyl Ester is similar in the molecular structure, but differ primarily in the location of their reactive sites, these being positioned only at the ends of the molecular chains. As the whole length of the molecular chains is available to absorb shock loadings. This makes vinyl ester resins tougher and more resilient than polyesters. It is better resistance to water. Bought from the shops for the manufacturing process to carry over.

3.2 Planetary milling

Individual milling of Reinforcements

Mechanical alloying is a powder processing technique which permit for the production of homogenous materials to form a blended elemental powder mixtures. Mechanical milling is mostly a dry, high – energy ball milling technique and it is used to produce a variety of commercially useful and scientifically interesting materials.

a) Process of mechanical milling

The mechanical milling is that the mixing of powders in the right proportion and loading the powder to the mill with the grinding medium, which is generally the steel balls. The mix is allowed to mill for the desired time with the desired speed to attain the steady state of proportion of the fibers and fillers. To achieve the desired density and property of the particles.

b) Raw materials

The raw materials used for the mechanical milling are widely available commercially pure powders that should have a particle size in the range of 1mm. The powder particle size should be not critical it should be smaller than the grinding ball size, the grinding ball size is about 10mm.The powder particle size decreases exponentially with the time and it reaches a small value of about 50 microns only after 30 minutes of milling as per our milling standard time for all the milling which is likewise as individual milling of all particles as well as homogeneous milling (with different composition) of the particles.

c) The mill (planetary ball)

Planetary ball mills is referred as pulverisette in which a few hundred grams can be milled at a time about 50% of vial should be empty while milling to get a good homogenous milling of the fibers. The movement of vial is planet like, the vials are arranged in a rotating disk, and it has a special drive mechanism which causes them to rotate around their own axis. The centrifugal force produced by the vials rotating around their own axes and that produced by the rotating support disk both act as on the vial contents, consisting of material to be ground and the grinding balls. The grinding vials (steel) and the balls (steel) is used for milling for the biodegradable wastage which is collected from the environment for the research works. The selection of the planetary ball mill is due to the linear velocity of the balls in this type of mill is higher than that in the spex mills. The frequency of impacts is much more in the spex mills. In comparison with the spex mill, the planetary ball mills be considered as lower energy mills.

d) Process variables

Mechanical alloying is a complex process and which hence involves the optimization of a number of variables to achieve the desired product phase and/or microstructure. The planetary ball mill owes its name to the planet – like movement of its vials. These are arranged on a rotating support disk and a special drive mechanism causes them to rotate around their own axis. The centrifugal force produced by the vials rotating around their own axes and that produced by the rotating support disk both act on the vial contents, consisting of material to be milled.

Planetary ball milling

Rotational speed and time

Steel vial and steel ball

Figure – 11 Individual milling of Reinforcements

e) Important parameters for the final constitution of powder

Table -2 Parameters for the final constitution of powder

Milling container	– steel,
Milling speed	– 200 rpm
Milling time	– 30 minutes
Grinding medium	– type- steel, size of ball – 10 mm,
Milling atmosphere	– room temperature,
Extent of filling of vial	– partially filled,

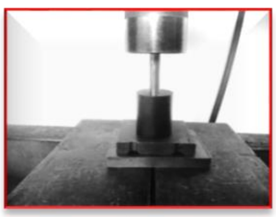
f) Planetary ball milling

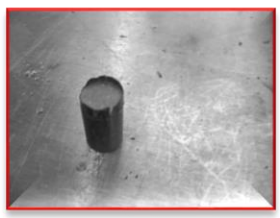
The popular mill for conducting the mechanical alloying is the planetary ball mill which is referred as pulverisette in which a few hundred grams of the powder can be milled at a time. The planetary ball mill owes its name to the planet – like movement of its vials. These are arranged on a rotating support disk and a special drive mechanism causes them to rotate around their own axis. The centrifugal force produced by the vials rotating around their own axes and that produced by the rotating support disk both act on the vial contents, consisting of material to be ground and the grinding balls. The grinding vials (steel) and the balls (steel) is used for milling for the biodegradable wastage which is collected from the environment for the research works. The selection of the planetary ball mill is due to the linear velocity of the balls in this type of mill is higher than that in the spex mills. The frequency of impacts is much more in the spex mills. In comparison with the spex mill, the planetary ball mills be considered as lower energy mills.

Measurement of Density and Particle size by Hydraulic Compacting and Optical Microscopy

A compactor is a machine or mechanism used to reduce the size of material through compaction, normally powered by hydraulics. The form of hydraulically powered sliding plates which sweep out the collection hopper and compress the material into what has already been loaded. The plant fiber is weighed by the required quantity and compressed in an ionic mould and placed in the compacting machine. The force applied in an axial direction towards the mould by powering up the hydraulic machine by hands. The applied pressure is viewed by using the dial gauge which is attached to the compacting machine. The powdered sample which is milled in an planetary milling and weighed by the weighing machine and then taken for the compacting respectively all the fiber and adhesives are milled by the same process and each of them are measured by the weighing machine and compacting is done separately. The materials which is going to be compacted is placed in a steel mould to carry out a perfect shape and size to determine the size and density of the each sample. The mould should be partially filled by the materials to avoid without fracture of the samples shown in below figure. The sample is placed under the load in the compacting machine for compaction to takes place which is to reduce the size of the material shown below, where the pressure is applied by hydraulics, to get compact and it can be compressed by manually by applying the load in tons.

Holding material (mould)   Natural plant fiber





Compacting   **Sample**   **Dial Gauge**

Figure 12 Compacting machine (Hydraulics)

a) Density of Natural Plant Fiber and Filler:

The Density of the reinforcements are calculated by

Each samples are measured by the Vernier caliper,

To determine the density of the green body.

To determine the dimensions (diameter and height) using the Vernier caliper.

Determine the volume of the cylinder (V) and with an analytical balance

To Calculate the density (ρ) =m/V.

Green body -1

<u>To find the volume:</u>

$$V = \pi r^2 h = 3.14 \times 0.2688 \times 1.444 = 1.22\ cm^3$$

<u>To find the density</u>:

$\rho = m/V = 1.40/1.219 = 1.15\ g/cm^3$

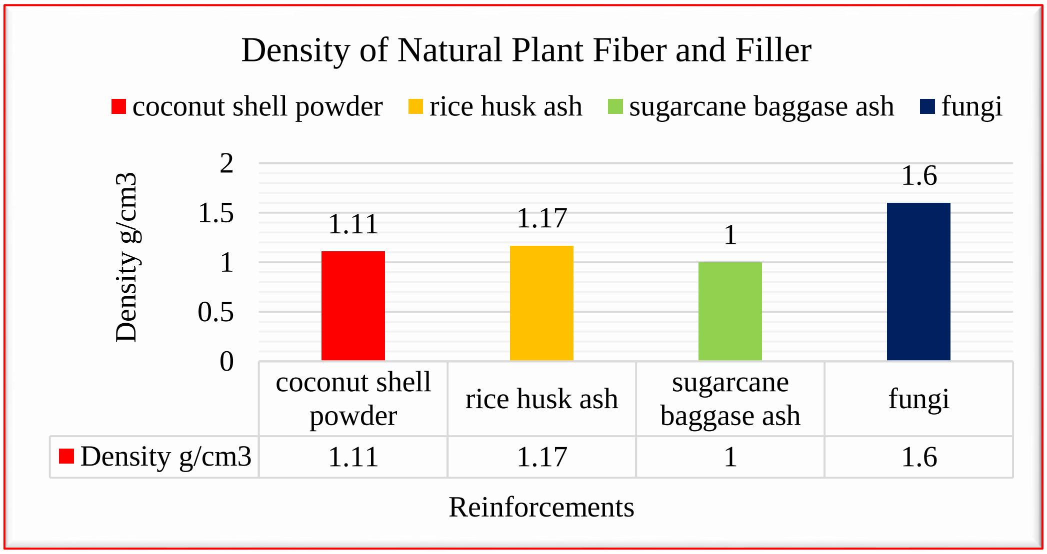
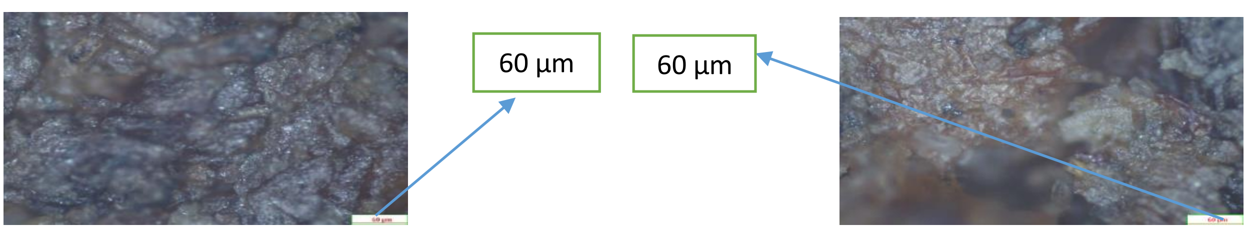


Figure 13 Density of Natural Plant Fiber and Filler

The above graph is drawn between the reinforcements and from the graph it is clearly shown that the density of the Sugarcane Baggase Ash is 1.00 g/cm^3. The minimum density is attained by the sugarcane baggase ash and maximum density id about 1.17 which is attained by the rice husk ash.

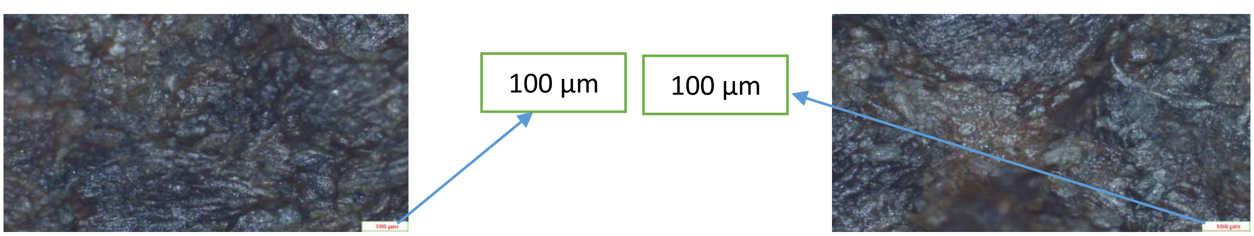
b) The particle size of Natural Plant Fiber and Filler:

Coconut shell powder:



Average particle size is 80.8 µm

Average particle size is 58.2 µm



Average particle size is 64.3 µm

Average particle size is 67.5 µm

Figure 14 Optical Microscopy Images of Coconut Shell Powder

Rice husk powder:

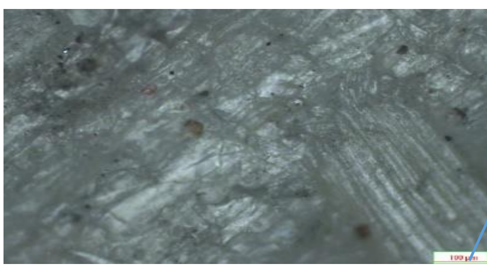
Average particle size 44.8µm

Average particle size 49.2µm

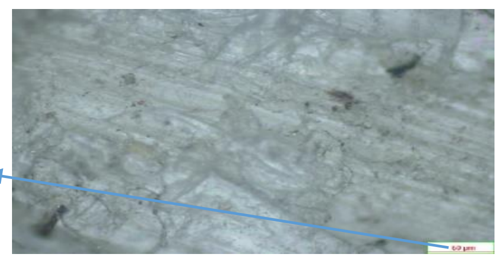
Average particle size 50.0 µm

Figure 15 Optical Microscopy Images of Rice Husk Powder

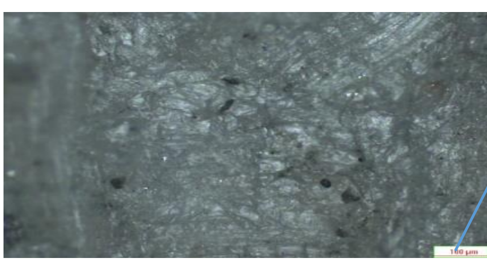
Sugarcane baggash powder:



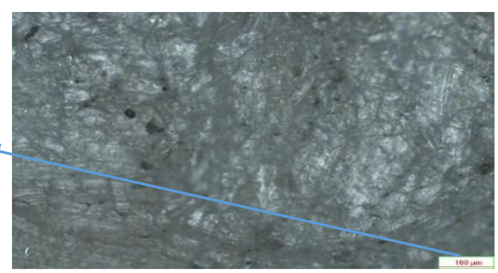
Average particle size is 41.6 µm



Average particle size is 30.5 µm



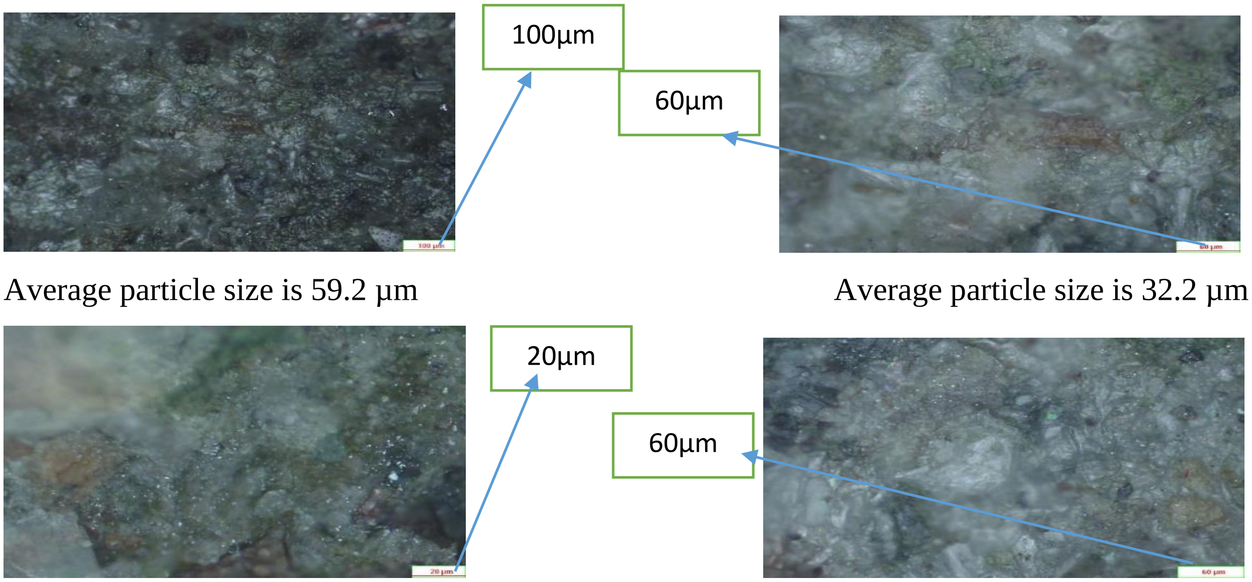
Average particle size is 67.1 µm



Average particle size is 45.7 µm

Figure 16 Optical Microscopy Images of Sugarcane Baggash Powder

Fungi



Average particle size is 59.2 µm

Average particle size is 32.2 µm

Average particle size is 15.7 µm

Average particle size is 33.3 µm

Figure 17 Optical microscope images of Fungi

The Below graph is drawn between the reinforcements and from the graph it is clearly shown that the particle size of the fungi is about 27.62 µm (microns). The minimum particle size is attained by the fungi and maximum particle size is about 67.75 µm (microns) which is attained by the Coconut shell powder.

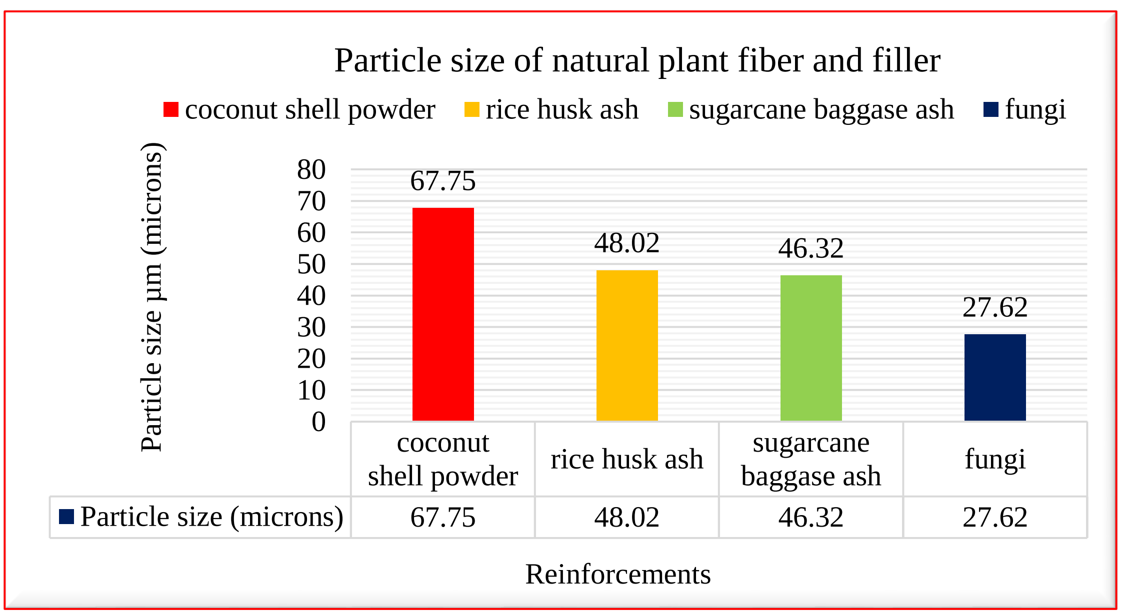


Figure 18 Particle size of Natural Plant Fiber and Filler

Homogenous milling (Reinforcements)

a) Composition 1

(Composition of homogenous milling (20 grams))

Table – 3 (Composition -1 of homogenous milling (20 grams))

Sl. No	Reinforcements (Material)	Mass (grams)	% Percentage
1	Coconut shell powder	5	25%
2	Rice husk powder	5	25%
3	Sugarcane – baggase ash	5	25%
4	Fungi	5	25%

b) Composition 2

(Composition of homogenous milling (25 grams))

Table- 4 (Composition -2 of homogenous milling (25 grams))

Sl. No	Reinforcements (Material)	Mass (grams)	% Percentage
1	Coconut shell powder	10	40%
2	Rice husk powder	5	20%
3	Sugarcane – baggase ash	5	20%
4	Fungi	5	20%

Composition 3

(Composition of homogenous milling (30 grams))

Table- 5 (Composition -3 of homogenous milling (30 grams))

Sl. No	Reinforcements (Material)	Mass (grams)	% Percentage
1	Coconut shell powder	10	33.3%
2	Rice husk powder	10	33.3%
3	Sugarcane – baggase ash	5	16.7%
4	Fungi	5	16.7%

Measurement of Density and Particle size by Hydraulic compacting and Optical Microscopy: A compactor is a machine or mechanism used to reduce the size of material through compaction, normally powered by hydraulics. The form of hydraulically powered sliding plates which sweep out the collection hopper and compress the material into what has already been loaded. The plant fiber is weighed by the required quantity and compressed in an ionic mould and placed in the compacting machine. The force applied in an axial direction towards the mould by powering up the hydraulic machine by hands. The applied pressure is viewed by using the dial gauge which is attached to the compacting machine. The powdered sample which is milled in an planetary milling and weighed by the weighing machine and then taken for the compacting respectively all the fiber and adhesives are milled by the same process and each of them are measured by the weighing machine and compacting is done separately.

a) Density of the compositions C1, C2, C3.

Calculations

Sample are measured by the Vernier caliper,

To determine the density of the green body.

To determine the dimensions (diameter and height) using the Vernier caliper.

Determine the volume of the cylinder (V) and with an analytical balance

To Calculate the density (ρ) =m/V.

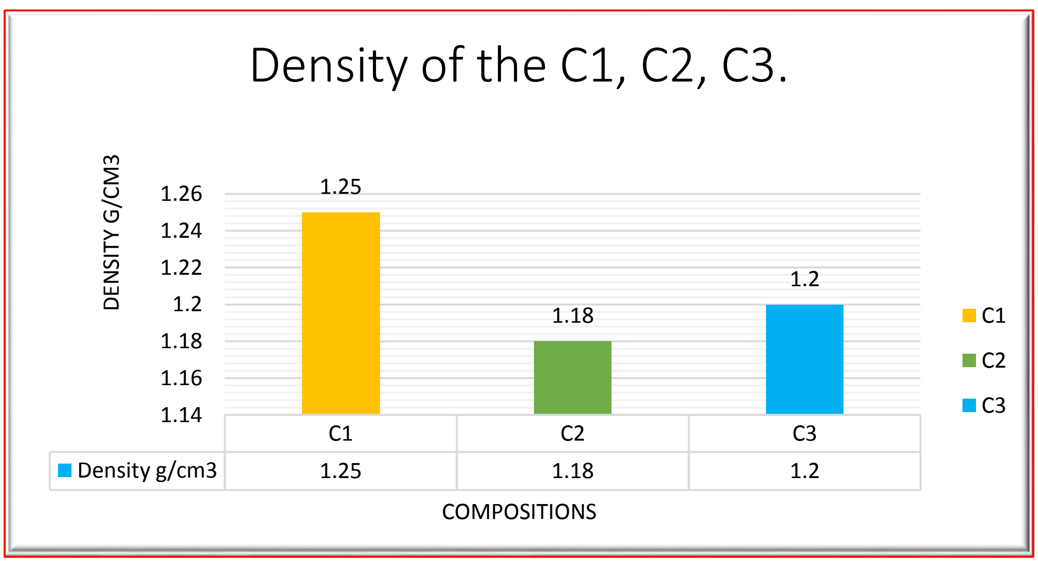


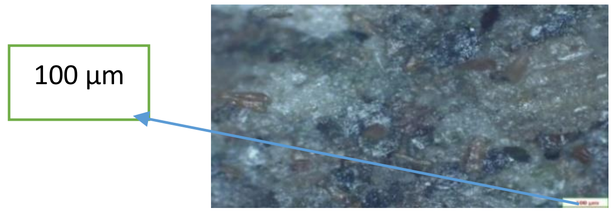
Figure 19 Density of the compositions C1, C2, C3.

b) Particle size of the compositions C1, C2, and C3.

