Synthesis and Analysis of Natural and Synthetic Laminae Composite

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***Abstract*— Polymer composites typically have fiber or particle phase that is stiffer and stronger than continuous matrix phase and serve as the principle load carrying members. The matrix acts as load transfer medium between fibers and less ideal cases where the loads are complex, the matrix may even have to bear loads transverse to the fiber axis. In this research the comparison of different synthesis and analysis of kenaf fiber treated with NAOH solution and the fibers reinforced with polypropylene resin and carbon fiber reinforced with epoxy resin respectively in a matrix form to prepare composite laminates to determine mechanical properties like tensile strength, compressive strength, impact strength and flexural strength with specimens by ASTM E-08, D- 638 standards. The analysis done in the Ansys 10.0 for various load and result factors. The composite nano structure is observed by using SEM (sesimic electron microscope) with 100x, 200x, 500x, 1000x, 2000x, 3000x, 4000x, 5000x. When designed and manufactured properly the new combined material exhibits better strength than each individual material. Composites are used not only for their structural properties but also for electrical, thermal, and Eco-friendly environmental applications.**

***IndexTerms*— Kenaf, Thespesialampus, Abelmoschusesculentus, ANSYS**

I. INTRODUCTION

The present day quality of human life can be attributed to the advances taking place in materials and technologies in various fields.It are a fact that any technological development has its impact on the biodiversity. Land, water and air are being polluted without concerned for the flora and faura resulting in extension of various living species.Global warming and green house effect are due to man`s undue exploration of the gifts of nature for his comfort and conveniences. To help our future generations in sustaining the hardships of life,it is our responsibility to contribute for preserving the nature as a safe abode for human existence.

It can be by adopting policies for development and application of materials and technologies that cause least damage to the environment. The earlier concept of producing things that are rare, exotic and for trade gains has altogether changed towards preserving or enhancing the environment and life processes. such concepts are now termed as to sustainable, eco-friendly or green technologies. Environmental considerations are of prime importance in the development of any technologies or products. sustainability is the keyword progress.

The entire human activity is entwined with the use of materials. For millennia, humans have endeavoured to use readily available materials like stone, clay, mud, wood, bone, hide and other vegetables produced for the construction of their homes, tools and implements and means of transport. As centuries rolled, man discoved the secrets of nature and learned exploit he started building synthetic materials. There has been a gradual decline of the direct application of natural resources. Further we have reached to view that use of traditional materials inferior to synthetic materials.

Fibre reinforced composite; a new class of synthetic materials have attracted the aero scope and transportation industry due to their weight savings and many other superior properties over conventional metallic materials.

Today they find wide applications in containers, sports goods, electronics and appliances as well as in medical fields these composers are synthesized from different kinds of fibres, such as: glass, aramid, graphite, carbon, boron, ect., and matrix material such as polyester and epoxy resins. Recycling and disposal of these materials as driven the scientists and engineers for reviving the use of natural materials and development of composites called green composites that can be disposed easily without posing problems to the environment.

The natural fibre composites are CO2 neutral and consume low energy for production. They give less problem concerning health and safety of workers. They are less abrasive, more pleasant to handle, give neutral image. They have good specific properties, good mechanical, thermal and acoustic properties. Most sustainable plastics cannot complete economical with conventional structural composites such as glass fibre reinforced plastics. Economically favourable composites are expected to be made from a expensive fibres and biodegradable matrices.

During the past decade, number of industries such as the automotives, construction and packaging, have turned towards utilisation of new bio composites materials as an alternative to synthetic fibre composites these composites have been developed using various natural fibres like sisal, jute, Kenaf, Palmyra, etc., and polyester and epoxy resins.

The objective of the present proposed work is to develop biodegradable compositelaminas. The aim of this Project is to project the potential of natural fibre compositelaminas and to explore the possibility of producing them on commercial basis.In this present work Fibre extracted from plant of Hibiscus Cannabinus.It is aimed to encourage more plantations that yield fibres which will provideemployment in the agriculture and handloom sectors for extracting fibres and preparingmats and further to promote cottage industries in the rural areas for producing naturalfibre products for domestic applications.

