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Evaluation of Properties of Hybrid Natural Short Fiber Reinforced Composites

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Abstract – Hybrid composites have taken the attention of many researchers as a way to enhance mechanical properties of composites. However, hybrid composites using natural fibers are less studied. And in such studies, the hybrid composite often consists of natural fibers are embedded in the resin matrix. The aim of present work is to prepare the laminas using the Hibiscus Cannabinus, Thespesia lampas short fiber polyester composites fiber using general purpose unsaturated Isopthalic resin by hand lay-up process. The fibers without chemical treatment and with chemical treatment with sodium hydroxide (NaOH) are considered in the work. The composites are prepared using NaOH treated & untreated short fibers with polyester matrix at room temperature between two thick glass plates. The prepared composites are tested as per ASTM standards for flexural test and SEM analysis have been done to study the morphology of the hybrid composite.

Index Terms – Hibiscus Cannabinus, Thespesia Lampas, Isopthalic resin.

1. INTRODUCTION

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. 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. The matrix also serves to protect the fibers from environmental damage before, during and after composite processing. When designed properly, the new combined material exhibits better strength than would each individual material. Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications.

Hybrid composites are more advanced composites as compared to conventional FRP composites. Hybrids can have more than one reinforcing phase and a single matrix phase or single reinforcing phase with multiple matrix phases or multiple reinforcing and multiple matrix phases. They have better flexibility as compared to other fiber reinforced composites. Normally it contains a high modulus fiber with low modulus fiber. The high-modulus fiber provides the stiffness and load bearing qualities, whereas the low-modulus fiber makes the composite more damage tolerant and keeps the material cost low. The mechanical properties of a hybrid composite can be varied by changing volume ratio and stacking sequence of different plies.

The interest in natural fiber-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, etc., as well as wood, used from time immemorial as a source of lignocellulosic fibers, are more and more often applied as the reinforcement of composites.

Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites. The natural fiber Containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling paneling, partition boards), packaging, consumer products, etc.

2. LITERATURE REVIEW

K.V. Arun, S. Basavarajappa, B.S. Sherigara [1] carried out experimental analysis on glass/textile fabric reinforced hybrid composites under normal condition and sea water environments have been reported. The critical stress intensity factor, interlaminar shear strength and impact toughness have been evaluated, both in interlaminar and translaminar directions. The matrix material used was a medium viscosity epoxy resin and fibers are plain weave E-glass fabric and silk based textile fabric. Yi Zou, Shah Huda, Yiqi Yang [2] studied the tensile strength, flexural strength, impact strength and sound absorption properties of laminas made of Whole and split wheat straws (WS) have been used with polypropylene (PP). Supranee Sangthong, Thirawudh Pongprayoon, Nantaya Yanumet [3] studied the mechanical property improvement of unsaturated polyester composite reinforced with admicellar-treated sisal fibers. P. Tyhreepopnatkul, N. Kaerkitcha, N. Athipongarporn [4] studied the mechanical properties like tensile strength, impact strength, And thermogravimetric analysis (TGA). The modified fiber identified using a Fourier transform infrared spectroscopy (FTIR) of laminas made of pineapple leaf fiber (PALF) polycarbonate composites. Y-Xu, S.Kawata, K.Hosoi, K.kawai and S.Kuroda [5] studied the dynamic thermo –mechanical properties of the salinized-kenaf polystyrene composites. The polymeric coupling agent treatment of the kenaf fiber increased the fiber matrix interaction. The DMA results showed that the modified fiber composites have higher storage modulus and lower loss factor. Byoung-Ho Lee, Hyun-Joong Kim, and Woong-Ryeol Yu [6] studied about Fabrication of Long and Discontinuous Natural Fiber Reinforced Polypropylene Biocomposites and Their Mechanical Properties. Mehdi Jonoobi, Jalaludin Harun,Alireza Shakeri ,Manjusri Misra and Kristiina Oksman [7] studied the chemical, crystallinity and thermal degradation of bleached and unbleached Hibiscus cannabinus pulp and nanofibers. Thermal stability increased in the material having undergone chemo-mechanical treatments. A.S. Singha and Vijay Kumar Thakur [8] studied thermal and mechanical properties of Grewia optiva fiber reinforced Urea-Formaldehyde (UF) matrix based polymer composites. Mechanical properties such as: tensile strength, compressive strength and wear resistance of urea - formaldehyde resin increases to a significant extent when reinforced with Grewia optiva fiber. Morphological and Thermal studies of the matrix and fiber reinforced biocomposites have also been carried out. Thermogravimetric analysis (TGA) of materials such as raw Grewia optiva fiber, polymeric UF resin and biocomposites was investigated as a function of % weight loss with the increase in temperature. Morsyleide F. Rosa , Bor-sen Chiou , Eliton S. Medeiros, Delilah F. Wood, Tina G. Williams, Luiz H.C. Mattoso, William J. Orts, Syed H. Imam[9] studied the Coir fibers which received three treatments, namely washing with water, alkali treatment (mercerization) and bleaching. Treated fibers were incorporated in starch/ethylene vinyl alcohol copolymers (EVOH) blends. Mechanical and thermal properties of starch/EVOH/coir biocomposites were evaluated.Treatments produced surface modifications and improved the thermal stability of the fibers and consequently of the composites.