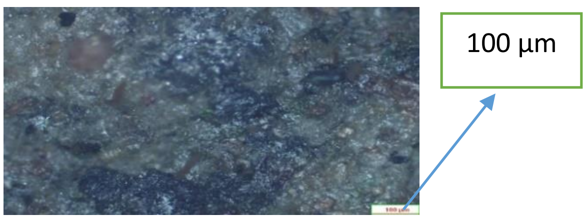
Composition -1

Optical microscope images

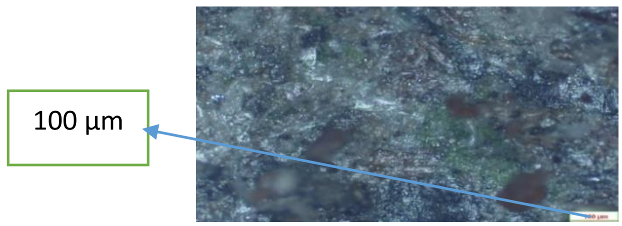
Average particle size is 52.6µm



Average particle size is 44.2µm



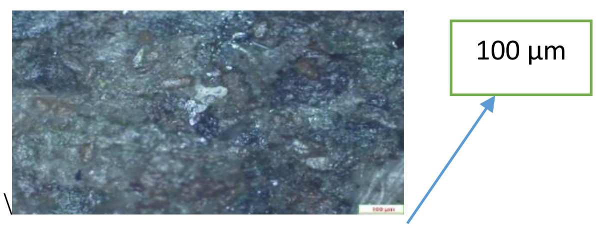
Average particle size is 37.9µm



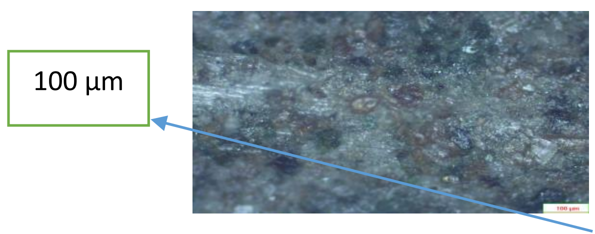
Average particle size is 43.3µm

Figure 20 Optical Microscopy Images of Composition -1

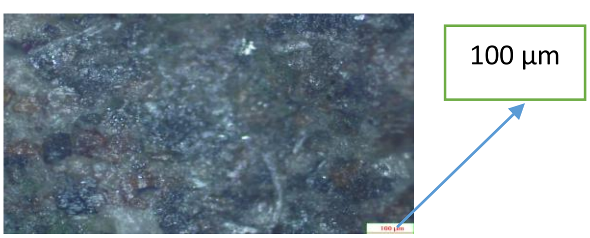
Composition -2



Average particle size is 34.2µm



Average particle size is 48.3µm

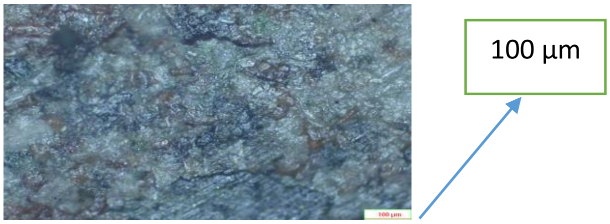


Average particle size is 51.2µm

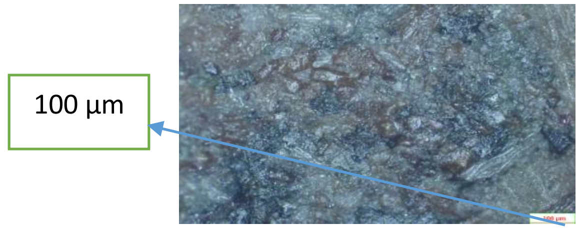
Average particle size is 44.2µm

Figure 21 Optical Microscopy Images of Composition -2

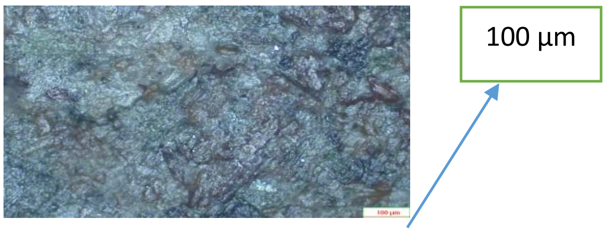
Composition -3



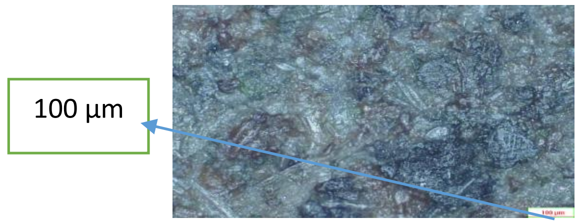
Average particle size is 59.2µm



Average particle size is 40.3µm



Average particle size is 44.3µm



Average particle size is 39.1µm

Figure 22 Optical Microscopy Images of Composition -3

Particle size of the compositions C1, C2, and C3.

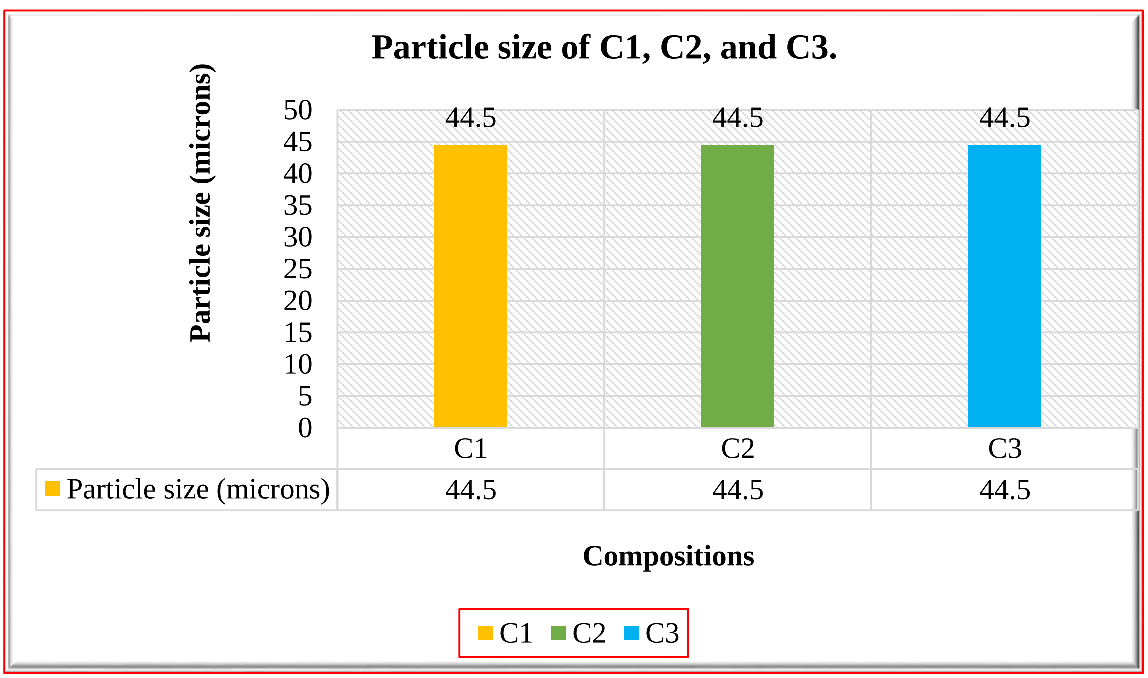


Figure 23 Particle size of the compositions C1, C2, and C3.

3.3 Steel Mould specification:

In this research work, the mould for preparing the specimen is designed in the solidworks and manufactured in the industry (center of technology of composites) for achieving a good surface finish. The die is made of metal which is steel, carbon which has a melting point 1425˚C -1540˚C / 2600˚F-2800˚F. The dimensions of the die are 140mm×70mm×50mm of outer span and the inner span of specimen size is 90mm×20mm×2mm. The upper part, frame and lower part is fixed by the screw of about four holes at each corner of the die with an diameter six this is fixed during the manufacturing process. The clear diagram of the steel die is shown in the figure below.

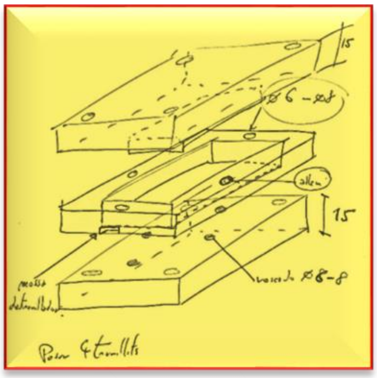


Figure 24 Steel mould drawing and mould parts

Upper part of Mould

The upper part of the steel die with the dimensions of 140mm×70mm×20mm. the upper part has an extrude materials at the center of the about dimensions of 90mm×20mm×8mm. this extrude portion is made especially for the compressing the specimen likely to transfer the pressure from the upper part to the center frame where the specimen is placed.

Figure 25 Upper part of Mould

Frame of the Mould

The frame of the die is the one of the most important part of the die, because the specimen is obtained from the frame of die such as manufactures sample. The specimen consist of natural materials which is extracted from the natural plants such as the reinforcement and matrix materials are placed in the frame inner span. The frame consist of outer span and the inner span, the outer span of dimensions 140mm×70mm×10mm whereas the inner span 90mm×20mm×2mm is the size of the specimen for the composite material. The frame figure is shown below.

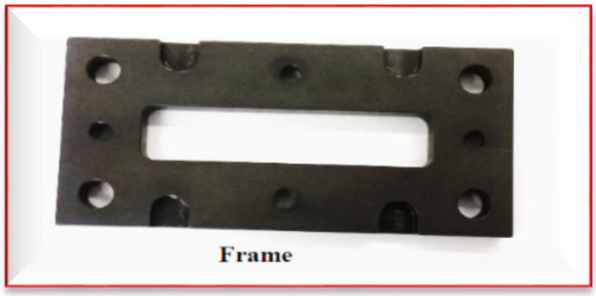


Figure 26 Frame part of Mould

Lower part of Mould

The lower part of the steel die with the dimensions of 140mm×70mm×15mm. the lower part has a flat surface where the other two parts such as the lower part and frame of the die are placed over the lower part. The lower part is the base of the die which is withstanding the whole weight of the upper part, the frame and the pressure (MPa) applied such as load. The lower part of the die is shown below.

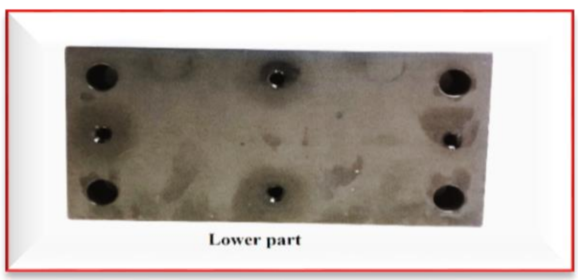


Figure 27 lower part of Mould

The assembly of the upper part, frame and lower part is shown in the below figure, after the matrix and reinforcements are placed in the die for manufacturing process, the pressure is applied to compress the composite material for bonding and transfer of stress to take place. After completing the manufacturing of composites the die can be easily removed from the specimen by using the screw driver because of pressure eliminator is designed for this die which can be easily viewed by our naked eyes. This pressure eliminator is to avoid the hazardous action which perhaps can be created by the pressure applied during the manufacturing process.

3.4 Carnauba wax

Carnauba wax is also known as ‘Queen of waxes’ is secreted from the leaves of a Brazilian palm tree (Copernicia prunifera Cerifera), which can produce about 100 grams for one tree in a year. It contains mainly fatty esters (80-55%), free alcohols (10-15%), acids (3-65) and hydrocarbons (1-3%). One of the most important property of the carnauba wax is that, it gives better dimensional accuracy. The Carnauba wax has a properties such as density of 0.99 gm/cc, melting point of 87˚C and volumetric shrinkage of 4.20% Omkar Bemblage and D. Benny Karunakar [30].Even though the paraffin wax can be used as a coating material due to its better shrinkage and better surface properties but it has a main drawback that the melting point is about 64˚C is really lower than the Carnauba wax 110˚C, because in the manufacturing process the die is placed in the furnace of about 90˚C ± 10˚C coated by the wax, so in this case the paraffin wax cannot withstand the temperature and it can be melted and losses its property. In this case the Carnauba wax is preferred for the process of coating of die because of its temperature 110˚C property.

The objective of the cassava starch – carnauba wax composite edible oil coating is to preserve the die and the specimen from the sticking property such as ease of release of the specimen from the steel die. The carnauba wax act as a releasing agent. The carnauba wax coating is an alternative material to maintain the quality of the processed product.

Figure -28 Carnauba wax

The coating act as a barrier to maintain the product when a pressure is applied because during the pressuring process the materials may splash and cause problems in the removal process such as removal of specimen from the steel die as well as compression process with high pressure. The selection of carnauba wax is especially due its high temperature property which is about 110˚C. It is one of the hard wax with a color of brown and has a melting point of about 110˚C. It is insoluble in water and has a flash point > 298˚C.

4. Composite Manufacturing

4.1 Natural plant fiber with Moringa Resin

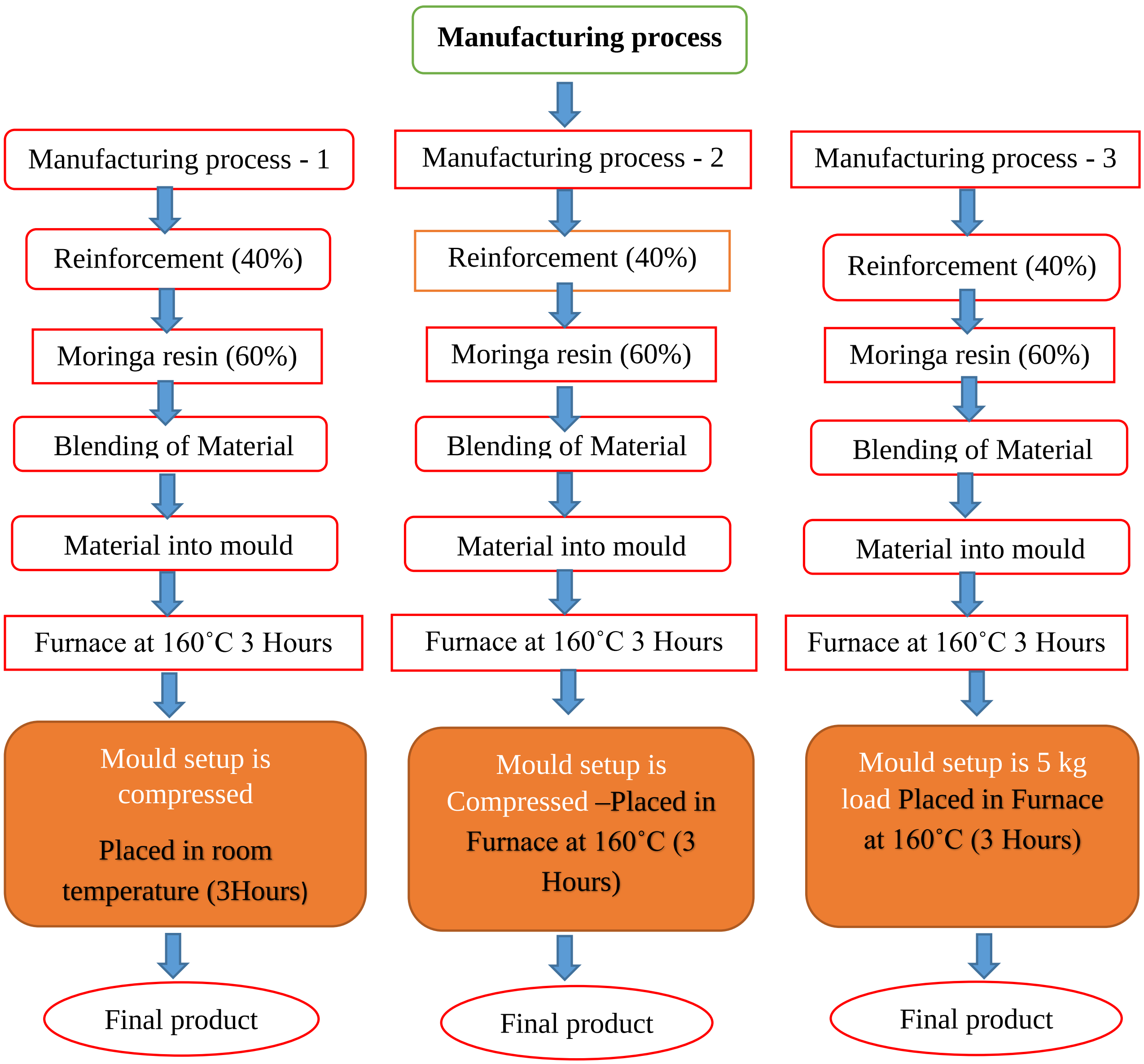


Figure 29 Natural plant fiber 40% with Moringa Resin 60%

a) Manufacturing process - 1

The natural plant fiber such as Coconut shell powder, Rice husk powder, Sugarcane bagasse ash and the filler as fungi are milled in the planetary milling (Homogenously) in the composition of C1, C2 and C3.The matrix materials such as moringa resins are crushed into particles by using the hammer. The crushed moringa resin is placed in a metallic cup and heated in the furnace at (160˚C) for two hours for solidification to take place. Unfortunately the resins has not been solidified after two hours. Even though the resin has not attained solidification the process has continued for an hour in the furnace to attain the solidification of moringa resins, certainly the matrix material does not solidified even after three hours in the furnace at 160˚C. The milled plant fiber and filler with the composition are blended with the matrix material such as moringa resins by the mechanical stirrer for 5 minutes for blending to take place between the reinforcements and matrix respectively. Eventually after the reinforcement and matrix are mixed by using the mechanical stirrer the blended reinforcements and matrix is poured into the mould (steel die).

The steel die is coated by the Wax (carnauba) for an ease removal of specimen from the mould. Three coating has been done for the mould for an interval of 10 minutes. After then, the mixed reinforcements and matrix material are poured in to the mould and screwed up by the bolts at the corner of the steel die for compression and curing to take place. After three hours the screws are removed from the steel die and the mould is removed. Unfortunately, the material has not blended with the reinforcements and the matrix material. The material has shown a poor characteristic which is seen by our eyes (powder like material). The below figure shows the specimen preparation and the results.

The moringa resin with the composition of 60% is placed in the metallic material and heated in the furnace at 160˚C for three hours. After three hours the moringa resins and the plants fibers in the composition of 60% (Matrix) and 40% (Reinforcement) are mixed with a mechanical stirrer for five minutes and poured in the steel die for specimen to attain. Once the blended composite material is mixed the material is poured into the steel die the lower part and the frame are screwed up by screws to avoid the leak of materials when it is compressed and curing to take place. Once the lower and the frame is fixed the upper part of the die comes into action to close the material which is placed in the frame, eventually the screws are fixed to the steel die to complete the preparation of specimen. After three hour of curing the steel die is dismantled by removing the screws to remove the specimen from the die. The specimen in the frame of the steel die is carefully removed from the lower part of the die to show the characteristics of the specimen.