The present day quality of human life can be attributed to the advances taking place in materials and technologies in various fields.It are a fact that any technological development has its impact on the biodiversity. The aim of present work is to prepare the laminas using the Hibiscus Cannabinus, lampas short fibres composites using general purpose unsaturated polypropylene resin and by compression moulding process. In this research the comparison of different synthesis and analysis of kenaffiber treated with NAOH solution and the fibers reinforced with polypropylene resin and carbon fiber reinforced with epoxy resin respectively in a matrix form to prepare composite laminates to determine mechanical properties like tensile strength, compressive strength, impact strength and flexural strength with specimens by ASTM E-08 standards. The analysis done in the Ansys for various load and result factors. The composite nano structure is observed by using SEM (sesimic electron microscope) with 100x, 200x, 500x, 1000x, 2000x, 3000x, 4000x, 5000x.

2. COMPOSITES INTRODUCTION

The use of the natural plant fibre as a reinforcement in fibre reinforced plastics (FRP) to replace synthetic fibre such as glass is receiving attention because of advantages such as renewability, low density and high specific strength natural fibres have already established track record has simple filler material in automobile parts. Natural fibres like sisal, jute, coir, oil and palm, Hibiscus Cannabinus, AbelmoschusEsculentusetc.have all been proved to be good reinforcement in thermo set and thermo plastic matrices.

India endowed with an abundant availability of natural fibre such as jute, coir, sisal, pineapple, Ramie, Bamboo, Banana etc., has focussed on the development of natural fibre composites primarily to explore value-added applications avenues. Such natural fibres as well suited as wood substitutes in the housing and construction sector. The development of natural fibre composites in India based on two pronged strategy of preventing depletion of forest resources as well as ensuring good economic returns for the cultivation of natural fibres.

The development in composite material ofter meeting the challenges of aerospace sector has cascaded down for catering to domestic and industrial applications. Composites, the wonder material with light weight: high strength to weight ratio stiffness properties have come a long way in replacing the conventional materials like metals wood etc. The material scientists all over the world focussed their attention on natural composites reinforced with jute, sisal, coir, pineapple etc. Primarily to cut down the cost of raw materials.

Composite:

A composite is combination of two materials in which one of the materials, called the reinforcing phase, is in the form of fibers, sheets, or particles, and is embedded in the other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Composites typically have a fiber or particle phase that is stiffer and stronger than the continuous matrix phase and serve as the principal load carrying members. The matrix acts as a load transfer medium between fibers, and in less ideal cases where the loads are complex, the matrix may even have to bear loads transverse to the fiber axis. The matrix is more ductile than the fibers and thus acts as a source of composite toughness.

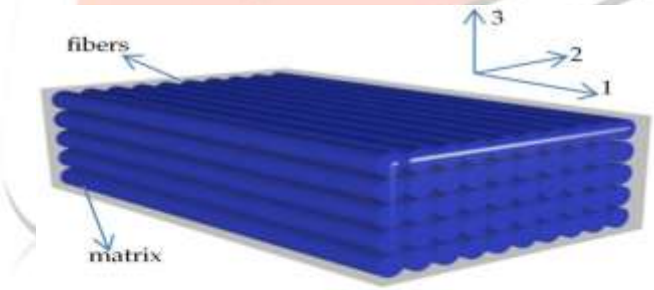

Fig: 1. Composite

Classification of Composites:

a) Metal Matrix Composites:

Higher strength, fracture toughness and stiffness are offered by metal matrices. Metal matrix can withstand elevated temperature in corrosive environment than polymer composites. titanium, aluminium and magnesium are the popular matrix metals currently in vogue, which are particularly useful for aircraft applications. Because of these attributes metal matrix composites are under consideration for wide range of applications viz. combustion chamber nozzle (in rocket, space shuttle), housings, tubing, cables, heat exchangers, structural members etc.

Fig: 2. Ti-alloy metal matrix composite, reinforced with a number of diamond-coated Textron (SiC) fibres.

b) Ceramic matrix Composites:

One of the main objectives in producing ceramic matrix composites is to increase the toughness. Naturally it is hoped and indeed often found that there is a concomitant improvement in strength and stiffness of ceramic matrix composites.

Fig: 3. Ceramic matrix composite material

c) Polymer Matrix Composites:

Most commonly used matrix materials are polymeric. In general the mechanical properties of polymers are inadequate for many structural purposes. In particular their strength and stiffness are low compared to metals and ceramics. These difficulties are overcome by reinforcing other materials with polymers. Secondly the processing of polymer matrix composites need not involve high pressure and doesn't require high temperature. Also equipments required for manufacturing polymer matrix composites are simpler. For this reason polymer matrix composites developed rapidly and soon became popular for structural applications.