3. TREATMENT OF FIBER

The quality of a fiber reinforced composite depends considerably on the fiber-matrix interface because the interface acts as a binder and transfers stress between the treatments of fibers using chemical agent like sodium hydroxide (NaOH)**.** For treatment process water by volume is taken along with 2% of NaOH. The fibers are soaked in the water for 24 hours as shown in Figure 1, and then the fibers are washed thoroughly with distilled water to remove the final residues of alkali. Good bonding is expected due to improved wetting of fibers with the matrix. In order to develop composites with better mechanical properties and good environmental performance, it is necessary to impart fibers by chemical treatments. The extracted fibres treated, untreated and chopped fibres are shown in figure 2(a) and figure 2(b)

Figure 1 Treatment of Fiber in 2% NaOH solution

Figure 2(a) Treated and Untreated fibers

Figure 2(b) Chopped fiber

4. PREPARATION OF LAMINA

The composites are prepared by hand layup technique shown in the figure 3. The hand layup is the one of the Fabrication technique. First Wax polish is applied on the surfaces of the base plates and poly vinyl alcohol (PVA) is applied with a brush and allowed to dry for few minutes to form a thin layer. These two items will help in easy removal of the laminate from the base plates.

Figure 3 Hand Lay-Up Method

The fiber piles were cut to size from the Kenaf and thespesia lampas. The appropriate numbers of fiber plies were taken two for each. Then the fibers were weighed and accordingly the resin and hardeners were weighed. Isopathlic and hardener were mixed by using glass rod in a bowl. Care was taken to avoid formation of bubbles. Because the air bubbles were trapped in matrix may result failure in the material. The subsequent fabrication process consisted of first putting a releasing film on the mould surface. Next a polymer coating was applied on the sheets. Then fiber ply of one kind was put and proper rolling was done. Then resin was again applied, next to it fiber ply of another kind was put and rolled. Rolling was done using cylindrical mild steel rod. This procedure was repeated until eight alternating fibers have been laid. On the top of the last ply a polymer coating is done which serves to ensure a good surface finish. Finally a releasing sheet was put on the top; a light rolling was carried out. Then a 20 kgf weight was applied on the composite. It was left for 24 hrs to allow sufficient time for curing and subsequent hardening. The various additives used for the process are shown in the figure 4 and 5. Figure 6 shows composites after preparation.

Figure 4 Wax, Accelerator, MEKP

Figure 5 Isopthalic, Glass Plate, Surface Plate.

Figure 6 Hybrid composites

5. SPECIMEN PREPARATION AND TESTING

Flexural Test Specimen

Specimens for flexural test are cut from laminas as per ASTM D790 standards [10]. The standard dimensions for test specimen are shown in the Figure 7 and the actual specimens are shown in Figure 8.

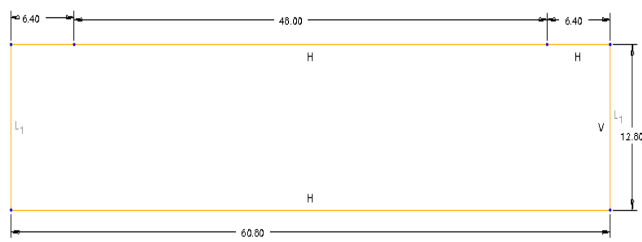

Figure 7 ASTM – D790 Flexural Test Specimen Details. [10]

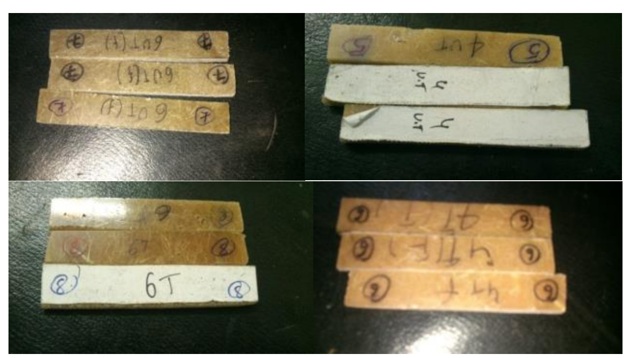

Figure 8 Flexural Test Specimens

Testing

a) 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. This stress decreased due to the flexural load is a combination of compressive and tensile stresses. There are two methods that cover 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.