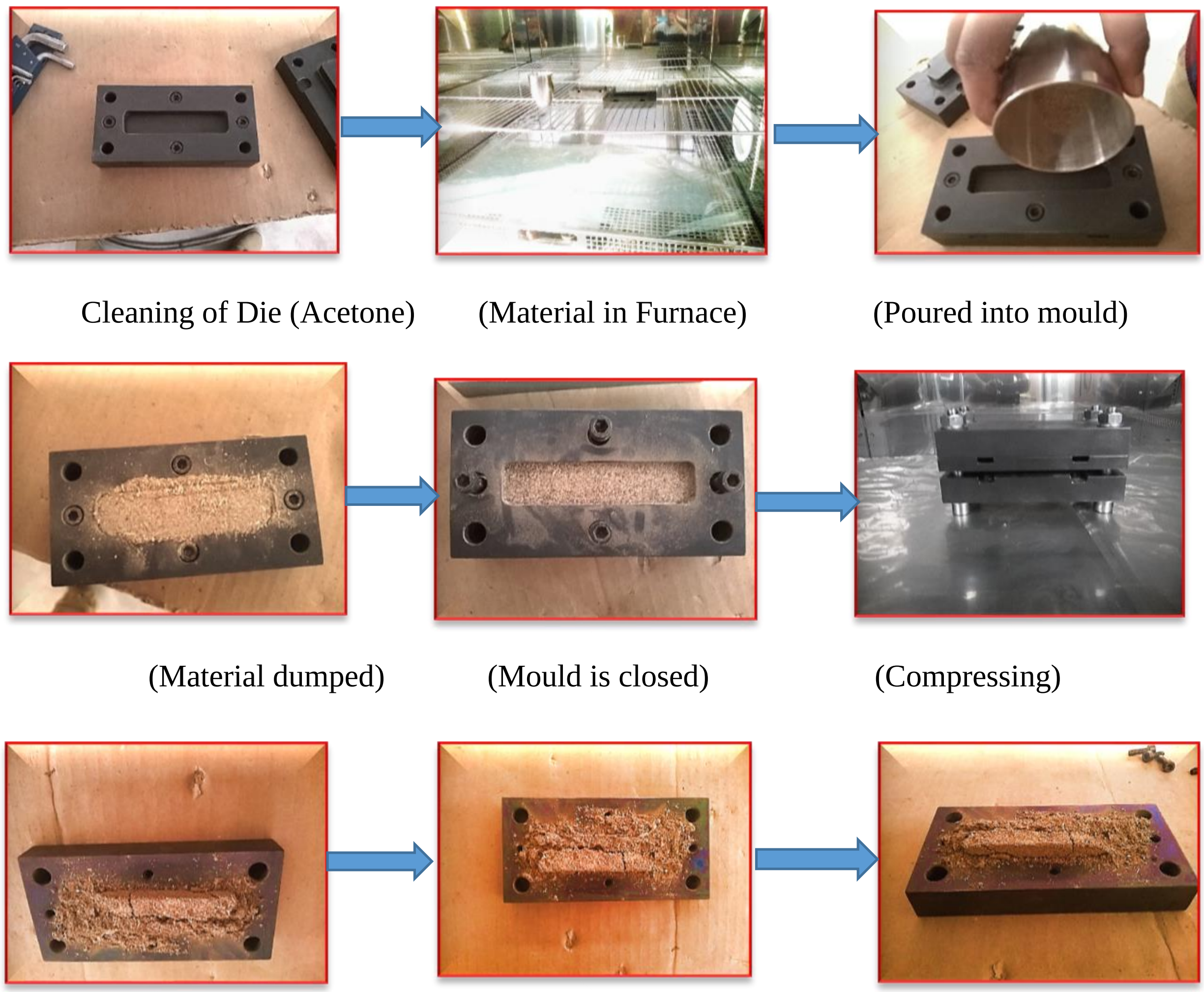


Figure -30 Manufacturing Process -1

The specimen removed from the die after the manufacturing process has shown a poor characteristics which clearly shows that the reinforcement and matrix material has not blended properly due to moringa crystal behavior such as dryness and hardness which has resulted a poor material. The main drawback could be the moringa crystal has lost its solidification property due to various temperature differences and it's not a freshly extracted from the plant as well as could be the manufacturing process perhaps may be a reason for the poor characteristic's. Eventually, after attaining the result the manufacturing technique has changed with the same composition as reinforcement (40%) and matrix (60%).

b) Manufacturing process – 2

The reinforcement as (40%) and matrix material as moringa resins has weighed (60%) has weighed in the weighing machine. The reinforcement and matrix material are blended for five minutes by using a mechanical stirrer. Eventually after the reinforcement and matrix are mixed by using the mechanical stirrer the blended reinforcements and matrix is poured into the mould (steel die). The steel die is coated by the Wax (carnauba) for an ease removal of specimen from the mould. After then, the mixed material are placed in to the mould and screwed up by the bolts at the corner of the steel die. Then the steel die is placed in the furnace chamber for three hours with the temperature of 160˚C. After three hours the steel mould is taken out from the furnace and placed in a room temperature for three hours for curing to take place. The below figure shows the manufacturing process and the result. Initially, the mould is cleaned by the alcohol to remove the dust from the mould, then the blended mixture is poured into the mould. After cleaning the die the blended mixture of reinforcement and matrix are poured into the die. Once the material is poured into the die the die is placed into the furnace at a temperature of 160˚C for three hours. Furnace temperature (Initial to final) Initially the furnace is powered for a minutes and then the room temperature of the furnace is noted and then the temperature is set of three hours for a 160˚C.The die is placed in the furnace at a temperature of about 160˚C for three hours with zero humidity. The specimen has attained by changing the manufacturing technique and the specimen has taken for the surface morphology.

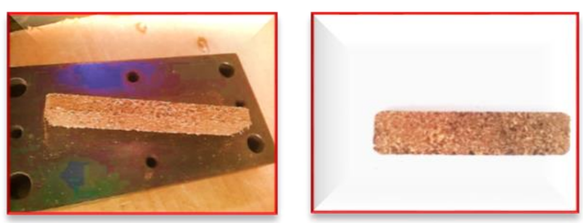


Figure -31 Manufacturing Process -2

c) Manufacturing process – 3

The reinforcement as (40%) and matrix material as moringa resins is milled by using the hammer into powder and milling has carried out and weighed (60%) in the weighing machine.

The reinforcement and matrix material are blended for five minutes by using a mechanical stirrer. Eventually after the reinforcement and matrix are mixed by using the mechanical stirrer the blended reinforcements and matrix is poured into the mould (steel die). Before pouring the material into the mould the mould had cleaned with the alcohol for the removal of dust. The steel die is coated by the Wax (carnauba) for an ease removal of specimen from the mould. After then, the mixed material are placed in to the mould and screwed up by the bolts at the corner of the steel die. Then the steel die is placed in the furnace chamber for three hours with the temperature of 160˚C. After three hours the steel mould is taken out from the furnace and placed in a room temperature for three hours for curing to take place. The below figure shows the manufacturing process and the result. Initially, the mould is cleaned by the alcohol to remove the dust from the mould, then the blended mixture is poured into the mould. After cleaning the die the blended mixture of reinforcement and matrix are poured into the die. Once the material is poured into the die the die is placed into the furnace at a temperature of 160˚C for three hours. The die is placed in the furnace at a temperature of about 160˚C for three hours with zero humidity.

Figure -32 Manufacturing Process -3

Surface characteristics:

USB Microscope

The microscopic image of the samples are analyzed such as mechanical behavior as well the particle size can be measured after the manufacturing process to show the surface morphology of the materials and as well as the failure point characteristics by using the microscopic image. These analysis is to show that whether the reinforcements and the matrix are blended each other to withstand the load. The possibility of the improvement of the composite can be identified.

Figure -33 USB Microscope

a) Manufacturing process -1

Manufacturing process has shown a poor characteristics which clearly shows that the reinforcement and matrix material has not blended properly due to moringa crystal behavior such as dryness and hardness which has resulted a poor material.

The main drawback could be the moringa crystal has lost its solidification property due to various temperature differences and it's not a freshly extracted from the plant as well as could be the manufacturing process perhaps may be a reason for the poor characteristic's. Eventually, after attaining the result the manufacturing technique has changed with the same composition as reinforcement (40%) and matrix (60%).

b) Manufacturing Process -2

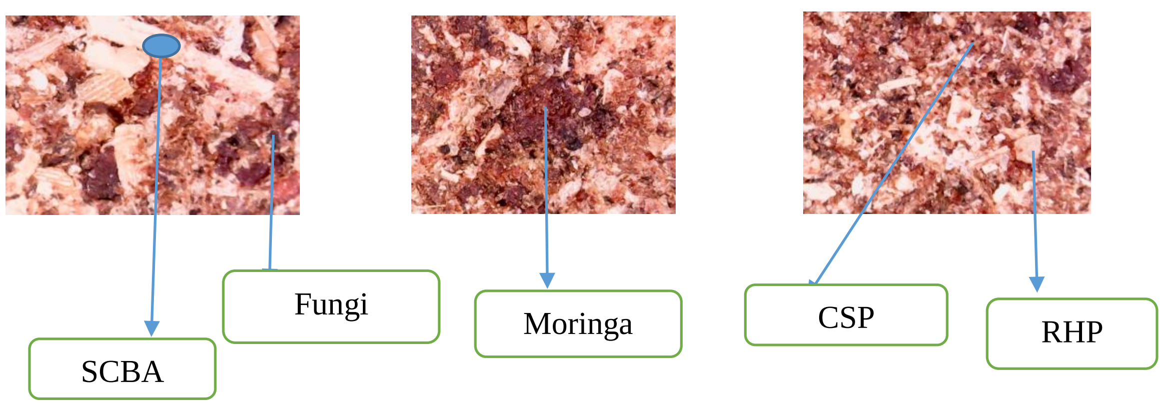


Figure -34 Microscopic Images of Manufacturing Process -2

The fiber streaks shows that the material has not blended with the matrix material, and this could be due to the unequal matrix grain size (particle size). Also the blending of the material as shown that the fiber has not stirred properly. These may lead to the poor property of the material, which eventually this could lead to void in the specimen.

The moringa resin does not blend with the matrix and the size of the moringa is higher than the fiber, these could be the reason for the poor property and surface characteristics. The moringa does not solidify and blend with the fiber due to temperature of solidification of moringa does not attained by this manufacturing technique.

c) Manufacturing Process -3

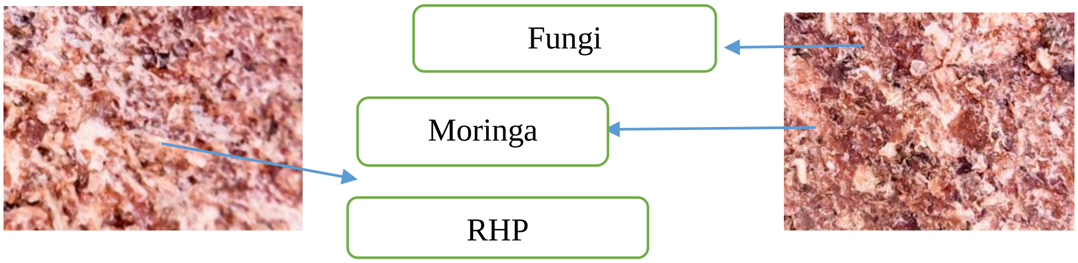


Figure -35 Microscopic Images of Manufacturing Process – 3

The above images shows that the reinforcements and the matrix has good adhesion property between them. The surface shows that they has good adhesion between the materials and there is no voids and streaks or may be pallets like structure for the ease of failure to occur. The slip may be reduced by this composition like reduction in the filler material and attain a better strength.

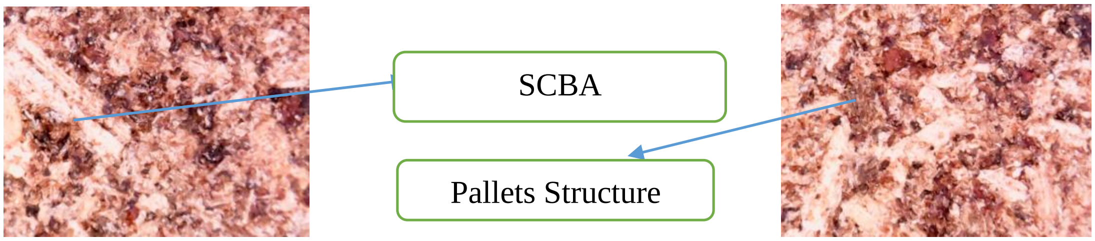


Figure -36 Microscopic Images of Manufacturing Process – 3

In the above images it clearly shows that the sugarcane baggase fiber are pallets like structure which could cause or initiate for the crack propagation while load is applied towards the material. These can be lead to slip of fiber and reduces the strength when applied at higher loads.

Mechanical Property:

a) Tensile testing

The specimen is taken out from the mould once the fabrication process has been completed. The geometry of the specimen is 90mm×20mm×2mm, with the C1, C2 and C3 composition. The test is carried out by the universal testing machine. The specimen was mounted by its ends into the holding grips of the testing apparatus. Then the load is gradually increased until the material attaining the failure state. The load and the displacement readings are recorded until the material attaining failure, which means failure of specimen occurs.

Specimens of 100% Natural Gripping of Specimen Fractured specimen

Figure -37 Universal Testing Machine

<u>Stress Vs Axial displacement</u>

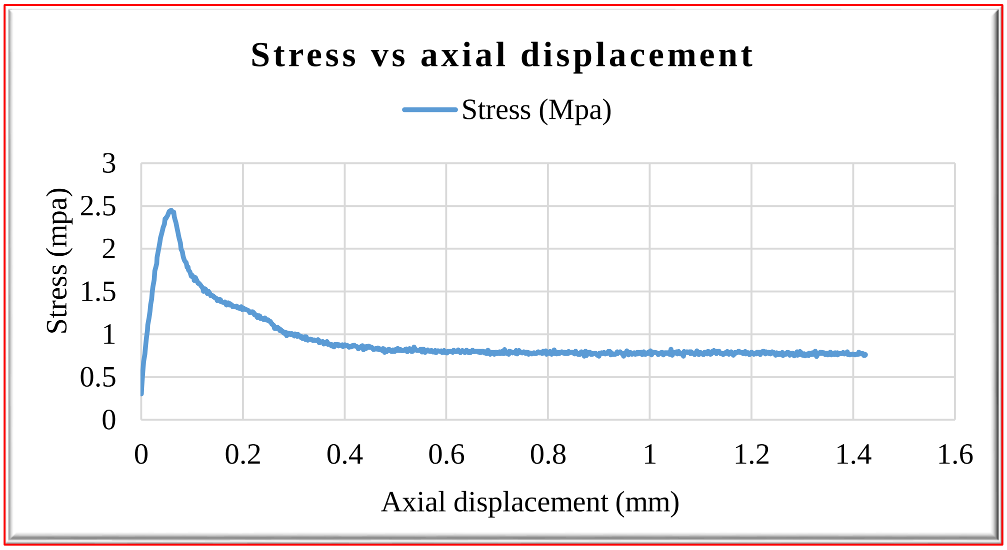


Figure 38 Stress Vs Axial displacement

The 100% natural composites has attained 2.45 MPa of tensile strength and further the density of the specimens is 1.10 g/cm^3. The defect of lower tensile strength is due to the adhesion property between the reinforcement and the matrix. These could be due to moringa resin because the moringa resin is crystalized condition while manufacturing the composites. Further to improve the material, the natural reinforcements are blended with the matrix material such as vinyl ester to show the comparison between the 100% natural reinforced composites and 40% natural reinforced fiber.

4.2. Composite of Natural plant fiber with Vinyl Ester Resin

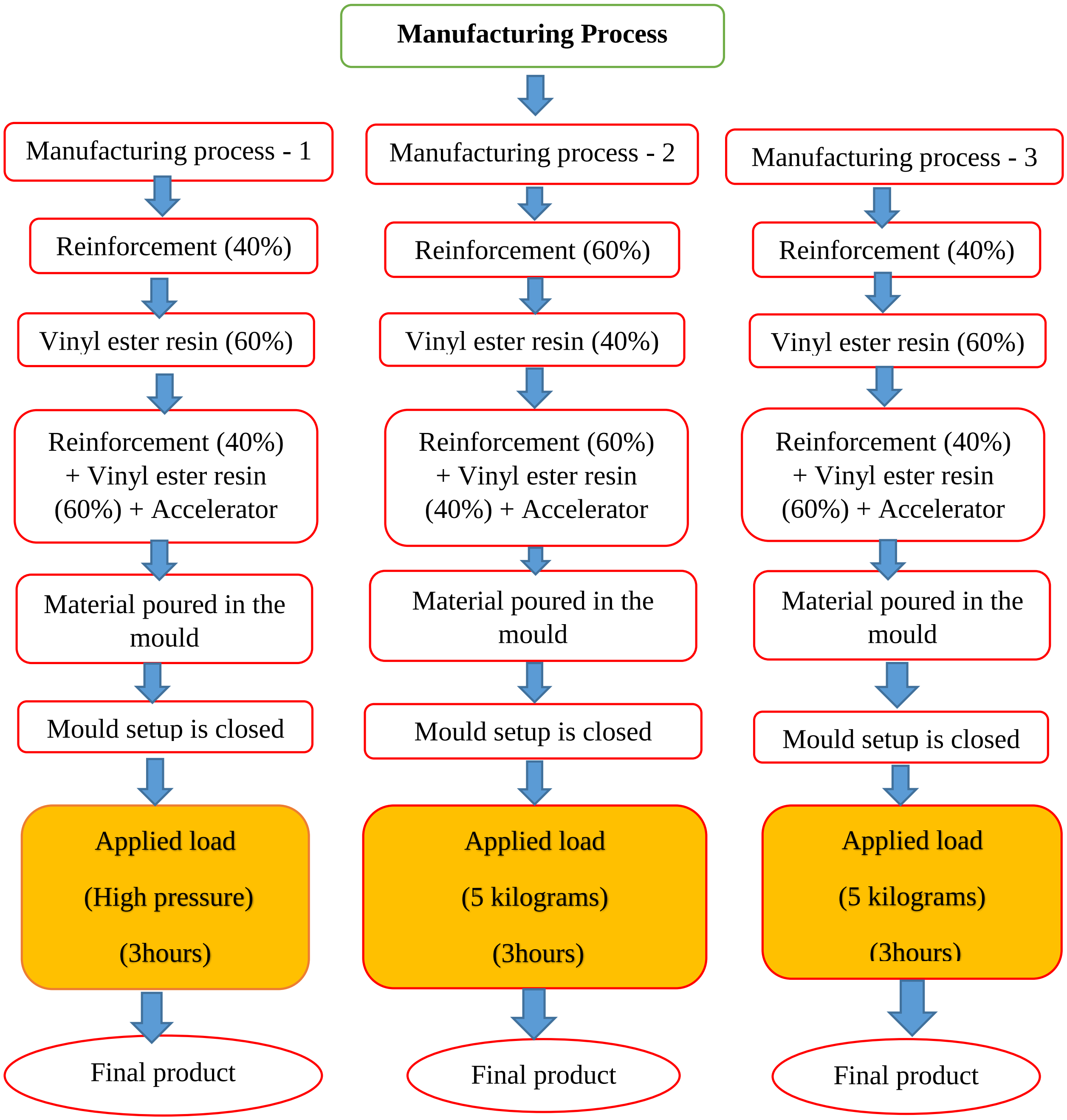


Figure 39 Manufacturing process (Natural fibers with Vinyl ester)

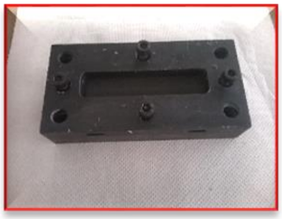
a) Manufacturing process-1

The natural plant fiber such as Coconut shell powder, Rice husk powder, Sugarcane bagasse ash and the filler as fungi are milled in the planetary milling (Homogenously) in the composition of C1, C2 and C3.The matrix materials such Vinyl ester is added to the natural plant fiber with the composition of 40% reinforcement from the C1, C2 and C3, where 60% of the vinyl ester is added for the materials and for initiating the reaction of vinyl ester the accelerator is added 2% to the vinyl ester for the curing process to take place. The milled plant fiber and filler with the composition C1, C2 and C3 are blended with the matrix material such as Vinyl ester with a catalyst of respected composition to initiate the reaction.

Firstly, the vinyl ester of 60% is weighed and the according to the weight ratio of vinyl ester the accelerator is added and mixed by using the mechanical stirrer for 5 minutes to initiate the reaction. Then the reinforcements and the matrix material are blended by using the mechanical stirrer for 5 minutes. Eventually after the reinforcement and matrix are mixed by using the mechanical stirrer, the blended reinforcements and matrix is poured into the mould (steel die). The steel die is coated by the Wax (carnauba) for an ease removal of specimen from the mould. Firstly the coating of wax is done and kept in the room temperature for 5 minutes and respectively for second coating and third coating for a time interval of 5 minutes. After then, the mixed reinforcements and matrix material are poured in to the mould and a load of 5 kilograms is applied for entire 3 hours.

After three hours the load is removed from the die and the mould (frame) is removed. Unfortunately, the material has not blended with the reinforcements and the matrix material. The material has shown a poor surface characteristic. The below figure shows the specimen preparation and the results. Firstly the die is cleaned by using the acetone and then cleaned by using the alcohol to remove the dust from the mould. Then the initial coating is done by using the wax. Secondaly the coating is done after 10 minutes interval and then the mould is screwd up between the frame and the lower part of the stell die. Then the third coating of the wax is applied to the mould.

Once the coating of wax is done the mould is kept in a room temperature for the dryness of the mould. Then 60% vinyl ester is weighed in a weighing in machine and accelerator is added up and stirred by using the mechanical stirrer for 5 minutes and then the natural fiber are weight according the composition of C1, C2 andC3 of remaining 40% materials is weighed and blended using the stirrer and poured into the mould for the specimen preparation. Once the mixing is done, the material is poured into the mould with equal distribution of the frame size. The die is screwed up by high pressure and kept for curing for a time duration of 3 hours. Finally the specimen is taken out from the mould. Unfortunately the specimen had a poor surface characteristics. The specimen is shown below and the by using the electron microscope the characteristics are investigated and resulted as below.