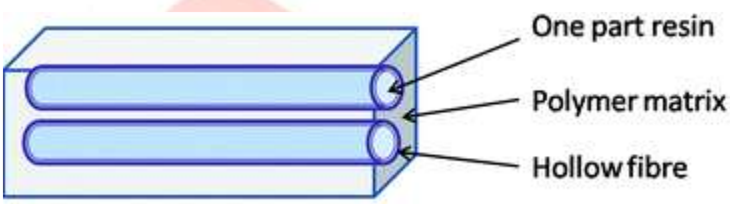

Fig: 4. polymer matrix composite materials

3. PREPARATION OF LAMINA

Preparation of lamina:

The fibres (Kenaf, Thespesialampus, Abelmoschusesculentus) were extracted from its bast by a conventional process called water retting process. Fibres were treated with 5% solution of NaOH. The fibres were submerged in the sodium hydroxide solution for 1 day at room temperature, rinsed with tap water and then neutralized in distilled water and dried at room temperature for 24 hours. These fibres are chopped to long lengths of the order 6cm, 8cm, 10cm.

Compression Moulding Technique:

Compression moulding is a well-known technique to develop variety of composite products. It is a closed moulding process with high pressure application. In this method the matched metal moulder used to fabricate composite product. In compression moulder the base plate is stationary while upper plate is movable. Reinforcement and matrix are placed in the metallic mold and the whole assembly is kept in between the compression moulder.

Fig: 5. Mould and bottom surface plate

Fig: 6. top surface plate

One of several molding forms; compression molding is the act of using compression (force) and heat to shape a raw material by means of a mold. In short, a raw material is heated until pliable, while the mold is closed for a certain time period. Upon removing the mold, the object may contain flash, excess product not conformed to the mold, which can be cut away.

Compression Molding Basics:

The following factors must be considered when using a compression molding method:

- Material
- Shape

- Pressure
- Temperature
- Part thickness
- Cycle Time

Plastics composed of both synthetic and natural materials are used in compression molding. Two types of raw plastics materials are most often used for compression molding:

- Thermo set plastics
- Thermoplastics

Thermoset plastics and thermoplastics are unique to the compression method of molding. Thermoset plastics refer to pliable plastics that once heated and set to a shape may not be changed, while thermoplastics harden as a result of being heated to liquid state and then cooled. Thermoplastics can be reheated and cooled as much as necessary.

The amount of heat required and necessary instruments to produce the desired product vary. Some plastics require temperature in excess of 700 degrees F, while others in the low 200 degree range.Time is also a factor. Material type, pressure, and part thickness are all factors which will determine how much time the part will need to be in the mold. For thermoplastics, the part and the mold will need to be cooled to an extent, so that piece being manufactured is rigid. The force with which the object is compressed will depend on what the object can withstand, particularly in its heated state. For fiber reinforced composite parts being compression molded, the higher the pressure (force), often the better the consolidation of the laminate, and ultimately the stronger the part.

The mold used depends on the material and other objects used in the mold. The three most common types of molds used in compression molding of pastics are:

- Flash - requires accurate product inserted in the mold, removal of flash
- Straight-does not require accurate product, removal of flash
- Landed-requires accurate product, does not require removal of flash

It is important to ensure that no matter what material is used, the material covers all areas and crevices in the mold to ensure the most even distribution.

The process of compression molding begins with the material being placed into the mold. The product is heated until somewhat soft and pliable. A hydraulic tool presses the material against the mold. Once the material is set-hardened and has taken shape of the mold, an “ejector” releases the new shape. While some final products will require additional work, such as cutting away the flash, others will be ready immediately upon leaving the mold.

What is commonly made with compression molds?

Car parts and household appliances as well as clothing fasteners such as buckles and buttons are created with the help of compression molds. In FRP composites, body and vehicle armor is manufactured by means of compression molding.