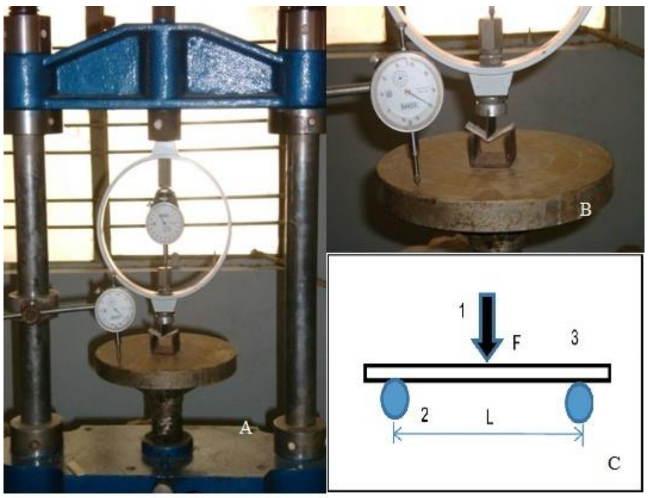

Figure 9 (a & b) Flexural Test Setup.

Flexural test was done by compression testing machine supplied by Hydraulic and Engineering Instruments, New Delhi, with a cross head speed of 1.25 mm/minute at standard laboratory atmosphere of 23°C ± 2°C (73.4°F ± 3.6°F) and 50 ± 5 percent relative humidity. There were two important parameters being determined in the flexural test, they are flexural strength and tangent modulus of elasticity in bending.

Figure 10: Flexural Test Specimens after Testing.

Flexural Strength

Flexural strength is the maximum stress in the outer specimen at the moment of break. When the homogeneous elastic material is tested with three-point system, the maximum stress occurs at the midpoint. This stress can be evaluated for any point on the load deflection curve using equation.

$$\sigma_f = \frac{3PL}{2bd^2} \text{-------------------------------} (1)$$

Where σ_f = Stress in the outer specimen at midpoint, MPa

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

L = Support span, mm

b = width of beam tested, mm

d = depth of beam tested, 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

$$E_B = \frac{mL^3}{4bd^3} \text{ ----------------- } (2)$$

Where E_B = modulus of elasticity in bending (MPa)

L = support span (mm)

m = slope of the tangent to the initial straight line portion of the load deflection curve of deflection (N/mm)

b = width of beam tested (mm)

d = depth of beam tested (mm)

b) Morphology

For morphological study, Scanning Electron Microscope (SEM) was used to reveal the nature of the bond between the fibers and matrix. It is an instrument for obtaining micro structural images using a scanning electron beam. In the SEM, a small electron beam spot (usually circa 1μm) is scanned repeatedly over the surface area of the sample. The importance of SEM is it produces image that likes a visual image of a large scale piece which allows the irregular surface of the material to be observed.

Figure 11 EVOMA15 Scanning Electron Microscope [11]

In this testing EVOMA15 Scanning Electron Microscope was used. The photo of this equipment is shown in Figure 11. The fractured specimens were placed on a stub, coated with platinum and inserted into the scanning barrel. The inter condition of the scanning barrel were vacuumed to prevent interference of scanning picture due to the presence of air. Magnification, focus, contrast and brightness of the result were adjusted to produce the best micrographs.

6. RESULTS AND DISCUSSIONS

Flexural Testing

Table 1 Flexure Test observations for *Hybrid fiber 4mm* T composite

Deflection (mm)	Specimen 1	specimen 2	specimen 3
0.5	13	10	13
1	22	16	23
1.5	31	24	32
2	40	30	40
2.5	45	35	45
3	50	45	47
3.5	52	43	55
4	-	45	58
4.5	-	49	61
5	-	50	62
5.5	-	-	62

Table 2 Mean values of flexure test observations for Hybrid *fiber 4mm* T composite.

Deflection (mm)	Mean Load	Stress in outer fiber (N/mm^2)
0.5	45.27	16.95
1	76.2	28.26
1.5	110.47	51.71
2	140.97	51.71
2.5	160.02	59.55
3	179.02	66.40
3.5	190.5	70.6
4	198.1	73.42
4.5	209.55	77.7
5	213.36	79.14
5.5	236.22	86.32

Table: 3 Flexure Test observations for hybrid *fiber 4mm U*T composite

Deflection (mm)	Specimen 1	Specimen 2	Specimen 3
0.5	11	8	9
1	20	14	20
1.5	27	20	28
2	36	22	37
2.5	40	29	40
3	43	38	43
3.5	45	39	44
4	50	40	50

Table 4 Mean values of flexure test observations for 4 hybrid *fiber 4mm U*T composite.