Cleaning by acetone

Clean by alcohol

Applying of wax

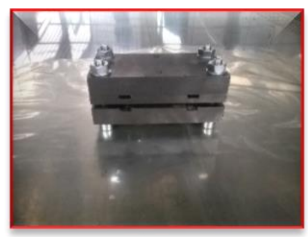
Applying of wax

Measuring of Vinyl Ester

Addition of Catalyst

Blending of material

Pouring on the mould



Mould is compressed

Specimen of 40% reinforcement (Natural plant fiber) and 60% Matrix (Vinyl Ester)

Figure -40 Manufacturing process (Natural fibers with Vinyl ester) – 1

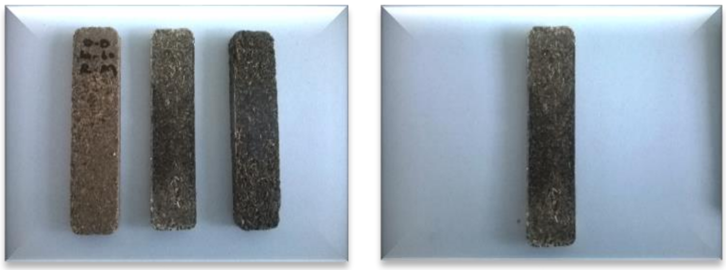
b) Manufacturing process -2

The natural plant fiber such as Coconut shell powder, Rice husk powder, Sugarcane bagasse ash and the filler as fungi are milled in the planetary milling (Homogenously) in the composition of

C1, C2 and C3.The matrix materials such Vinyl ester is added to the natural plant fiber with the composition of 60% reinforcement from the C1, C2 and C3, where 40% of the vinyl ester is added for the materials and for initiating the reaction of vinyl ester the accelerator is added 2% to the vinyl ester for the curing process to take place. The milled plant fiber and filler with the composition C1, C2 and C3 are blended with the matrix material such as Vinyl ester with a catalyst of respected composition to initiate the reaction. Firstly, the vinyl ester of 60% is weighed and the according to the weight ratio of vinyl ester the accelerator is added and mixed by using the mechanical stirrer for 5 minutes to initiate the reaction. Then the reinforcements and the matrix material are blended by using the mechanical stirrer for 5 minutes. Eventually after the reinforcement and matrix are mixed by using the mechanical stirrer, the blended reinforcements and matrix is poured into the mould (steel die).

The steel die is coated by the Wax (carnauba) for an ease removal of specimen from the mould. Firstly the coating of wax is done and kept in the room temperature for 5 minutes and respectively for second coating and third coating for a time interval of 5 minutes. After then, the mixed reinforcements and matrix material are poured in to the mould and a load of 5 kilograms is applied for entire 3 hours. After three hours the load is removed from the die and the mould (frame) is removed. Unfortunately, the material has not blended with the reinforcements and the matrix material. The material has shown a poor surface characteristic. The below figure shows the specimen preparation and the results. Firstly the die is cleaned by using the acetone and then cleaned by using the alcohol to remove the dust from the mould. The coating is done after 10 minutes interval and then the mould is screwd up between the frame and the lower part of the stell die. Then the third coating of the wax is applied to the mould.

Once the coating of wax is done the mould is kept in a room temperature for the dryness of the mould. Then 60% vinyl ester is weighed in a weighing in machine and accelerator is added up and stirred by using the mechanical stirrer for 5 minutes. Then the natural fiber are weight according the composition of C1, C2 andC3 of remaining 40% materials is weighed and blended using the stirrer and poured into the mould for the specimen preparation. Once the mixing is done, the material is poured into the mould with equal distribution of the frame size. The die is screwed up by high pressure and kept for curing for a time duration of 3 hours. Finally the specimen is taken out from the mould. Unfortunately the specimen had a poor surface characteristics. The specimen is shown below and the by using the electron microscope the characteristics are investigated and resulted as below.



Specimen of 60% reinforcement (Natural plant fiber) and 40% Matrix (Vinyl Ester)

Figure – 41 Manufacturing process (Natural fibers with Vinyl ester) – 2

c) Manufacturing process-3

The natural plant fiber such as Coconut shell powder, Rice husk powder, Sugarcane bagasse ash and the filler as fungi are milled in the planetary milling (Homogenously) in the composition of C1, C2 and C3.The matrix materials such Vinyl ester is added to the natural plant fiber with the composition of 40% reinforcement from the C1, C2 and C3, where 60% of the vinyl ester is added for the materials and for initiating the reaction of vinyl ester the accelerator is added 2% to the vinyl ester for the curing process to take place.

The milled plant fiber and filler with the composition C1, C2 and C3 are blended with the matrix material such as Vinyl ester with a catalyst of respected composition to initiate the reaction. Firstly, the vinyl ester of 60% is weighed and the according to the weight ratio of vinyl ester the accelerator is added and mixed by using the mechanical stirrer for 5 minutes to initiate the reaction. Then the reinforcements and the matrix material are blended by using the mechanical stirrer for 5 minutes. Eventually after the reinforcement and matrix are mixed by using the mechanical stirrer, the blended reinforcements and matrix is poured into the mould (steel die).

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Then the natural fiber are weight according the composition of C1, C2 andC3 of remaining 40% materials is weighed and blended using the stirrer and poured into the mould for the specimen preparation. Once the mixing is done, the material is poured into the mould with equal distribution of the frame size. The die is screwed up by high pressure and kept for curing for a time duration of 3 hours. Finally the specimen is taken out from the mould. The specimen is shown below and the by using the electron microscope the characteristics are investigated and resulted as below.

Specimen of 40% reinforcement (Natural plant fiber) and 60% Matrix (Vinyl Ester)

Figure –42 Manufacturing process (Natural fibers with Vinyl ester) – 3

Surface characteristics:

USB Microscope (Surface morphology)

a) Manufacturing Process -1

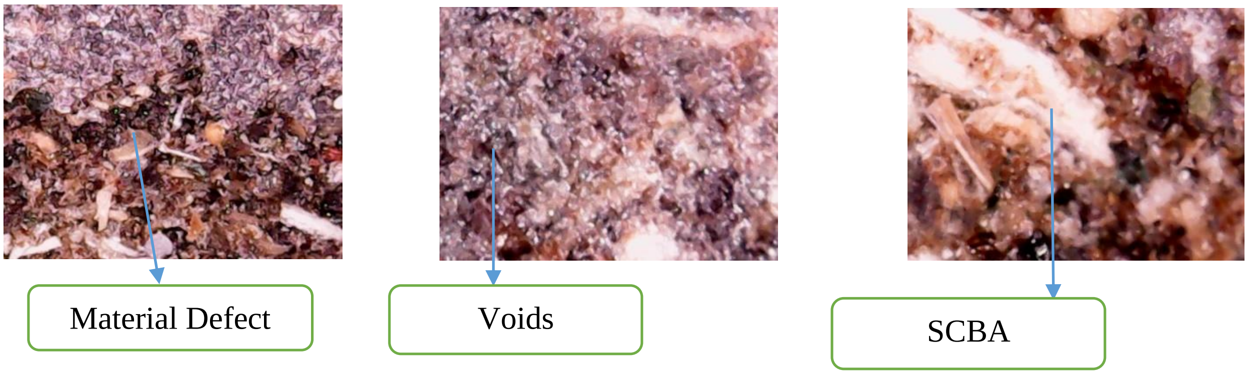


Figure – 43 Microscopic Images of Manufacturing Process -1

The specimen prepared from the above manufacturing process shows that the resin and natural fiber composites are not blended properly during the mixing of the reinforcement and the matrix. Also due to high load some amount of resin comes out from the die and this which could lead to the abrasion of material.

Figure – 44 Microscopic Images of Manufacturing Process -1

The uneven voids are created from the preparation of the specimen could be due to the high stress created by the load applied during the compression process. These void are created throughout the material due to uneven distribution of load and could be due to the high load application. The image at the center shows some positive things about the property of the reinforcement and matrix are good bonding nature.

b) Manufacturing Process -2

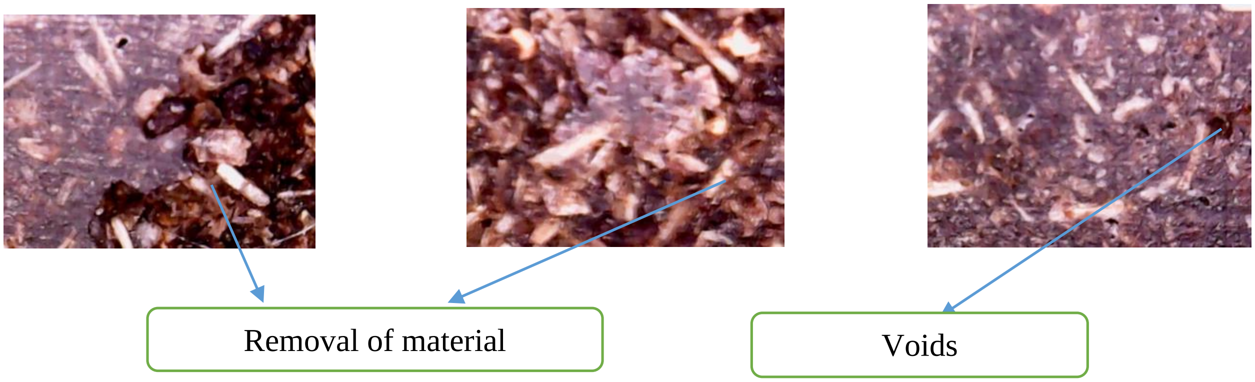


Figure – 45 Microscopic Images of Manufacturing Process -

The surface of the specimen as well as the bonding of the reinforcement and matrix has shown poor characteristics. The voids are created between the reinforcement and matrix.

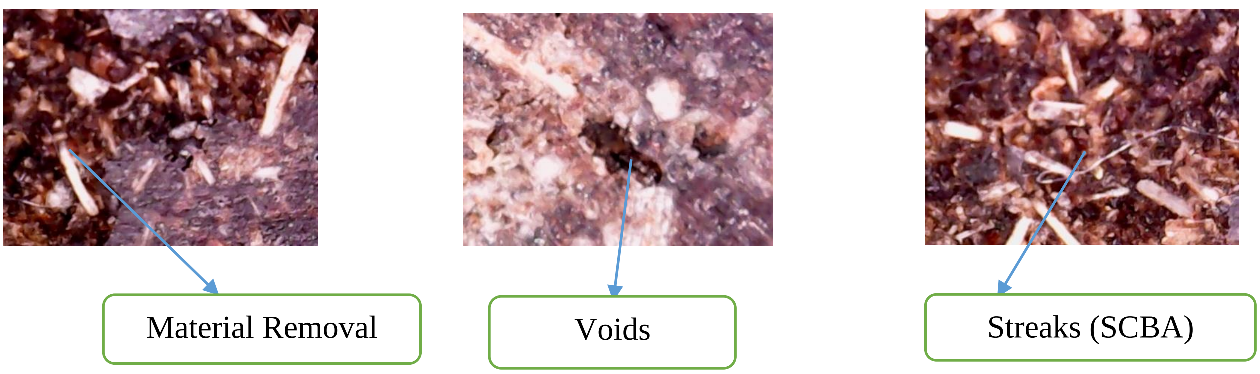


Figure – 46 Microscopic Images of Manufacturing Process -2

The uneven voids are created from the preparation of the specimen could be due to the high stress created by the load applied during the compression process. These void are created throughout the material due to uneven distribution of load and could be due to the high load application. The bonding between the reinforcement materials has not bond with the matrix material.

c) Manufacturing Process -3

Composition -1

Figure – 47 Microscopic Images of Composition -1

The specimen with the compositon C1 has shown good surface morpholgy such as good surface finish and better bonding properties between the reinforcements and matrix. the increse in the amount of vinly ester shown a better surface properties and avoidance of pallets like structure which is main property for restriction of crack in the material.

Composition -2

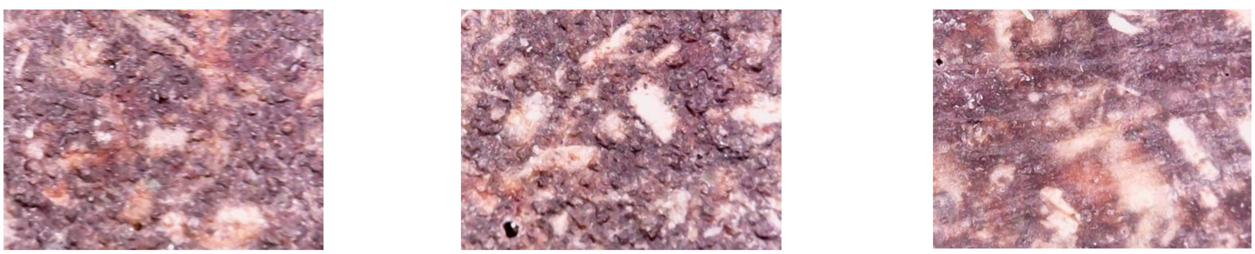


Figure – 48 Microscopic Images of Composition -2

The specimen with the compositon C2 has shown a small void in some places of the samples but the surface finish is good and taken into consideration for testing of the speimento identify the tesile property of the specimen.

Composition -3

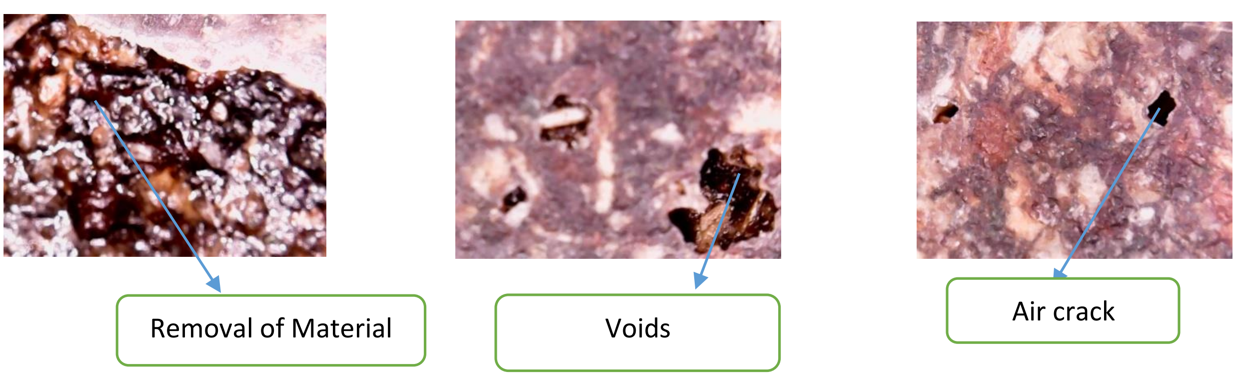


Figure – 49 Microscopic Images of Composition -3

The composition -3 has shown a very large voids on the surface at some of the surface of the specimen and these may reduce the strength of the material to withstand high load and losses it property in the weight bearing applications like beaming such as structural application.

Mechanical testing

Testing of mechanical properties of composites.

The study of mechanical properties such as, tensile strength, Brinell hardness testing are carried out. The results ate estimated and shown.

Tensile testing

The specimen is taken out from the mould once the fabrication process has been completed. The geometry of the specimen is 90mm×20mm×2mm, with the C1, C2 and C3 composition. The test is carried out by the universal testing machine. The testing process are carried out in the room temperature. The specimen was mounted by its ends into the holding grips of the testing apparatus. Then the load is gradually increased until the material attaining the failure state. The load and the displacement readings are recorded until the material attaining failure, which means failure of specimen occurs.

<u>a) Composition-1</u>

Stress Vs Axial displacement of Composition - 1

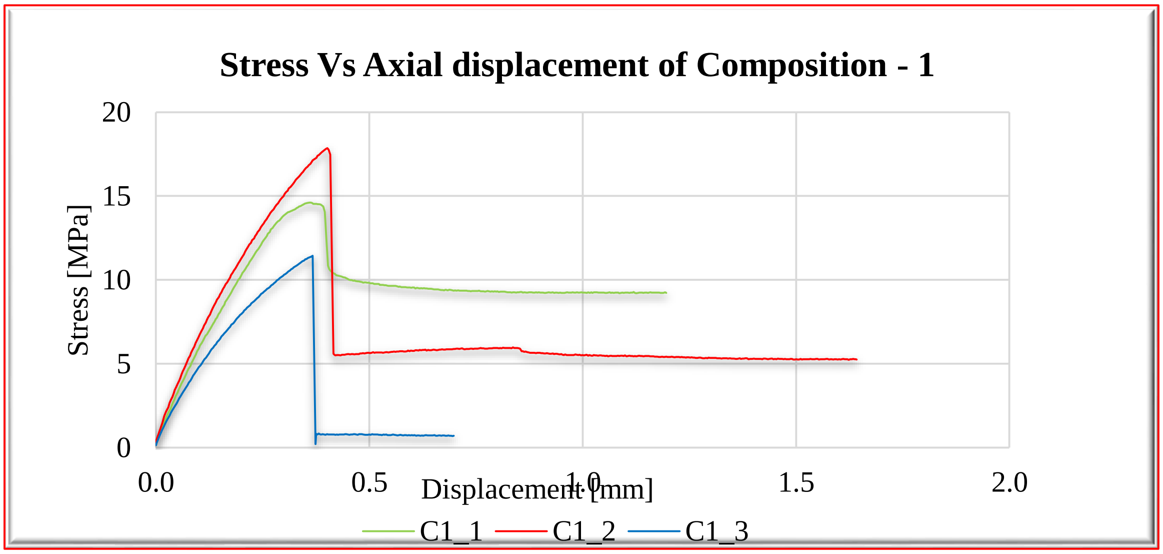


Figure 50 Stress Vs Axial displacement of the Compositions – 1

<u>Tensile strength of Composition -1</u>

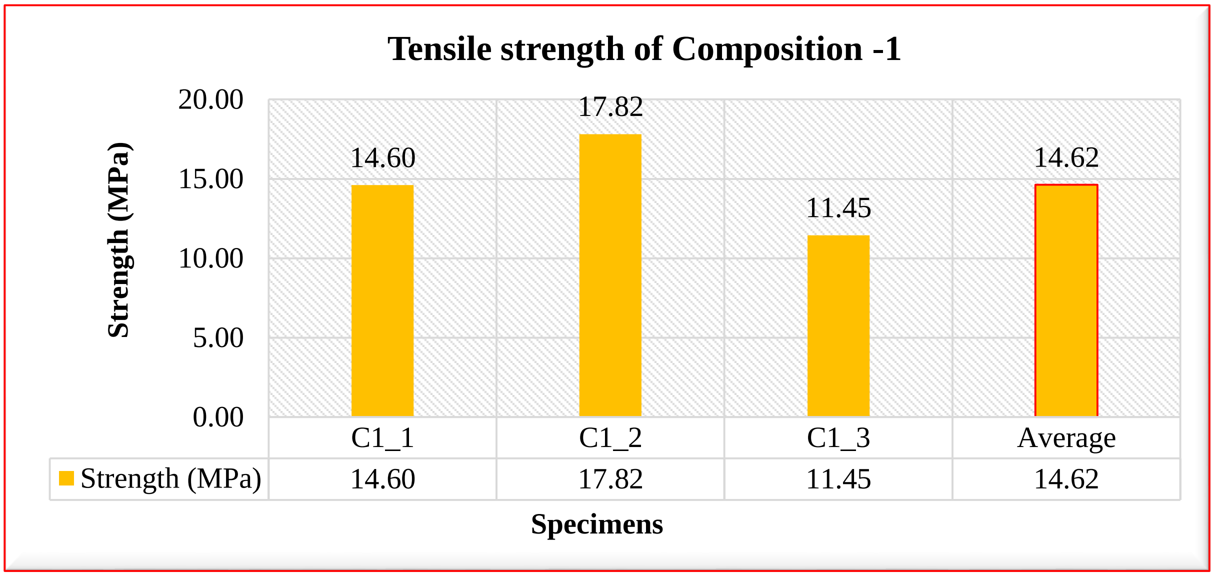


Figure 51 Tensile strength of Composition -1

b) Composition -2

Stress Vs Axial displacement of composition -2

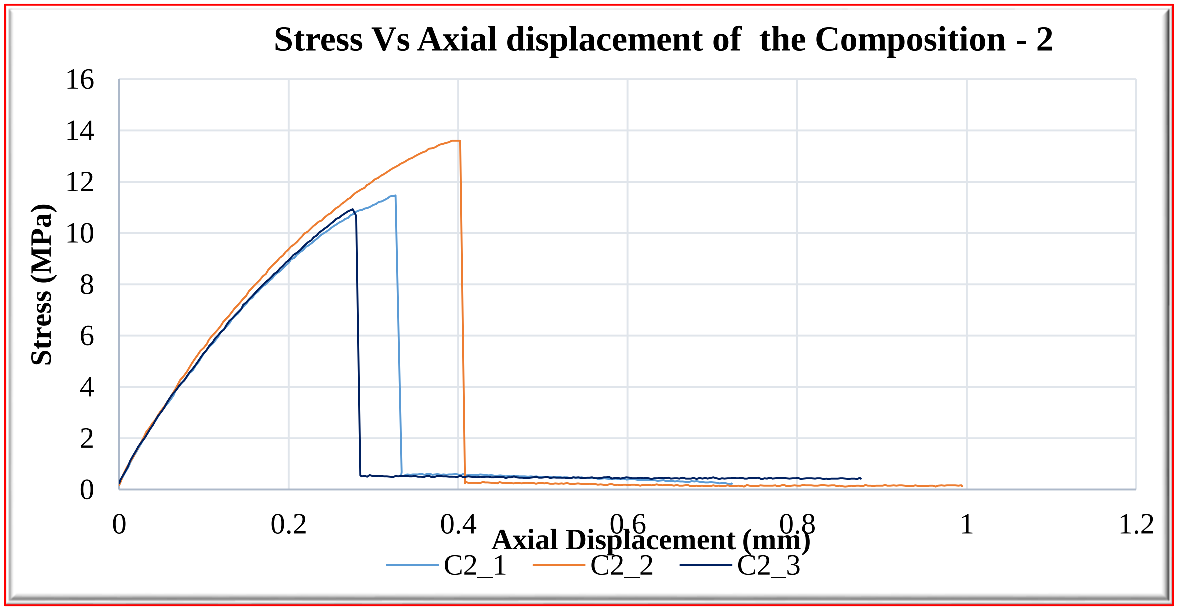


Figure 52 Stress Vs Axial displacement of the Compositions - 2

Tensile strength of Composition -2

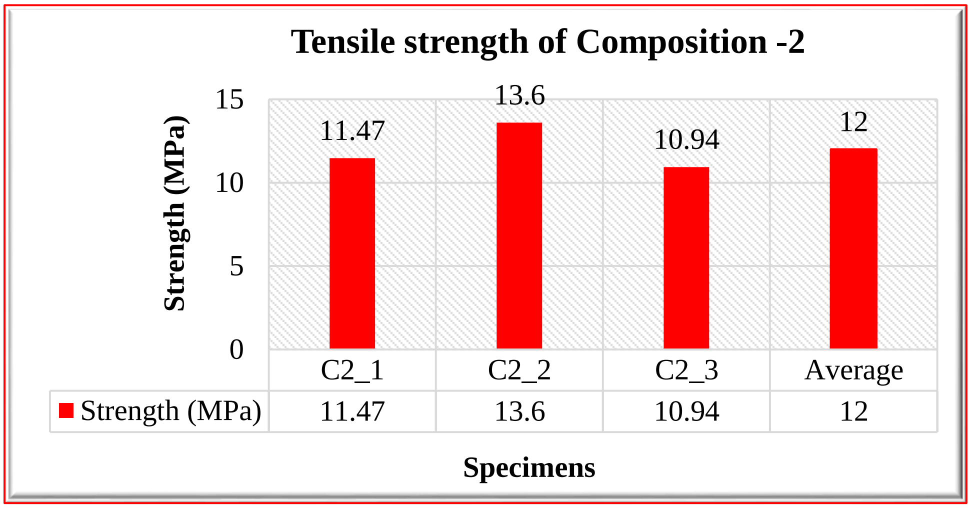


Figure 53 Tensile strength of Composition -2

The tensile strength of the composition 2 which is 40% of Reinforcement and 60% of Resin has a strength of 12 MPa. The axial displacement and the stress are calculated by using the MTS software under the Universal testing Machine. The graph is drawn between the displacement and the stress.