Fig: 7. Actual compression moulding machine

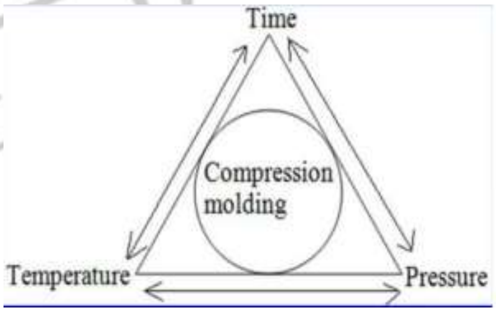

Fig: 8. Parameters used in compression moulding

4. TESTING

TESTING STANDARDS:

All the mechanical testing methods that were carried out were based on American standard testing methods (ASTM).

PREPARATION OF SPECIMENS:

FFLEXUAL TEST SPECIMEN:

Specimens for the flexural test are cut on a jig saw machine as per the ASTM standards. The dimensional details of each type of specimen are presented in respective diagrams. Specimens are cut from laminas on a jig saw machine as per ASTM D790 standards. Rhe standard regulated shaped specimens are used for testing. The dimensions of the flexural test specimen are shown in the FIG. And the actual specimens are shown in the FIG.

Fig:9. Dimensions of a flexural test specimen

FLEXURAL TEST SPECIMENS:

Fig: 10. Flexural test specimens

TENSILE TEST SPECIMEN:

Specimens for the tensile test are cut on a jig saw machine as per the ASTM standards the dimensional details of each type of specimen are presented in respective diagrams. Specimens are cut from laminas on a jig saw machine as per ASTM D638 standards. The standards type 4 dumbbell shaped specimens are used for testing. The dimensions of the tensile test specimen are shown in the FIG. And the actual specimens are shown in the FIG.

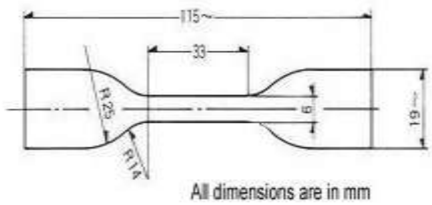

Fig: 11. Dimensions of tensile test specimen

Fig: 12. Kenaffiber tensile test specimen

Fig:13. Typical tensile carbon fiber composite test specimen (before & after testing)

5. TESTING METHODS:

Flexural Test:

Flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. Sometime it is referred as cross breaking strength where maximum stress developed when a bar-shaped test piece, acting as a simple beam, is subjected to a bending force perpendicular to the bar. There are two methods that covered the determination of flexural properties of material: three-point loading system and four point loading system. As described in ASTM D790,three-point loading system applied on a supported beam was utilized. Flexural test is important for designer as well as manufacturer in the form of a beam. If the service failure is significant in bending, flexural test is more relevant for design and specification purpose than tensile test.

The specimen dimensions were 127mm (L) x 12.7 mm (W) and 3.2 mm thickness. The specimens were tested at a crosshead speed of 5 mm/min. The bending stress is calculated from the measured load, as follows:

$\sigma_{max} = 3PL/2bd^2$

Where,

σ_{max} = Flexural strength,

P=load at yield (max. load),

L=support span (mm),

B=width (mm),

D=thickness (mm).

Flexural Modulus:

Flexural modulus or Modulus of elasticity is a measure of the stiffness during the initial of the bending process. This tangent modulus is the ratio within the elastic limit of stress to corresponding strain. A tangent line will be drawn to the steepest initial straight line portion of the load deflection curve and the value can be calculated using equation.

$E_B = L^3P/4d^3bx$

$E_B =$ Flexural modulus (N/mm^2),

L= Length of the flexural specimen (mm),

P= Load at a given point on the load deflection curve (N),

d = Thickness (mm),

b= Width (mm)

x= Deflection (mm)

Tensile test:

Tensile testing also known as tension testing is a fundamental materials science test in which a sample is subjected to controlled tension until failure. Tension test is widely used to provide basic design information on the strength of materials and is an acceptance test for the specification of materials. The major parameters that describe the stress-strain curve obtained during the tension test are the tensile strength (UTS), Yield strength or yield point (σ_y), Elastic modulus(E), Percent elongation and reduction in area. Toughness, Resilience, Poissions ratio can also be found by the use of this testing technique.

Fig: 14. Tensile testing Machine

The experiments were conducted on tensile testing machine under axial loading. Avarages of three measurements were taken of each lamina specimens.The lamina was carefully positioned at the centre of the cross head with its end faces exactly perpendicular to the longitudinal axis to get accurate results.The experiments were conducted at a constant cross head seed 1.5mm/min. The stress vs strain plots were obtained for each lamina specimen from the automatic computerized chart recorder. Tensile failure strength were recorded from machine for all lamina along the length of composite. Using recorded data, Graphs, were prepared for variation of tensile failure stress and young's modulus.