c) Composition -3

Stress Vs Axial displacement of compositions- 3

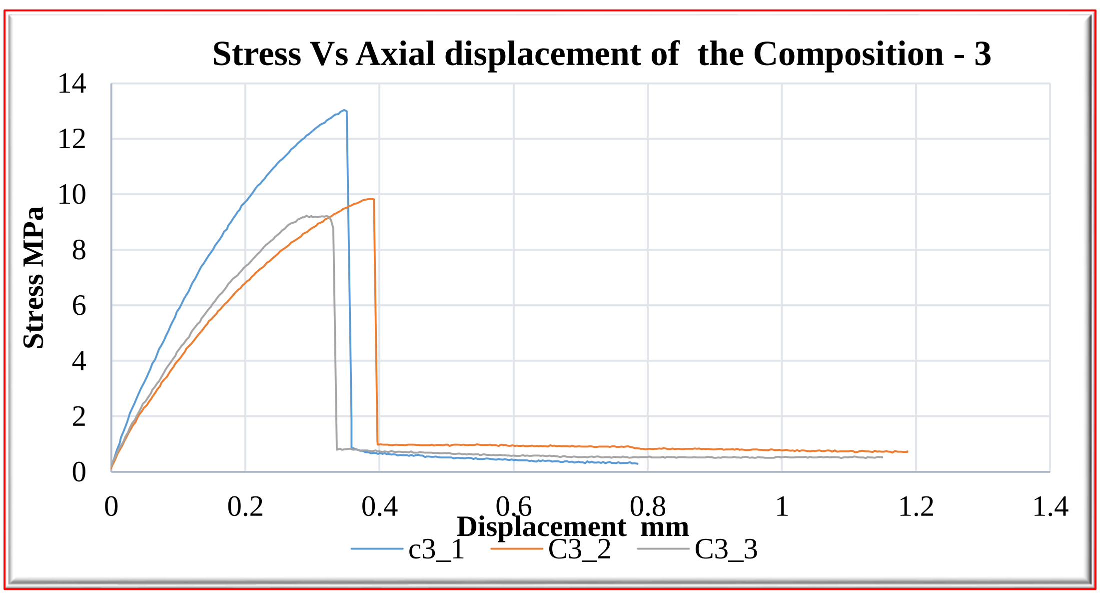
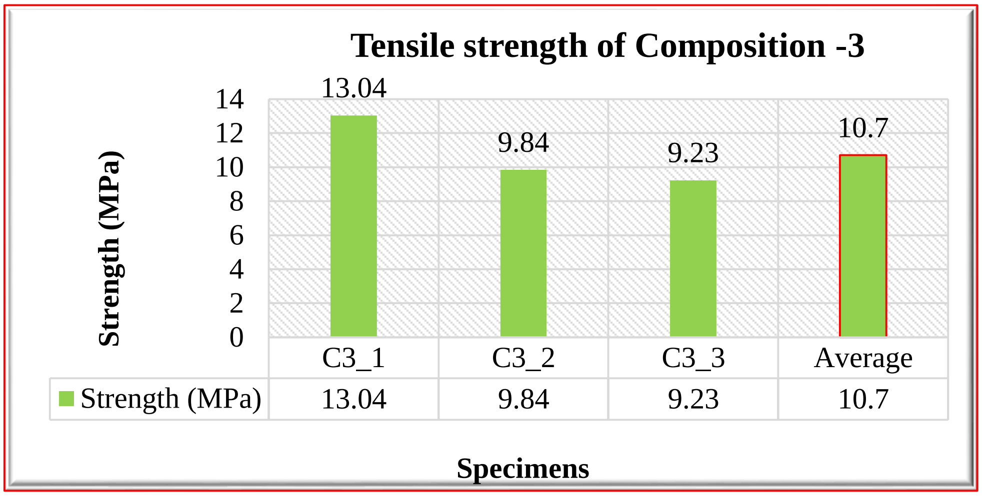


Figure 54 Stress Vs Axial displacement of the Compositions - 3

Tensile strength of Composition -3



Graph 55 Tensile strength of Composition -3

The tensile strength of the composition 3 which is 40% of Reinforcement and 60% of Resin has a strength of 10.7 MPa. The axial displacement and the stress are calculated by using the MTS software under the Universal testing Machine.

Experimental Results

Tensile test result of composition of C1, C2, and C3

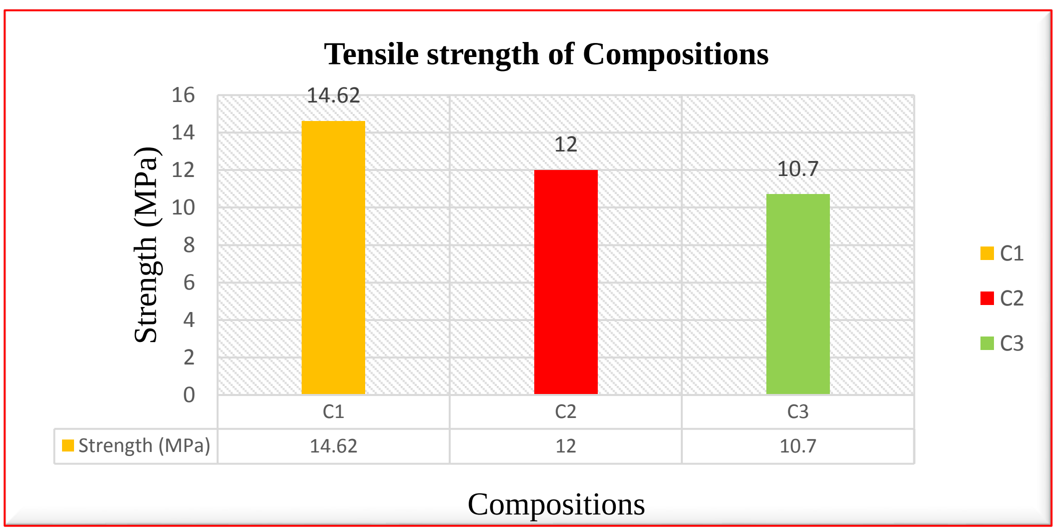


Figure 56 Overall Tensile test result of composition of C1, C2, and C3)

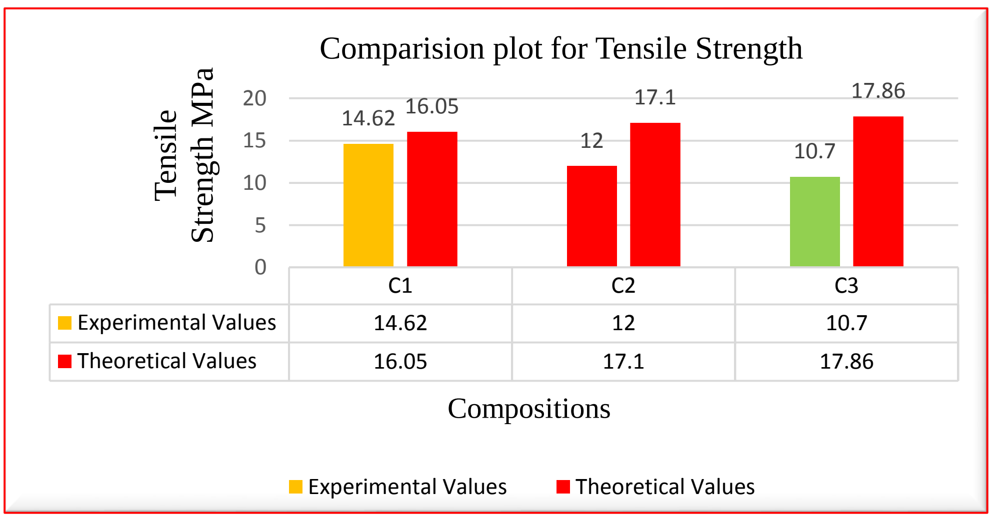
Variation in the reinforcement (Composition)

The specimen are carried out for testing under Universal testing machine, it is clearly shown that the composition 1 has a tensile strength of 14. 62 MPa which has a reinforcement composition of (5 grams Coconut shell powder , 5grams of Rice husk powder, 5grams of Sugarcane baggase ash and 5 grams of Fungi). Composition 2 has a tensile strength of 10. 7 MPa which as a reinforcement composition of (10 grams Coconut shell powder, 10 grams of Rice husk powder, 2.5 grams of Sugarcane baggase ash and 2.5 grams of Fungi). Composition 3 has a tensile strength of 12 MPa which as a reinforcement composition of (10 grams Coconut shell powder, 10 grams of Rice husk powder, 5 grams of Sugarcane baggase ash and 5 grams of Fungi).

Theoretical Tensile strength (TS) for RSM

In fabrication of composites materials, there will be two or more process variables that are inherently related and it is necessary to explore the nature of their relationship. A model has been proposed relating the process parameters with the output response (Mechanical properties). This model is used for prediction, process optimization or control purposes. In general, there will be response or dependent variables (e. Tensile strength etc...), which dependent on some independent variables (e.g. Fiber length (f_1) and Fiber Volume fraction (v_f) etc.). (Response surface modelling (RSM) is the collection of experimental strategies, mathematical methods and statically inferences that enable an experimental to make efficient empirical exploration of the system of interest. The response function has been determined in un-coded units as

$$\mathbf{T.S = 8.93 + 0.474 * V_f - 0.084 * f_1 - 0.00587 * (V_f)^2 + 0.012 (f_1)^2 + 0.00058 * V_f * f_1} \quad ....[16]$$



	C1	C2	C3
Experimental Values	14.62	12	10.7
Theoretical Values	16.05	17.1	17.86

Graph 57 Tensile Strength for Theoretical and Experimental values

Summary of the Result

The experimental and theoretical values are developed and it clearly reveals that the characterization of the composites such as fiber volume (v_f) shows significant effect on the

Mechanical properties of composites and in the theoretical point of view it states that the bonding between the fiber and the matrix is better when the volume of fiber increases. As in experimental point of view the tensile strength increases when the fiber volume decreases. But on the other hand in theoretical point of view, if the fiber volume increases the tensile strength increases. The mechanical properties that is tensile strength of natural plant based fiber is greatly influenced on the fiber volume.

Hardness testing:

The Hardness of the three compositions such as composition 1, composition 2 and composition 3 of natural based plant fiber reinforced composites with vinyl ester are carried out for determining the hardness by using the Brinell Hardness Testing machine. The specimen size is average of about 90 mm in length, 20mm breadth and 6mmWidth. The specifications of machine are ball indenter diameter of about 20mm and load of about 2500 N. The formula used to determine the BHN of the specimens is BHN = P/A

Where,

P – Load applied to the specimen, A – Area of indentation

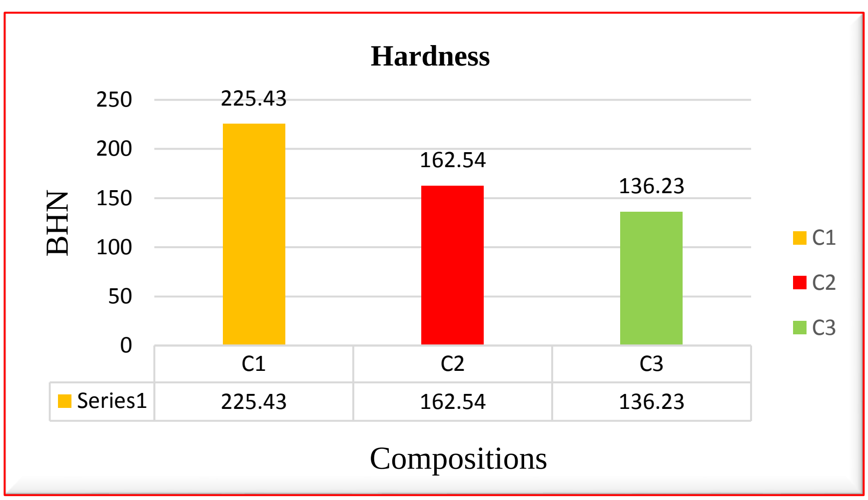
$$\text{Area of indentation (A), } A = (\pi * D/2)*((D-(D^2-d^2))^{0.5} \quad \ldots\ldots \quad [17]$$

D = Diameter of the ball indenter, d = Diameter of the indentation

$$A = (\pi * D/2)*((D-(D^2-d^2))^{0.5} = (\pi * 20/2)*((20-(20^2-4^2))^{0.5} = 15.38 \text{ mm2}$$

$$BHN = P/A = 2500/15.38 = 225.43 \text{ BHN}$$

Brinell hardness for composition C1, C 2 and C3



Graph- 58 Brinell hardness for composition C1, C 2 and C3

Summary of the Result

The tensile strength of the composition 1 which is 40% of Reinforcement and 60% of Matrix has shown a strength of 14.62 MPa with a hardness of 245 BHN is better when compared to composition2 and composition 3. The axial displacement and the stress are calculated by using the MTS software under the Universal testing Machine. Also the other combination has carried with the composition of 60% natural reinforcement and 40% matrix (Vinyl ester) and these material has leaded to impregnated and leads to failure.

4.3 Composites of Vinyl Ester with Coarse, Fine (CSP) and Coarse, Fine (RHP).

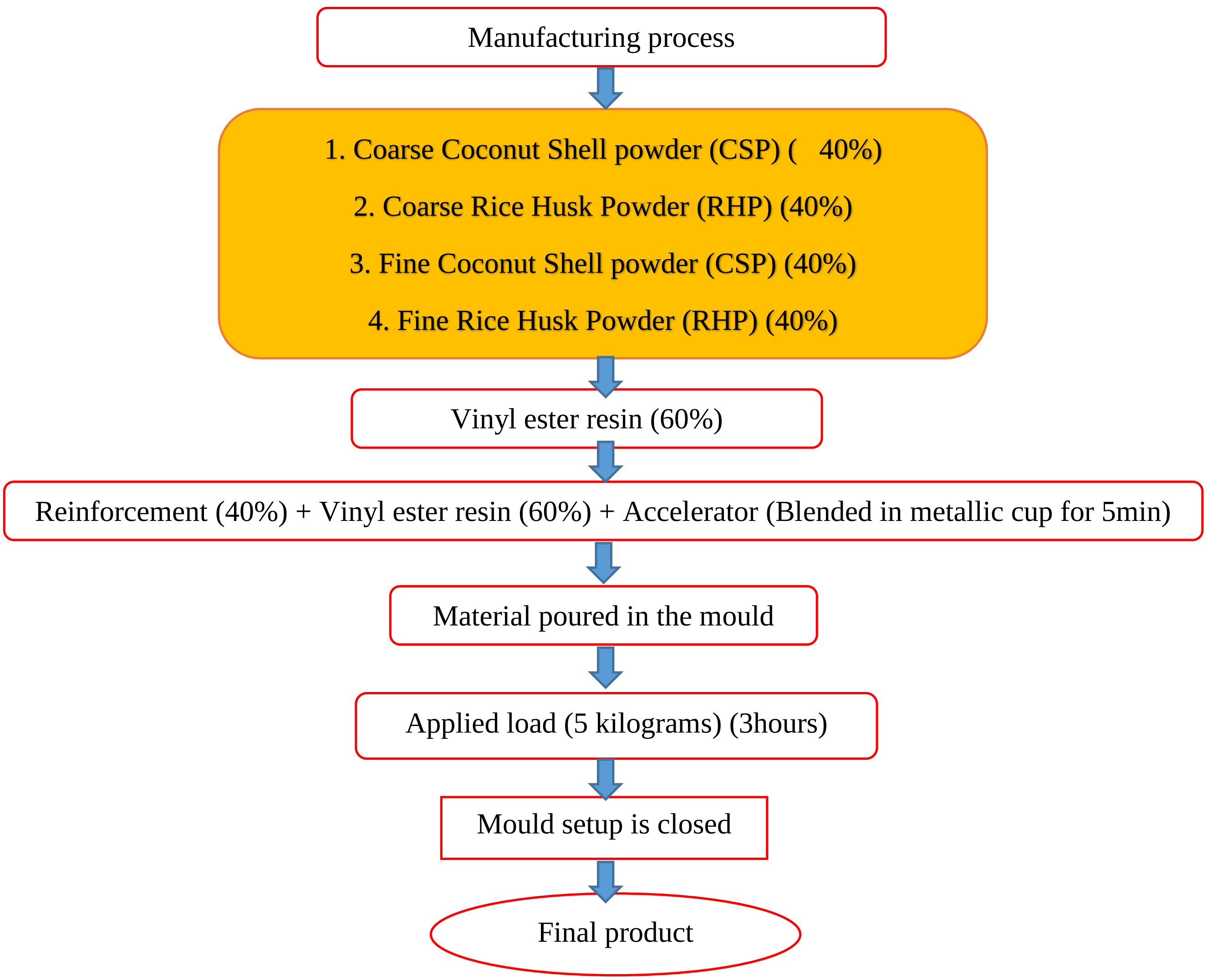


Figure 59 Manufacturing process of Vinyl Ester with Coarse and Fine Coconut Shell powder (CSP) and Coarse and Fine Rice husk Powder (RHP).

a) Manufacturing process

The natural plant fiber and matrix materials such Vinyl ester is added to the natural plant fiber with the composition of 40% reinforcement and 60% of the vinyl ester is added for the materials and for initiating the reaction of vinyl ester the accelerator is added 2% to the vinyl ester. The milled plant fiber are blended with the matrix material such as Vinyl ester with a catalyst of respected composition to initiate the reaction. Firstly, the vinyl ester of 60% is weighed and the according to the weight ratio of vinyl ester the accelerator is added and mixed by using the mechanical stirrer for 5 minutes to initiate the reaction. Then the coconut shell powder and the matrix material (Vinyl ester) are blended by using the mechanical stirrer for 5 minutes.

Eventually after the reinforcement and matrix are mixed by using the mechanical stirrer, the blended reinforcements and matrix is poured into the mould (steel die). The steel die is coated by the Wax (carnauba) for an ease removal of specimen from the mould. Firstly the coating of wax is done and kept in the room temperature for 5 minutes and respectively for second coating and third coating for a time interval of 5 minutes. After then, the mixed reinforcements and matrix material are poured in to the mould and a load of 5 kilograms is applied for entire 3 hours. After three hours the load is removed from the die and the mould (frame) is removed.