6. RESULTS AND DISCUSSION

Flexural testing:

Table 6.1: Flexural test observations for kenaffibre composite

Deflection(mm)	Load(N)		
	Specimen1	Specimen2	Specimen3
0.5	9	8	9
1	16	16.5	17
1.5	24	24.5	24
2	30	30	30
2.5	34	34.5	34.5
3	38	39	39.5
3.5	41	41	41.5
4	43	43.5	43.5
4.5	44	44	44
5	45	45.5	44
5.5	45	-	-

Table 6.2: Mean values of flexural test observations for kenaffibre composite

Deflection(mm)	Mean load (1 Div=3.75N)	Flexural stress(N/mm^2)
0.5	8.6	18.53
1	16.5	35.55
1.5	24.1	51.93

2	30	64.65
2.5	34.3	73.91
3	38.8	83.61
3.5	41.1	88.57
4	43.3	93.31
4.5	44	94.82
5	44.8	96.54
5.5	45	96.97

Table 6.3: Flexural test observations for carbon fiber composite

Deflection(mm)	**Load(N)**		
	Specimen1	**Specimen2**	**Specimen3**
0.5	10	10	9
1	16	16	17
1.5	23	22	24
2	28	29.5	28
2.5	32	32.5	32
3	36	36	36
3.5	39	39.5	39
4	41	41.5	41
4.5	42	42.5	42
5	44	44	46
5.5	46	45	-

Table 6.4: Mean values of flexural test observations for carbon fiber composite

Deflection(mm)	**Mean load (1 Div=3.75N)**	**Flexural stress(N/mm^2)**
0.5	9.6	20.68
1	16.3	35.12
1.5	23	49.56
2	28.5	64.42
2.5	32.1	69.17
3	36	72.58
3.5	39	84.04
4	41.1	88.57
4.5	42.1	90.72
5	44.6	96.117
5.5	45.5	98.05

Table 6.5. Mean values of flexural test observations for Kenaf and carbon composites

Fibre	**Flexural Strength (MPa)**	**Specific flexural strength (MPa/g/cm^3)**	**Flexural modulus (MPa)**	**Specific Flexural modulus (MPa)**
Kenaf	96.97	80.47	2311.69	1918.57
Carbon	98.05	81.30	2337.37	1938.12

Tensile Testing Results

Table 6.6 Tensile Properties of different types of fibre composites

Fibre	**Ultimate Tensile Strength (MPa)**	**Specific Tensile Strength (MPa/g/cm^3)**	**Tensile Modulus (Mpa)**	**Specific Tensile Modulus (MPa/g/cm^3)**	**% of Elongation**
Kenaf	29.73	24.65	823.96	683.217	3.60
Carbon	34.5	28.465	901.068	743.455	3.82

Compressive strength

Table 6.7 Compressive test result Impact strength

Fiber	**Compressive strength(MPa)**	**Impact strength J**
Kenaf	140	457

Carbon	161	510

ANSYS analysis

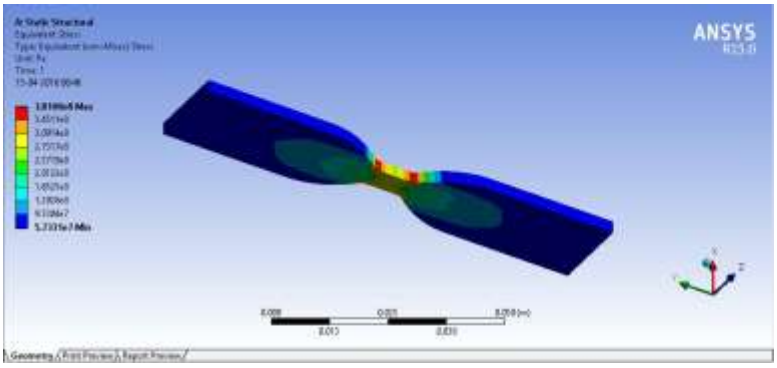

Fig:15. Equivalent stress of the composite specimen

From the analysis it is observed that stress variation in the material shown by the different colours in the above image

The maximum stress is at red colour that is

σ_{max} =3.8108*10^8 Pa

σ_{max} =381.08 MPa (1Pa=1N/m^2)

The minimum stress is at the green colour section that is

σ_{min}=5.7331*10^7Pa

σ_{min}=57.331 MPa (1Pa=1N/m^2)

The actual value obtained by the calculations is less then the ANALYSIS value so the material Properties are accurate and accepted.

Note: all the dimensions of the designed specimen is equal to the actual tensile specimen.

SEM-ANALYSIS

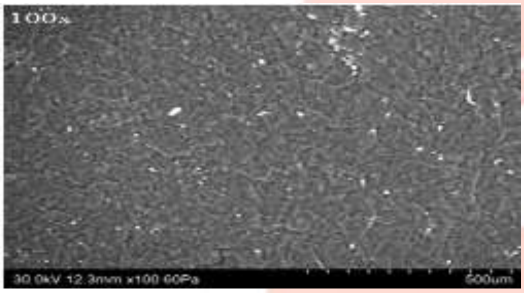

Fig: 5.4.1 100x Image

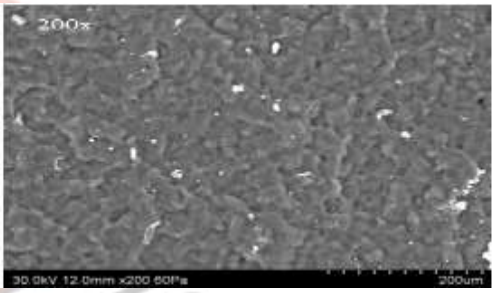

Fig: 5.4.2 200x Image

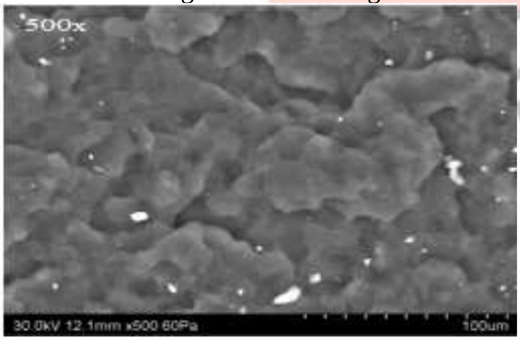

Fig: 5.4.3 500x Image

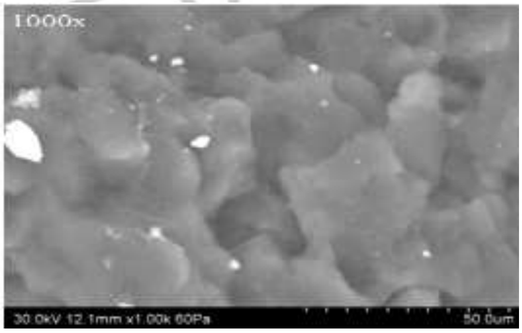

Fig: 5.4.4 1000x Image

Results

- In terms of flexural strength the slight comparison observed that kenaffiber got 96.97 MPa and carbon have 98.05MPa.
- Comparing the tensile strength kenaffiber got 29.67MPa and Carbon fiber have 34.6 MPa.
- In terms of compressive strength kenaf got 140Mpa and carbon fiber 161MPa.
- In terms of impact strength 356J for kenaf and 510J for Carbon fiber.

Model Calculations

TENSILE CALCULATIONS

Kenaffiber lamina specimen:

1. Ultimate Tensile Load=1548.6 N
2. Ultimate tensile stress(UTS) =Ultimate tensile load/initial cross sectional are(P/A)

   UTS=1548.6/60

   UTS=25.81 MPa
3. Specific Tensile Strength=UTS/Specific gravity

STS=25.81/1.2049

STS=21.42 MPa/g/cm^3

4. Tensile Modulus=UTS/Strain at UTL ;Strain=1.1319/33 (Change in length/Original length)

Srain=0.0323

Tensile Modulus=25.81/0.0323

Tensile Modulus=796.63MPa

5. Specific Tensile Modulus=(Tensile Modulus/Specific Gravity)

Specific Tensile Modulus=796.63/1.2049

Specific Tensile Modulus=663.85 MPa/g/cm^3

FLEXURAL TESTINGS

Flexural strength(σ max)=3PL/2bd^2

Mean load=(L_1+L_2+L_3/3)

σmax=Flexural Strength

P=41.1*LC(Load at yield) (LC= 3.75N/mm^2)