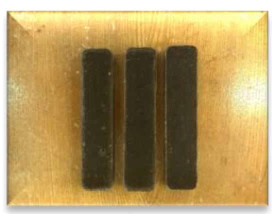


Figure 60 Coarse Coconut Shell powder (CSP) with Vinyl Ester

Figure 61 Coarse Rice Husk Powder (RHP) with Vinyl Ester

Figure 62 Fine Coconut Shell powder (CSP) with Vinyl Ester

Figure 63 Fine Rice Husk Powder (RHP) with Vinyl Ester

Tensile testing

The test is carried out by the universal testing machine. The testing process are carried out in the room temperature.

a) Coarse Coconut Shell powder (CSP) with Vinyl Ester

Force vs Axial Displacement

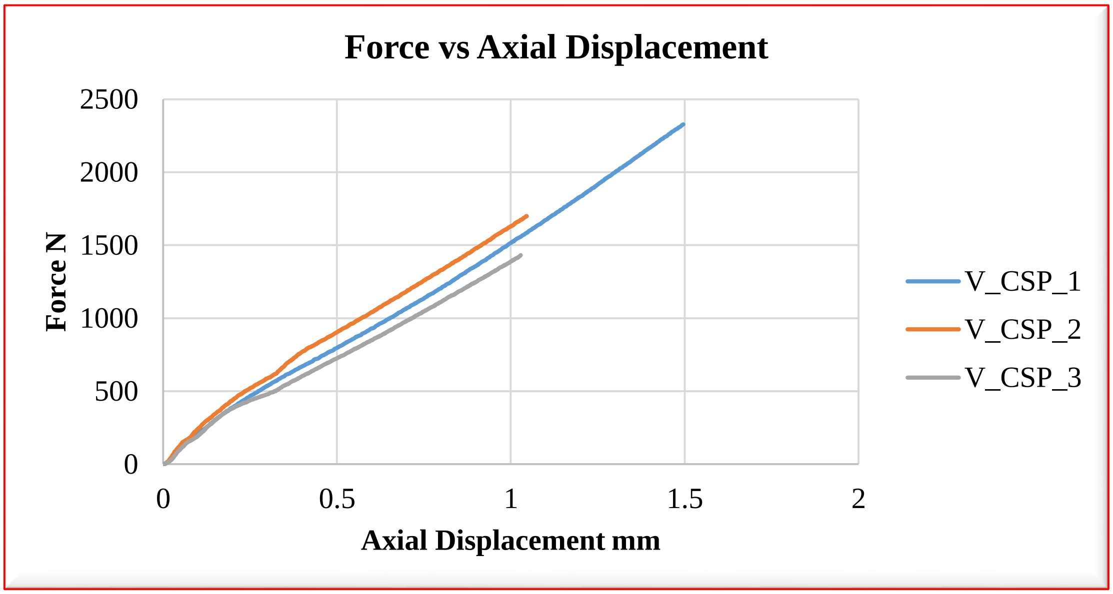


Figure 64 Force vs Axial Displacement of Coarse Coconut Shell powder (CSP) with Vinyl Ester

Tensile Strength Coarse Coconut Shell powder (CSP) with Vinyl Ester

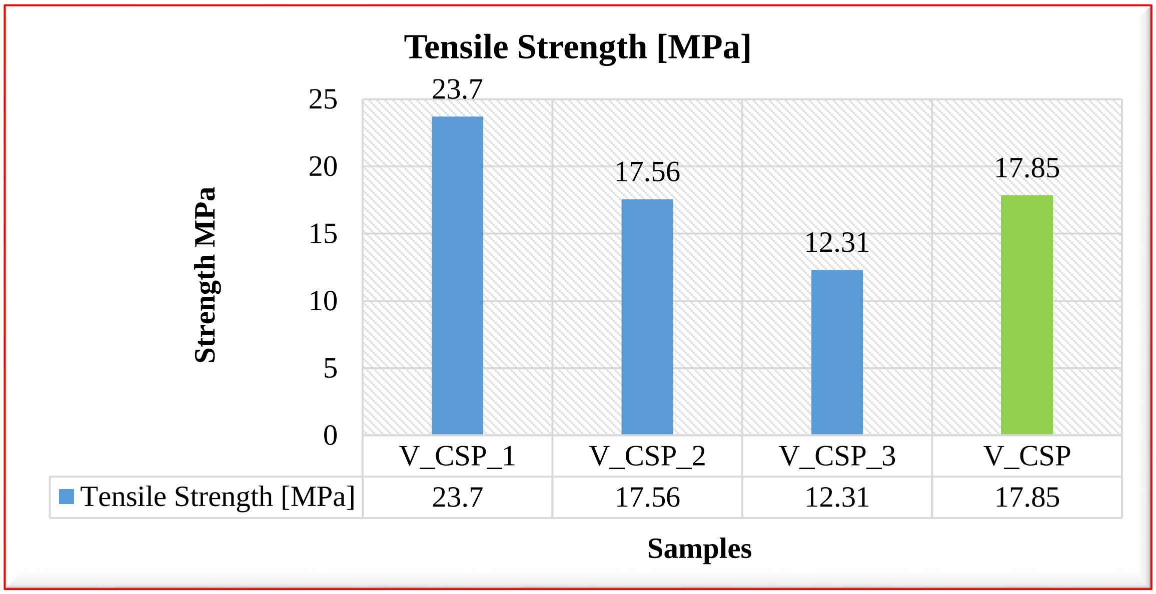


Figure 65 Tensile Strength Coarse Coconut Shell powder (CSP) with Vinyl Ester

b) Coarse Rice Husk Powder (RHP) with Vinyl Ester

Force vs Axial Displacement

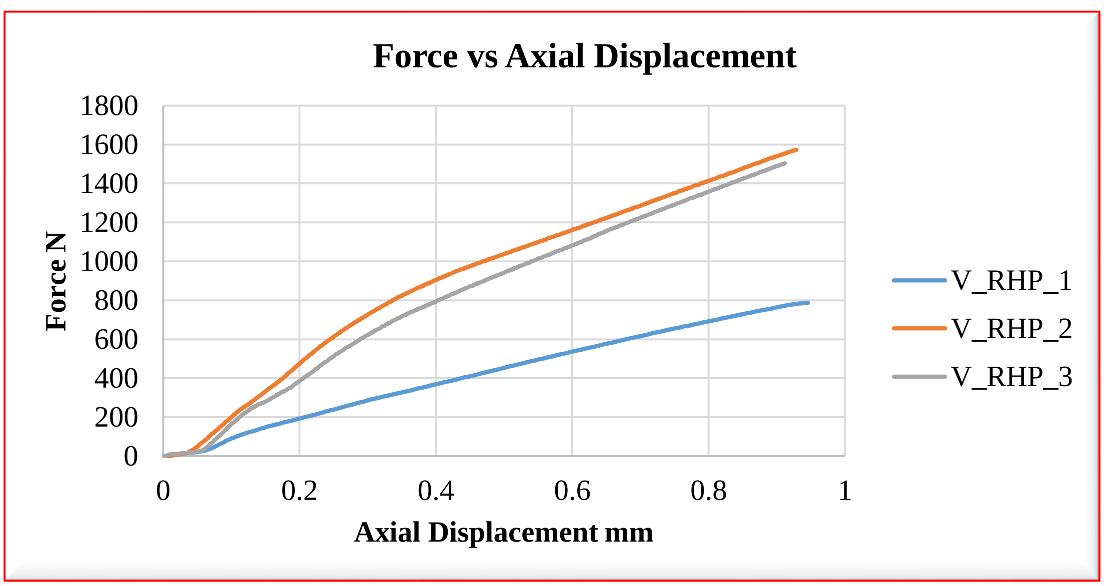


Figure 66 Force vs Axial Displacement of Coarse Rice Husk Powder (RHP) with Vinyl Ester

Tensile Strength of Coarse Rice Husk Powder (RHP) with Vinyl Ester

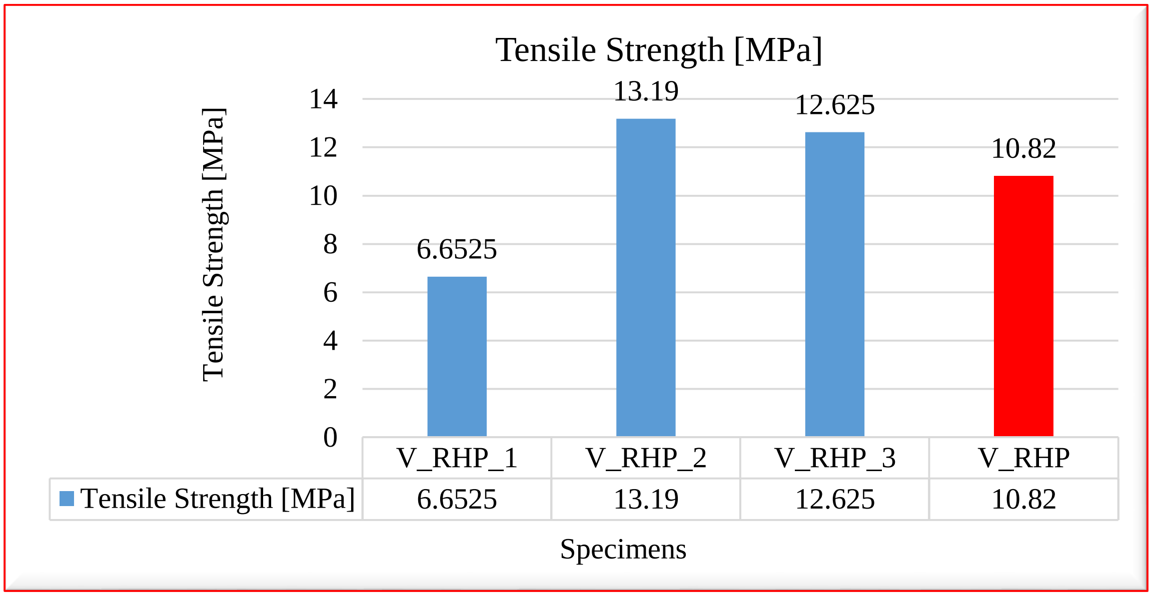


Figure 67 Tensile Strength of Coarse Rice Husk Powder (RHP) with Vinyl Ester

c) Fine Coconut Shell powder (CSP) with Vinyl Ester

Force vs Axial Displacement

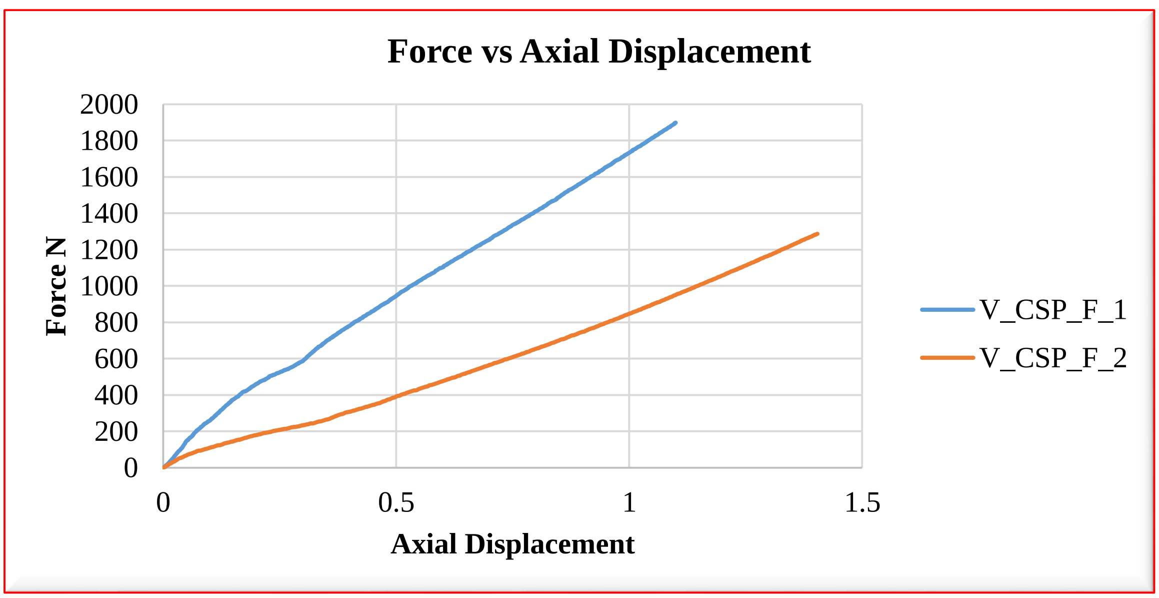


Figure 68 Force vs Axial Displacement of Fine Coconut Shell powder (CSP) with Vinyl Ester

Tensile Strength of fine Coconut Shell powder (CSP) with Vinyl Ester

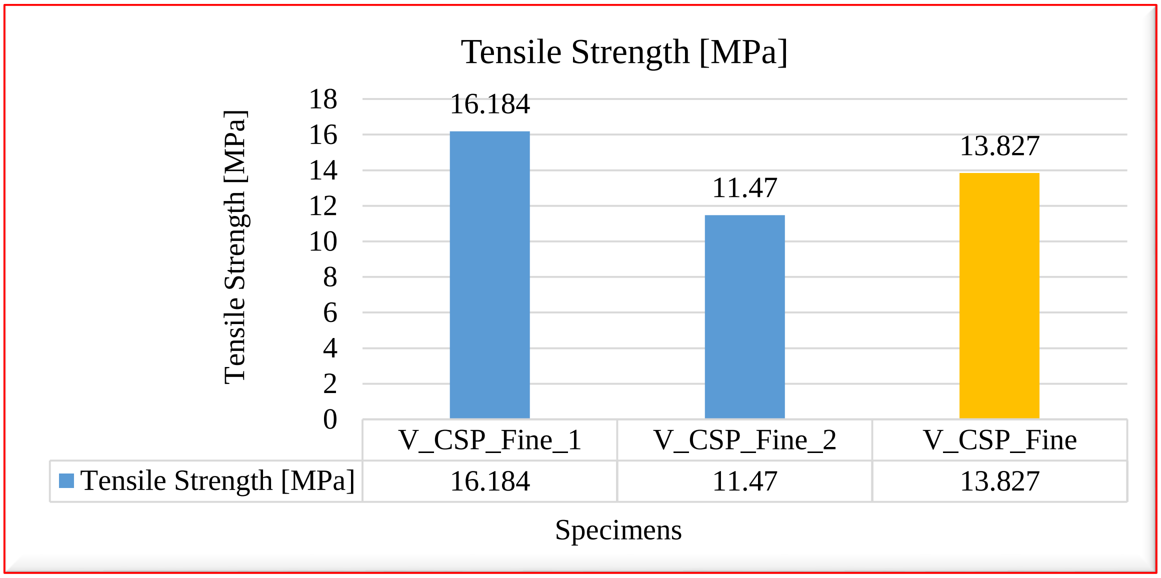


Figure 69 Tensile Strength of Fine Coconut Shell powder (CSP) with Vinyl Ester

d) Fine Rice Husk Powder (RHP) with Vinyl Ester

Force vs Axial Displacement

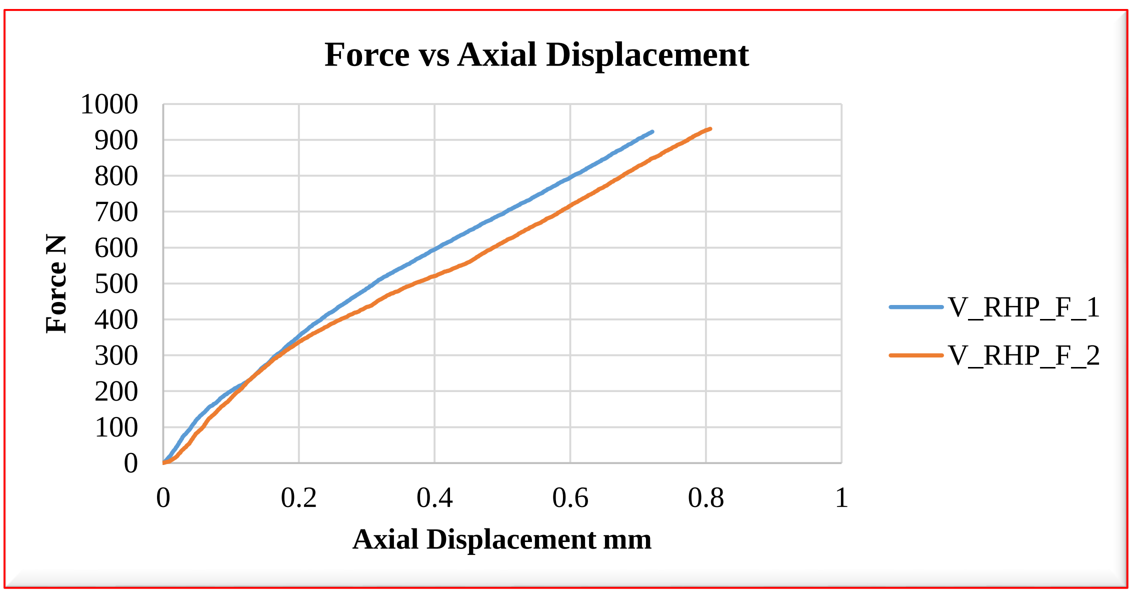


Figure 70 Force vs Axial Displacement of Fine Rice Husk Powder (RHP) with Vinyl Ester

Tensile strength Fine Rice Husk Powder (RHP) with Vinyl Ester

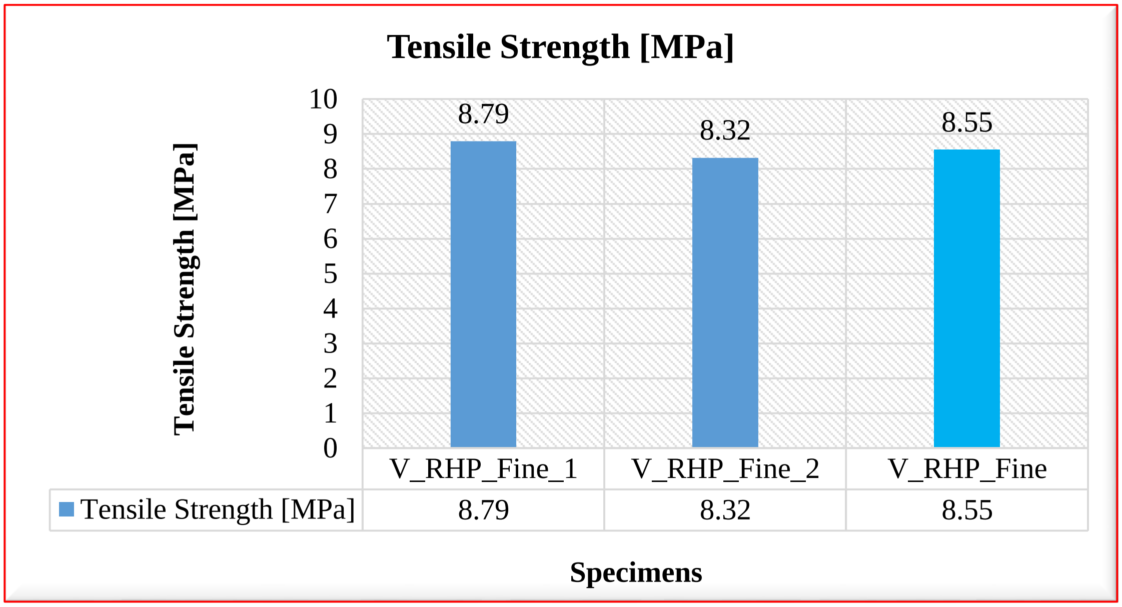


Figure 71 Tensile Strength of Fine Rice Husk Powder (RHP) with Vinyl Ester

Experimental Results

Tensile strength of the Coarse and fine CSP and RHP

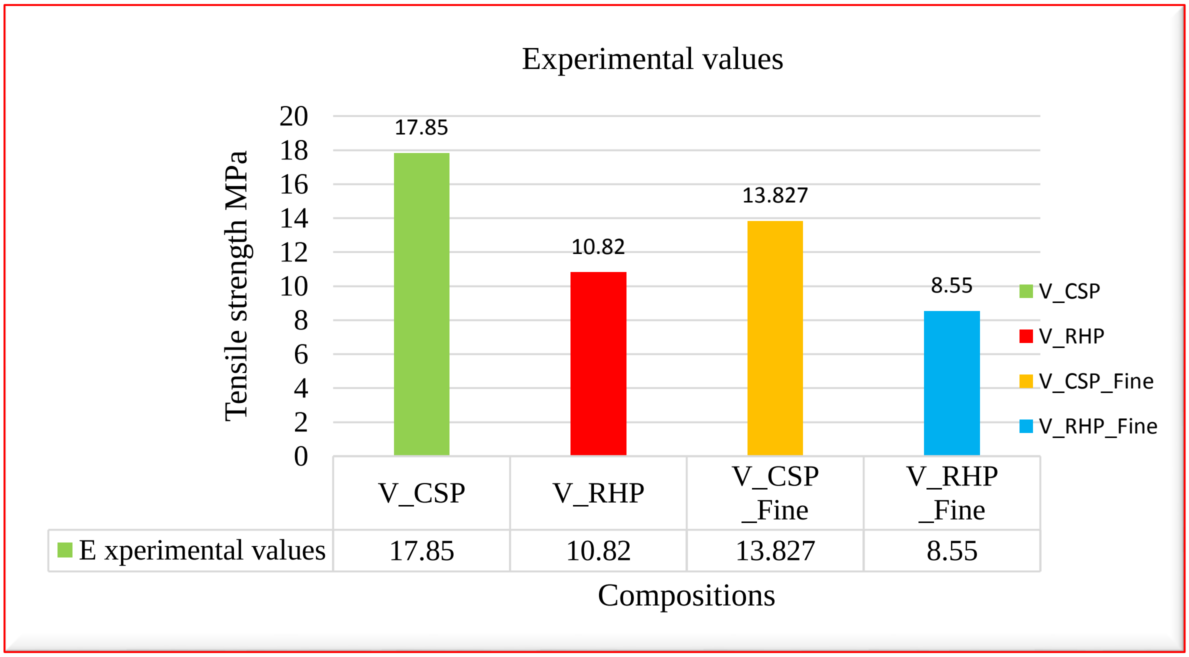
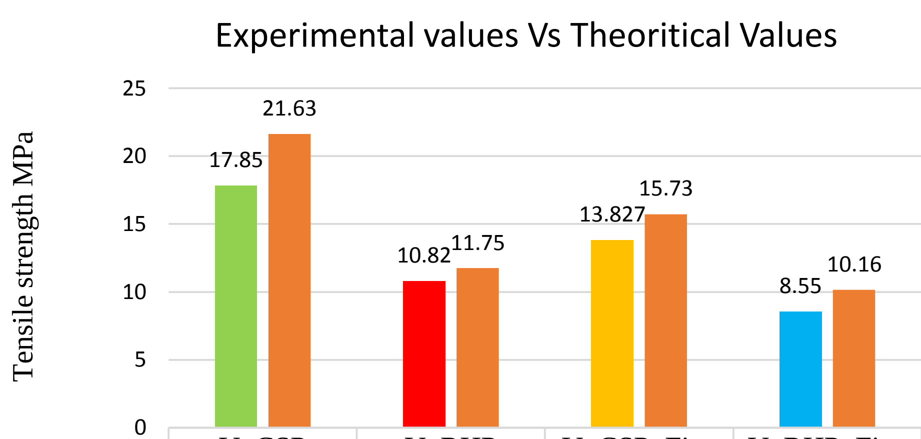


Figure 72 Tensile strength of the Coarse and fine CSP and RHP

The tensile testing is carried out for the coarse coconut shell powder and coarse rice husk powder on the other hand the fine coconut shell powder and the fine rice husk powder is Manufactured and the strength of the specimens are taken by using the tensile testing machine. The coarse coconut shell powder shows that the strength is higher than the coarse Rice Husk powder. On the other hand the fine coconut shell powder has shown higher tensile strength then the Fine rice husk powder. As from the experimental result it clearly states that the tensile strength of coconut shell with vinyl ester show better strength compared to other type of manufactured specimens.