L=48mm (Support Span)

B=15mm (Width)

d=2.89mm (Thickness)

σmax=(3*41.1*3.75*48)/(2*15(2.89)^2)

σmax=88.57 N/mm^2

Flexural Modulus

E_B=L^{3}P/4d^{3}bx

E_B= (48)^3*41.1*3.75/(4(2.89)^3*15*5)

E_B=2322.47 MPa

7. CONCLUSIONS AND SCOPE FOR FUTURE WORK

The conclusions drawn from the present investigation are as the kenaf fibres were successfully used to fabricate composites with 30% fibre and 70% resin these fibres are bio degradable and highly crystalline with well aligned structure. So it has been known that they also have higher tensile strength than other natural and synthetic composites and intern it would not induce any serious environmental problem like in synthetic fibre like carbon fiber composites even though they exhibit better mechanical properties.These composite may find applications as structural materials where higher strength and cost considerations are important. In the present investigation a compression moulding technique was used to fabricate the composites. However there exists other manufacturing process for polymer matrix composite.However the results provided in this project can act as a base for the utilisation of these fibres.

The entire activity is aimed to develop new materials for enhanced performanceand for sustainability of the environment for the generations to come.The plants are abundantly found in the forest areas of A.P.These plants yield strong fibres that are traditionally used by the farmers in domestic andagricultural applications. Observing these features, fibre have been chosen to producegreen composite products that can be used for several applications such as panels inconstruction, casings for various domestic products, packaging applications, sport goods.

REFERENCES

[1]. K. V. Arun, S. Basavarajappa, B.S. Sherigara, Damage characterization of glass textile fabric polymer hybrid composites in sea water environment. *Materials and Design* 31(**2010**), pp 930 – 939.

[2]. Yi Zou, Shah Huda, Yiqi Yang, Lightweight composites from long wheat straw and polypropylene web. Bioresource Technology 101(**2010**), pp 2026–2033.

[3]. SupraneeSangthong, ThirawudhPongprayoon, NantayaYanumet, Mechanical property improvement of unsaturated polyester composite reinforced with admicellar-treated sisal fibers. Composites: Part A 40 (**2009**), pp 687–694.

[4]. P. Threepopnatkul, N. Kaerkitcha, N. Athipongarporn, Effect of surface treatment on performance of pineapple leaf fiber–polycarbonate composites. *Composites: Part B* 40 **(2009**), pp 628–632.

[5]. Y-Xu, S.Kawata, K.kawai and S.KurodaThermo mechanical properties of the silanized-kenaf/polystyrene composites eXPRESS Polymer Letters Vol.**3**, No.10 **(2009)** 657–664

[6]. Byoung-Ho Lee, Hyun-Joong Kim, and Woong-Ryeol Yu Fabrication of Long and Discontinuous Natural Fiber Reinforced Polypropylene Biocomposites and Their Mechanical Properties Fibers and Polymers **(2009)**, Vol.**10**, No.1, 83-90

[7]. Mehdi Jonoobi.;JalaludinHarun.;AlirezaShakeri.;,ManjusriMisra and KristiinaOksman.; Chemical, Crystallinity, and Thermal degradation of Bleached and Unbleached Hibiscus cannabinus pulp and Nanofibers, *BioResources*, (**2009),** vol4(2), pp 626-639.

[8]. Singha A.S.; and Vijay Kumar Thakur; GrewiaoptivaFiber Reinforced Novel, Low Cost Polymer Composites, (**2009),** vol 6(1), pp 71-76.

[9]. Morsyleide F. Rosa.; Bor-senChiou.; Eliton S. Medeiros.; Delilah F. Wood.; Tina G. Williams.; Luiz H.C. Mattoso.; William J. Orts.; and Syed H. Imam.; Effect of fiber treatments on tensile and thermal properties of starch/ethylene vinyl alcohol copolymers/coir biocomposites, *Bioresource Technology*, (**2009) ,** pp5196–5202 .

[10]. R. Mat Taib1*, S. Ramarad1, Z. A. Mohd Ishak1, M. Todo2 , Water absorption and tensile properties of kenafbastfiber-plasticized poly(lactic acid) biocomposites , *Proceedings of the Polymer Processing Society 24th Annual Meeting ~ PPS-24 ~ June 15-19, **(2008)** Salerno (Italy).*