Experimental Vs Theoretical of the Coarse and fine CSP and RHP



	V_CSP	V_RHP	V_CSP_Fine	V_RHP_Fine
E xperimental values	17.85	10.82	13.827	8.55
Theoritical Values	21.63	11.75	15.73	10.16

Compositions

Figure 73 Experimental Vs Theoretical of the Coarse and fine CSP and RHP

the result of vinyl with coconut shell powder shows higher strength then the vinyl with rice husk ash and it clearly reveals that the strength of the vinyl ester with coconut shell powder shows the twice the strength of the vinyl with rice husk powder. The theoretical values show higher than the experimental values. So as from the coconut shell powder with vinyl it is clearly known that the tensile strength of the 17.85 is achieved for the coarse coconut shell powder with vinyl.

Hardness testing of the Coarse and fine CSP and RHP

The Hardness of the natural based plant fiber reinforced composites with vinyl ester are carried out for determining the hardness by using the Brinell Hardness Testing machine. The specimen size is average of about 90 mm in length, 20mm breadth and 6mmWidth. The specifications of machine are ball indenter diameter of about 20mm and load of about 2500 N. The formula used to determine the BHN of the specimens is

$$BHN = P/A$$

Where,

P – Load applied to the specimen

A – Area of indentation

Area of indentation (A)

$$A = (\pi * D/2)*((D-(D^2-d^2))^{0.5}$$

Where,

D = Diameter of the ball indenter

d = Diameter of the indentation

$A = (\pi * D/2)*((D-(D^2-d^2))^{0.5}$

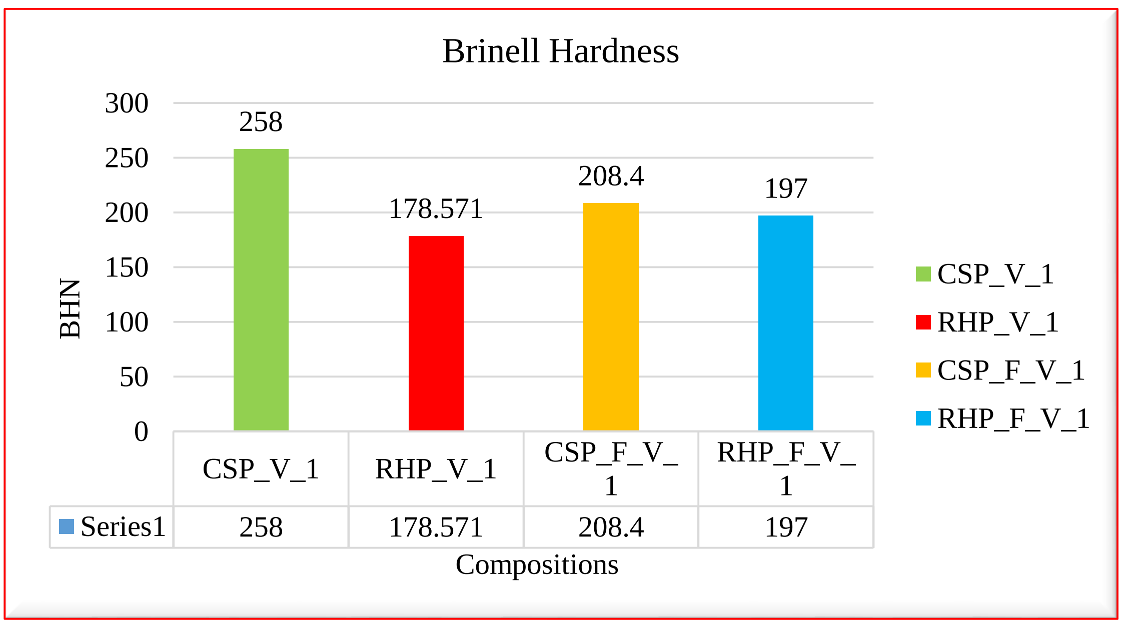


Figure 74 Hardness testing of the Coarse and fine CSP and RHP

4.4 Composites of Vinyl Ester with Linen fiber

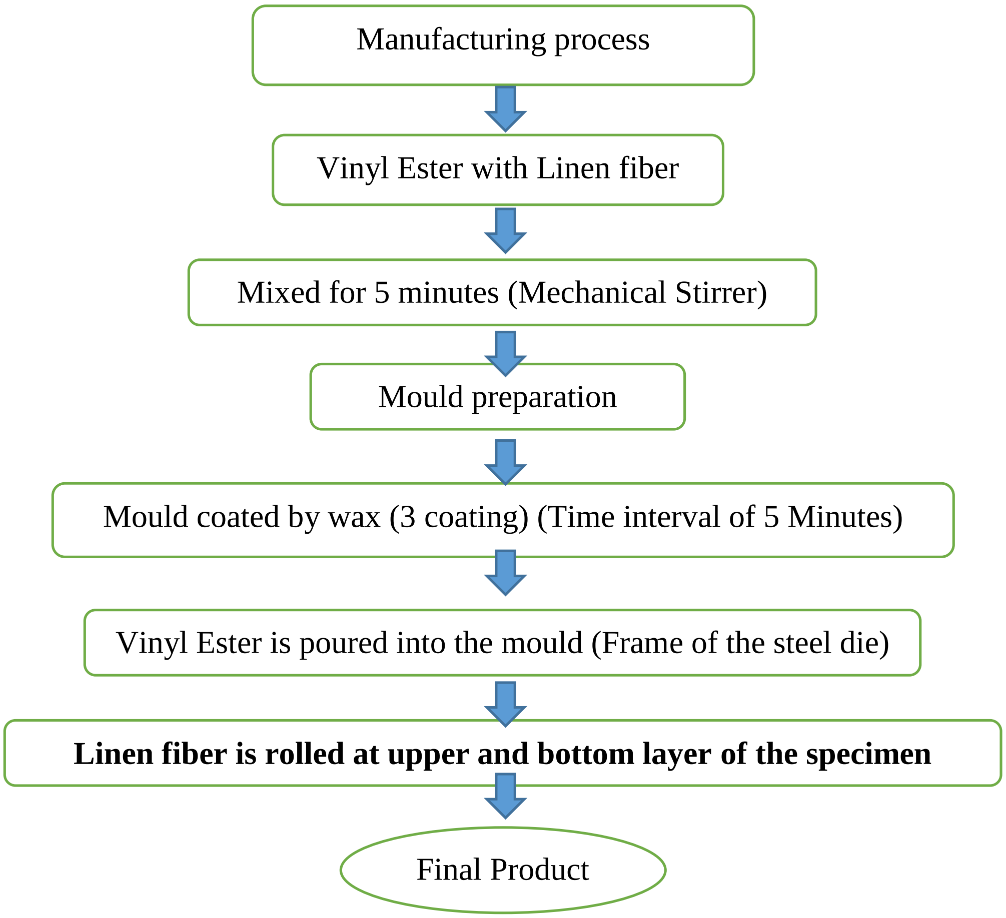


Figure 75 Manufacturing process of Vinyl Ester with Linen fiber

Linen fiber Fabrication Specimens

Figure -76 Specimen made of Vinyl Ester with Linen fiber

Tensile testing of Vinyl Ester with Linen Fiber

Force vs Axial Displacement

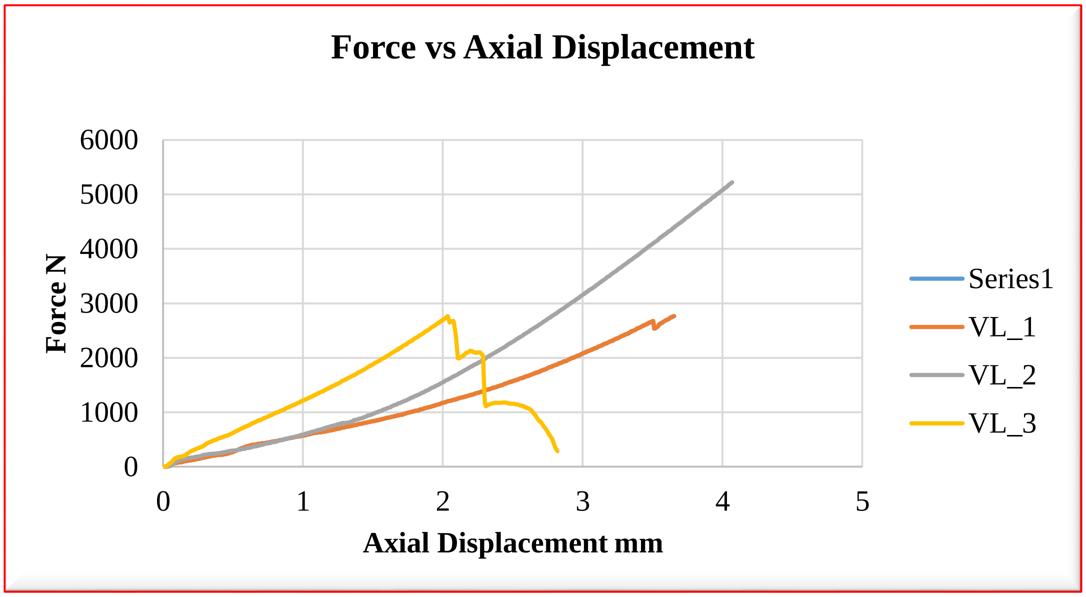


Figure 77 Force vs Axial Displacement of Vinyl Ester with Linen Fiber

Tensile Strength of Vinyl Ester with Linen Fiber

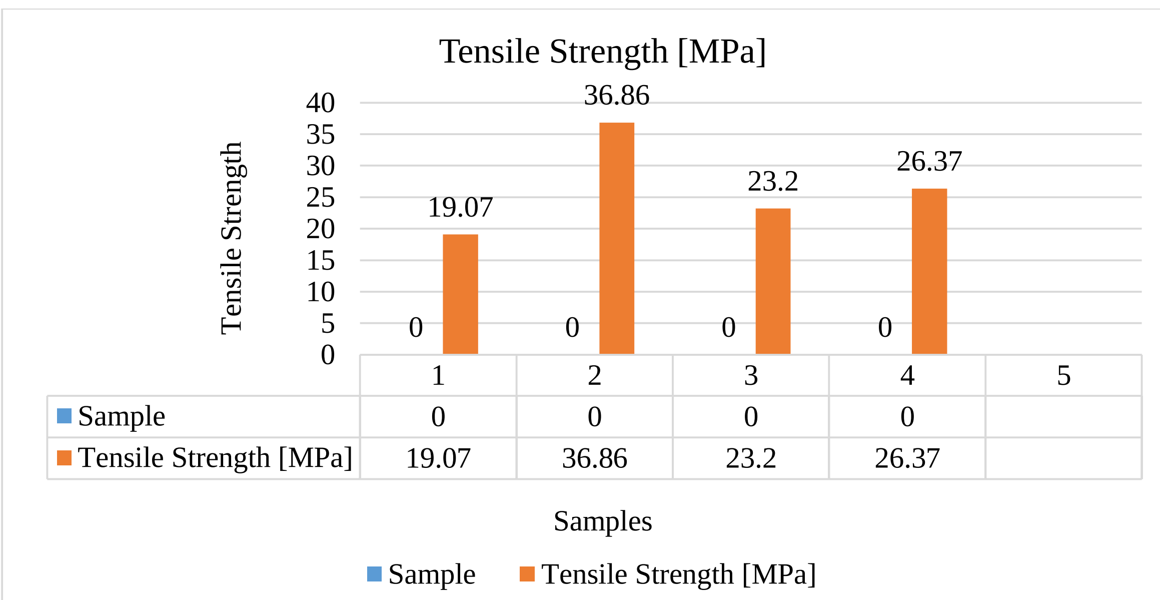


Figure 78 Tensile Strength of Vinyl Ester with Linen Fiber

The fiber such as coconut shell fiber (40%) with (60%) of Vinyl Ester and rice husk fiber (40%) with (60%) of Vinyl Ester are manufactured individually to identify the individual mechanical properties. In this case the fiber are characterized into coarse fiber and fine fiber. The fine fiber is made by using blending and the filtering technique. Once the filtering got over the fiber is placed in a vacuum machine to remove the air bubble. The difference is mechanical properties is noticed between the coarse and fine fiber. The coarse coconut shell powder with the tensile strength 17.85 MPa and hardness is 258 BHN and fine coconut shell powder with the tensile strength 10.82 MPa and hardness is 208.4 BHN. The coarse rice husk powder with the tensile strength 13.827 MPa and hardness is 178.571 BHN and fine rice husk powder with the tensile strength 8.55 MPa and hardness is 197 BHN. The main thing is noticed that the tensile strength drops when the size is reduced in the coconut shell fiber and rice husk fiber, the reason could be due to the significant effect on the material which led to losses its adhesion properties. On the other case the hardness of coconut shell powder decreases when the grain size reduces but on the rice husk if the grain size reduces the hardness increases.

4.5. Composites of Pure Vinyl Ester

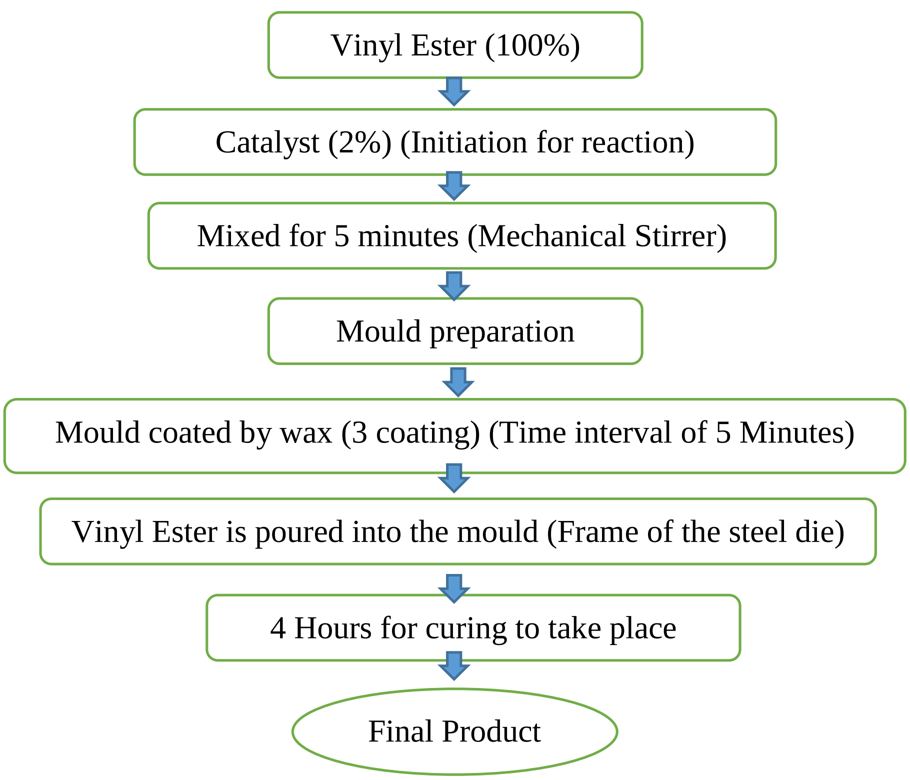
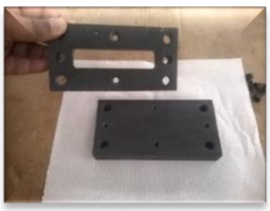
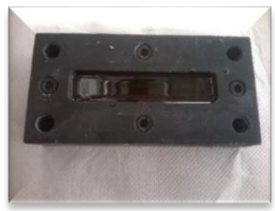


Figure 79 Manufacturing process of Pure Vinyl Ester

a) Manufacturing process

Firstly, the Vinyl Ester is measured for the required quantity and according to the composition of Vinyl Ester the catalyst is added in the ratio of 100:2. In this work the Vinyl Ester is about a quantity of 100% and catalyst of 2% is acquired for preparing the resin. Once the measured is done by using the weighing machine, the resin is mixed up by using the mechanical stirrer for five minutes for blending to take place and initiation of reaction to take place in the Vinyl Ester. Then the mould made of steel and is coated with the wax for three times for a time interval of 5 minutes for ease of removal of material from the mould. The resin is poured into the mould and then after three hours of curing process the specimen is taken out as a product.





Fixing of Die **Pouring of Vinyl Ester** **Curing process** **Specimens**

Figure-80 Specimen of Pure Vinyl Ester Process

Tensile testing of Vinyl Ester

Force vs Axial Displacement

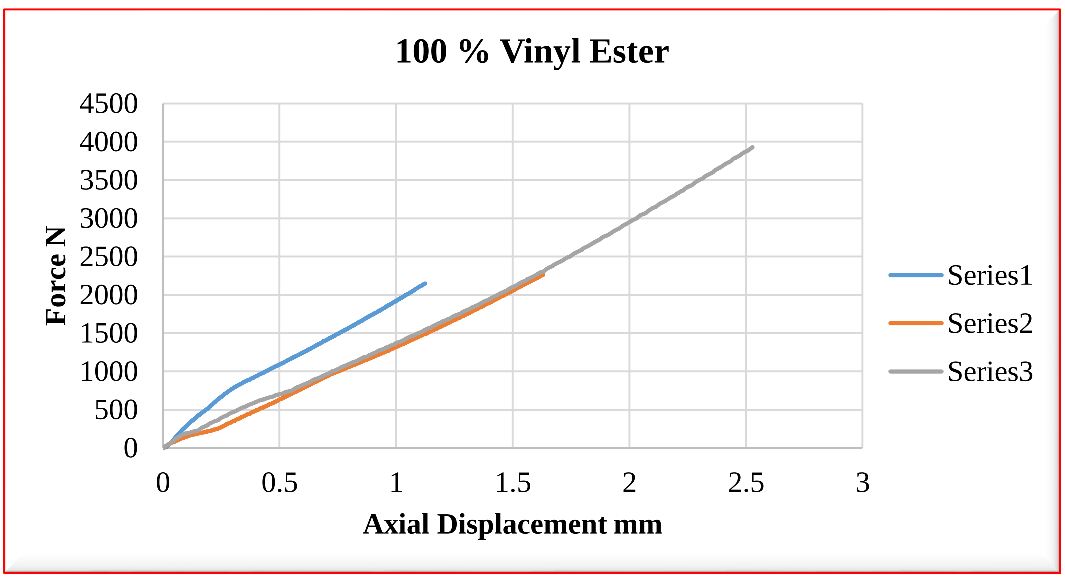


Figure 81 Force vs Axial Displacement of Pure Vinyl Ester Process

Tensile Strength of vinyl ester

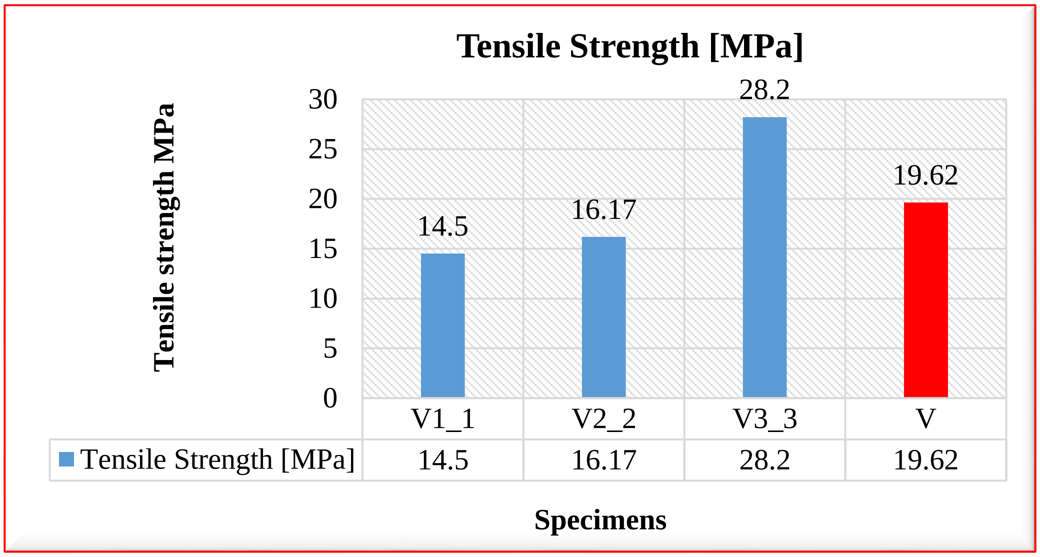


Figure 82 Tensile Strength of vinyl ester

The tensile strength of the pure Vinyl Ester has a strength of 28.72 MPa. The axial displacement and the stress are calculated by using the MTS software under the Universal testing Machine. The graph is drawn below between the displacement and the stress.

5. Result and Discussion

Overall tensile strength of the fiber (Case – 3, 4, 5)

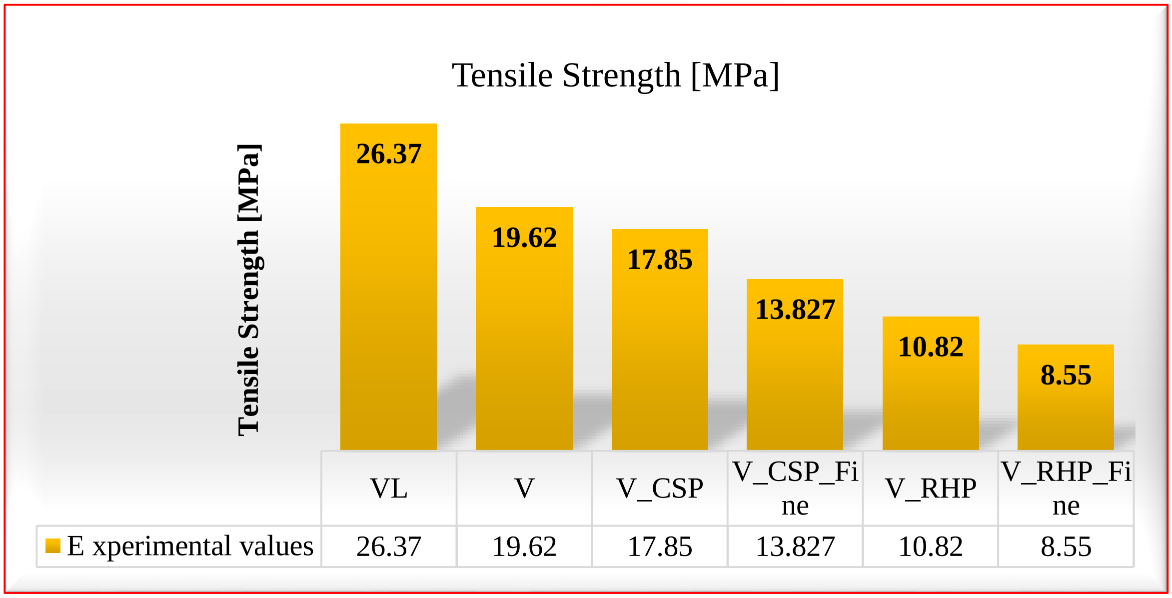


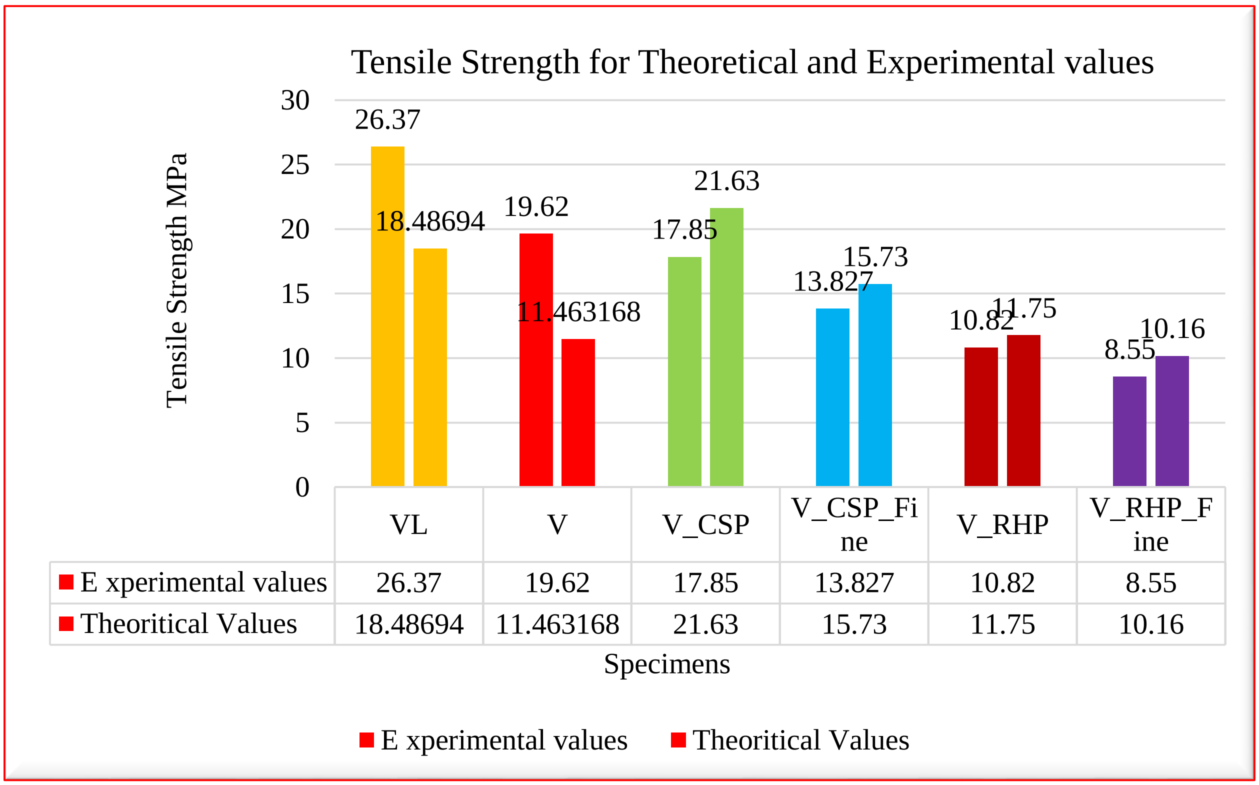
Figure 83 Overall tensile strength of the fiber with Vinyl Ester

Theoretical Tensile strength (TS) for RSM

In fabrication of composites materials, there will be two or more process variables that are inherently related and it is necessary to explore the nature of their relationship. A model has been proposed relating the process parameters with the output response (Mechanical properties). This model is used for prediction, process optimization or control purposes. In general, there will be response or dependent variables (e. Tensile strength etc...), which dependent on some independent variables (e.g. Fiber length (f_1) and Fiber Volume fraction (v_f) etc.). (Response surface modelling (RSM) is the collection of experimental strategies, mathematical methods and statically inferences that enable an experimental to make efficient empirical exploration of the system of interest. The response function has been determined in un-coded units as

$$\mathbf{T.S = 8.93 + 0.474 * V_f - 0.084 * f_1 - 0.00587 * (v_f)^2 + 0.012 (f_1)^2 + 0.00058 * V_f * f_1}$$

Tensile Strength for Theoretical and Experimental values:



	VL	V	V_CSP	V_CSP_Fine	V_RHP	V_RHP_Fine
E xperimental values	26.37	19.62	17.85	13.827	10.82	8.55
Theoritical Values	18.48694	11.463168	21.63	15.73	11.75	10.16

Figure 84 Theoretical Tensile strength (TS) for RSM

Summary of the Result

The experimental and theoretical values are developed and it clearly reveals that the characterization of the composites such as fiber volume (v_f) shows significant effect on the Mechanical properties of composites and in the theoretical point of view it states that the bonding between the fiber and the matrix is better when the volume of fiber increases. As in experimental point of view the tensile strength increases when the fiber volume decreases. But on the other hand in theoretical point of view, if the fiber volume increases the tensile strength increases. The mechanical properties that is tensile strength of natural plant based fiber is greatly influenced on the fiber volume.

Hardness testing:

The Hardness of the natural based plant fiber reinforced composites with vinyl ester are carried out for determining the hardness by using the Brinell Hardness Testing machine. The specimen size is average of about 90 mm in length, 20mm breadth and 6mmWidth. The specifications of machine are ball indenter diameter of about 20mm and load of about 2500 N. The formula used to determine the BHN of the specimens is

$$BHN = P/A$$

Where,

P – Load applied to the specimen

A – Area of indentation

Area of indentation (A)

$$A = (\pi * D/2)*((D-(D^2-d^2))^{0.5}$$

Where,

D = Diameter of the ball indenter

d = Diameter of the indentation

$$A = (\pi * D/2)*((D-(D^2-d^2))^{0.5} = (\pi * 20/2)*((20-(20^2-2.7^2))^{0.5} = 5.7462 \text{ mm}^2$$

$$BHN = P/A = 2500/15.38 = 435 \text{ BHN}$$

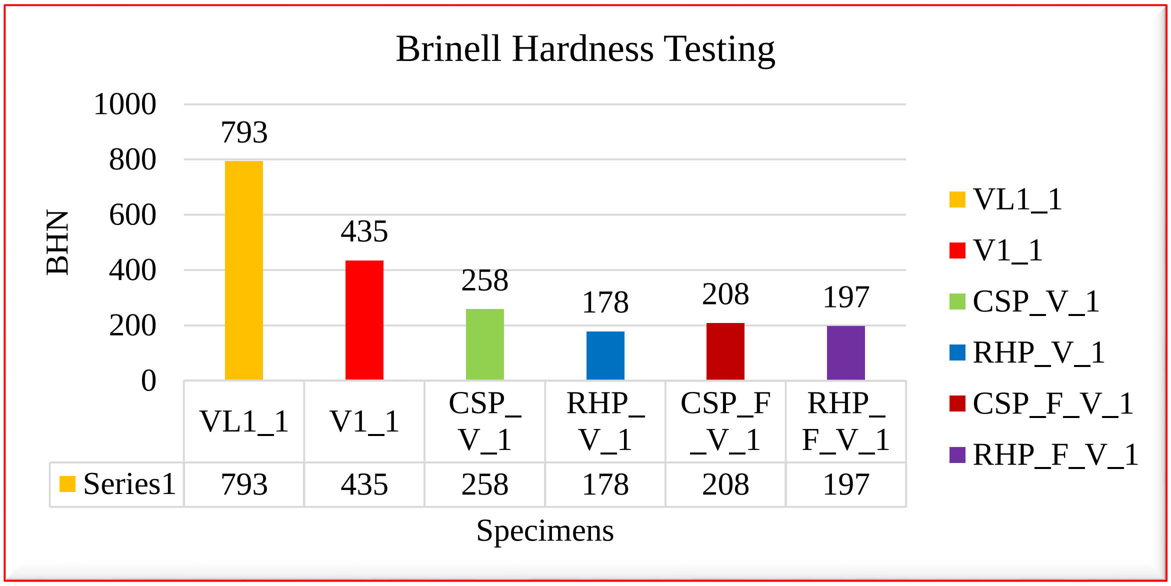


Figure 85 Overall Hardness testing of the fiber with vinyl Ester

The hardness of the linen fiber with vinyl ester shown higher hardness then the other fiber and it shows the fine powder and the coarse powder are lower than the coarse powders.

Young's Modulus

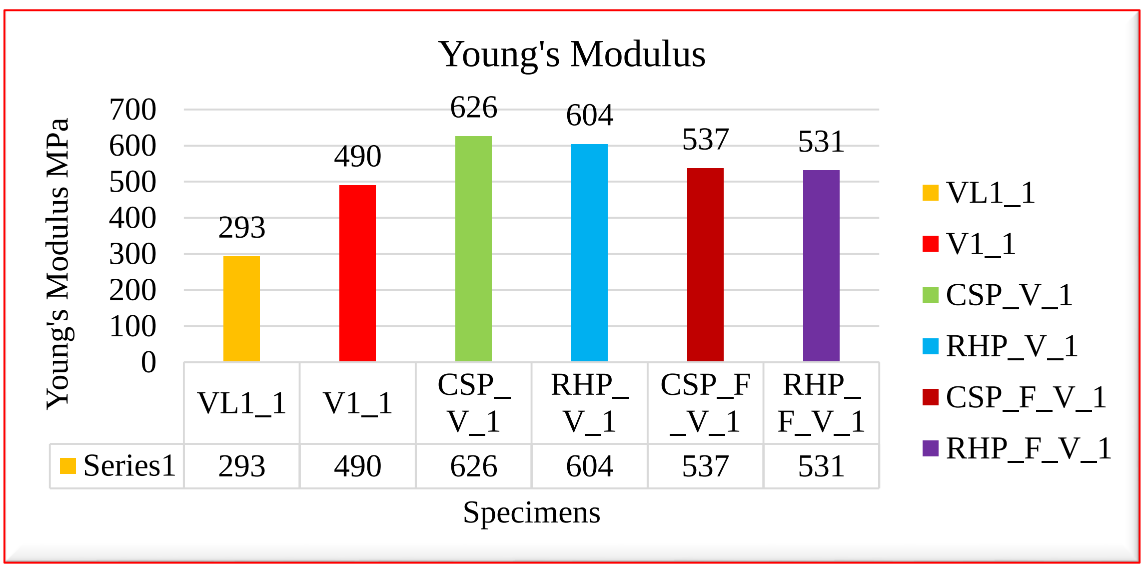


Figure 86 – Overall Young's Modulus of the fiber with Vinyl Ester

The young's modulus for the coconut shell powder show higher than the all the fiber and in this case the vinyl ester with the linen fiber are low as compared to all the fiber. Therefore it clearly states that the difference in the long and short fiber have major difference in the young's modulus.

Case -1 (Natural fiber with Moring Resins)

Initially, the combination of material with 40% reinforcement and 60% matrix which is 100% natural composites has carried out and investigated. The reinforcement with the composition of different natural filler and natural fiber are milled individually and the properties such as particle size and density has shown. Then eventually the reinforcement material which is milled individually are mixed with the different composition for obtaining the homogeneity of fiber and filler, So the homogenous milling is carried out in Planetary milling machine and particle size and the density are calculated. The 100% natural material had attained 2.45 MPa of tensile strength with the density of 1.10 g/cm^3. The reason of the lowest tensile strength is due to the non-adhesion property between the reinforcement and the matrix which as shown by the surface characteristic. These loss of adhesion property could be due to moringa resin because the moringa resin are in crystalized condition during the manufacturing process.

The moringa resin is hard and does not solidify at 160˚C for a time of duration of 3 hours at furnace. In this research work different manufacturing process has been carried to improve the adhesion property between the reinforcement and the matrix. Unfortunately, the manufacturing process -3 the reinforcement and the matrix are blended after applying a high load. Finally the 100% natural material had attained with a 2.45 MPa of tensile strength this low strength is due to the crystalized condition of moringa which has led to loss of adhesion and a drop in to lower tensile strength.

Case-2 (Natural fiber with Vinyl Ester)

Secondly, On the other hand, the natural reinforcements are blended with the matrix material such as vinyl ester. Different combinations on reinforcements and manufacturing process had carried for the preparation of composite material. Initially the composition C1 has carried out with high applied load, the specimen resulted the removal of material on the surface. The specimen has carried out for surface morphology and surface characteristic has been identified and resulted that abrasion on the surface which is leads to removal of material on the surface has resulted. Secondly the manufacturing process has carried out in a low load with a 5 kilograms. The specimen has carried out for the electron microscope for the surface characteristic. The surface is good enough and carried out for the tensile test in the universal testing machine. The tensile strength of the composition 1 which is 40% of Reinforcement and 60% of Matrix has shown a strength of 14.62 MPa with a hardness of 245 BHN is better when compared to composition2 and composition 3.

The axial displacement and the stress are calculated by using the MTS software under the Universal testing Machine. Also the other combination has carried with the composition of 60% natural reinforcement and 40% matrix (Vinyl ester) and these material has leaded to impregnated and leads to failure.

Case – 3 (Individual fibers with Vinyl Ester)

The fiber such as coconut shell fiber (40%) with (60%) of Vinyl Ester and rice husk fiber (40%) with (60%) of Vinyl Ester are manufactured individually to identify the individual mechanical properties. In this case the fiber are characterized into coarse fiber and fine fiber. The fine fiber is made by using blending and the filtering technique. Once the filtering got over the fiber is placed in a vacuum machine to remove the air bubble. The difference is mechanical properties is noticed between the coarse and fine fiber.

The coarse coconut shell powder with the tensile strength 17.85 MPa and hardness is 258 BHN and fine coconut shell powder with the tensile strength 10.82 MPa and hardness is 208.4 BHN. The coarse rice husk powder with the tensile strength 13.827 MPa and hardness is 178.571 BHN and fine rice husk powder with the tensile strength 8.55 MPa and hardness is 197 BHN. The main thing is noticed that the tensile strength drops when the size is reduced in the coconut shell fiber and rice husk fiber, the reason could be due to the significant effect on the material which led to losses its adhesion properties. On the other case the hardness of coconut shell powder decreases when the grain size reduces but on the rice husk if the grain size reduces the hardness increases.

Case -4 (Vinyl Ester with Linen fiber)

The vinyl ester with linen fiber has shown a better mechanical properties when compared to all the above cases. The tensile strength of vinyl ester with linen fiber is 26.37 and hardness of 793.65 BHN. The vinyl ester with linen fiber can be tailored to the meet the requirements of furniture industry and other low load application like partition boards.

Case -5 (Pure Vinyl Ester) The pure Vinyl Ester has attained a Tensile strength of 19.62 MPa, with the harness of 435 BHN. The results is better than the case 2, but the 25 % of the strength only increases by the pure vinyl ester when compared to Natural fiber with Vinyl Ester.

Conclusion

In Research work the experimental investigation of mechanical property of Natural fiber reinforced composites with moringa and vinyl ester are carried and experimented.

1. The materials is extracted from the environment and it is milled by using the planetary milling. Firstly, the fibers and the filler are milled individually and secondly homogenously and the particle size and the density of the fiber and the filler are determined such as for coconut shell powder with 1.11g/cm^3, Rice husk powder with 1.17 g/ cm^3, Sugarcane baggase ash with 1.00 g/ cm^3 and Fungi with 1.60 g/ cm^3. When the compositions are made between the fiber and the filler the density and the particle size has variation such as the compositions 1(20grams) has shown higher tensile strength of 14.62 MPa with the density of 1.25 g/cm^3. Compositions 2(25grams) has shown a tensile strength of 12 MPa with a density of 1.18 g/cm^3 which is higher than the compsoitions-3 (30grams) with the density of about 1.20 g/cm^3.

2. Initially, the manufacturing of the specimens is carried to identify the perfect manufacturing process for this powder based natural plant fiber. The different types of manufacturing has been attempted for the manufacturing of specimens at right one. The 1st manufacturing process has been carried out with high load and when it comes under the morphology of surface characteristics it has shown a poor surface morphology. The 2nd Manufacturing process is carried with a load of 5 kg with the compression the material again leads to the poor surface characteristics like removal of material on the upper layer. Then the 3rd manufacturing process has been attempted for the manufacturing of specimens, in this manufacturing process the material is poured into the mould and a low load is applied constantly off about 5 kg for the entire preparation of the specimen.

3. The Mechanical properties of composites material is carried out and it clearly reveals that the characterization of the composites such as fiber volume (v_f) and fiber length (f_l) shows significant effect such as increase in fiber Volume decrease the Tensile strength by such as composition 1 (20 grams -40%) of fiber and filler has tensile strength of 14.62 when we regularly increase the fiber and filler volume the strength decrease like 12 MPa for 25 grams and 10.7MPa for 30 grams. In experimental point of view the tensile strength increases when the fiber volume decreases. Such as for the composition 1 (20grams – 40% of fiber and filler shown tensile strength of 14.62 Mpa) which is higher the Composition 2 (25 grams – 40%) increase in the fiber and filler content leads to decrease in the Tensile strength of 12 MPa, further in the composition 3 (30 grams -40% of fiber and filler content leads to further decrease in the Tensile Strength 10.7 MPa. But on the other hand in theoretical point of view, if the fiber volume increases the tensile strength increases. The mechanical properties that is tensile strength of natural plant based fiber is greatly influenced on the fiber volume and fiber length. The combination of natural reinforcement and matrix as Vinyl ester which is 20% of Reinforcements has a tensile strength higher than the tensile strength of 25% and 30%.

The surface morphology and Hardness of 20% is higher than the 25% and composition 30%. Mechanical property has evaluated, however, benefits of the including of bio based materials must be considered, as reduction of carbon footprint, use of renewable materials, and reductions in cost. The advantage of using the natural plant based fiber material is giving birth to the bio-plants and in the industrial means the reduction of cost can be obtained by increasing the filler material and utilization of natural wastage can decrease the hazardous damage to the earth. As compared to all the fiber and the filler such as fine and coarse material, the linen fiber has shown a higher tensile strength and higher Hardness when compared to other fiber.

The long fiber such as linen fiber has shown higher tensile strength of 26.37 MPa which higher when compared to all other fiber and the lower tensile strength has been by Fine Rice Husk Powder of about 8.55 MPa. Where the tensile strength of the vinyl with linen fiber has 25% better than the pure vinyl ester of about 19.62 MPa. The hardness of the vinyl ester with linen also is higher than all the fibers of about 793 BHN. Where the young modulus of the vinyl ester with linen has lower than all the other fiber and the here the coconut shell powder has a higher young’s modulus of 626 Mpa.

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