Deflection (mm)	Mean Load	Stress in outer fiber (N/mm^2)
0.5	40.27	14.25
1	68.13	26.34
1.5	105.68	36.80
2	138.19	44.31
2.5	151.76	48.28
3	168.03	56.41
3.5	182.61	62.43
4	187.37	66.32

Table 5 Flexure Test observations for *hybrid fiber 6mm* T composite

Deflection (mm)	Specimen 1	Specimen 2	Specimen 3
0.5	5	6	5
1	9	10	8
1.5	13	14	13
2	16	17	16
2.5	21	22	20
3	24	25	25
3.5	26	29	29
4	28	32	30
4.5	31	35	32
5	31	36	34
5.5	-		35

Table 6: Mean values of flexure test observations for hybrid *fiber 6mm* T composite.

Deflection (mm)	Mean Load	Stress in outer fiber (N/mm^2)
0.5	20.19	16.11
1	27.9	22.26
1.5	49.3	39.3
2	60.96	48.84

2.5	80.01	63.91
3	95.25	76
3.5	104.03	83.3
4	114.3	91.03
4.5	125.73	100.32
5	129.54	103.36
5.5	133.35	106.4

Table 7 Flexure Test observations for *hybrid fiber 6mm* UT composite

Deflection (mm)	specimen 1	specimen 2	specimen 3
0.5	5	8	6
1	8	14	9
1.5	11	20	15
2	14	25	20
2.5	16	21	24
3	18	33	30
3.5	19	36	35
4	21	39	39
4.5	23	40	42
5	24	42	44
5.5	25	45	45
6	26	46	45
6.5	26	46	45

Table 8: Mean values of flexure test observations for hybrid *fiber 6mm* UT lamina.

Deflection (mm)	Mean Load	Stress in outer fiber (N/mm^2)
0.5	24.003	10.78
1	28.1	17.1
1.5	58.29	26.16
2	76.2	34.2
2.5	76.2	34.27
3	102.87	46.17
3.5	114.3	51.3
4	128.73	56.43
4.5	133.35	59.85
5	140.97	63.27
5.5	144.76	64.97
6	148.59	66.69
6.5	148.89	66.69

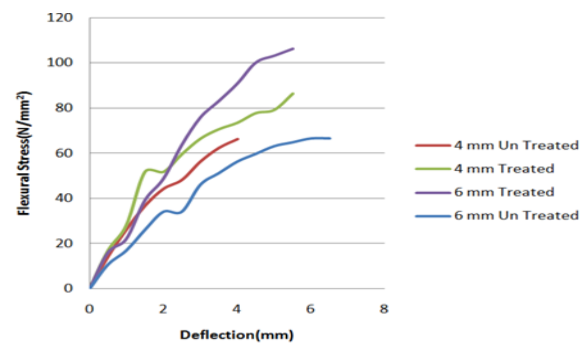

Figure 12 Flexural Stress – Deflection Curve.

The figure shows Curve between flexural stress (N/mm^2) and deflection (mm). Treated lamina have flexural strength is higher compare to untreated hybrid lamina.

Table 9: Flexural strength, Specific flexural strength, Flexural Modulus and specific Flexural Modulus for different composites

Treatment	Length	Flexural Strength (MPa)	Specific Flexural	Flexural Modulus (MPa)	Specific Flexural Modulus (MPa/ g/cm^3)
Untreated	4mm	66.82	59.7	186.4	163.5
	6mm	79.69	61.69	976.4	866.59
	8mm	85.7812	71.542	1938.2	1674.9
Alkali Treated	4mm	86.32	73.77	774.33	660.8
	6mm	106.4	81.84	1228.4	945.8
	8mm	124.84	96.41	2113.92	1865.12

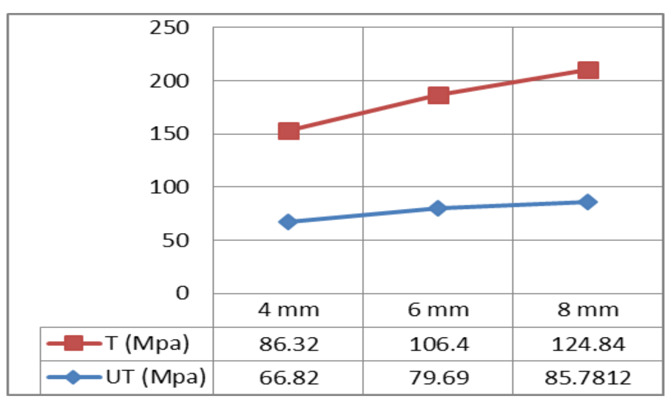

Figure 13 Flexural length of fiber

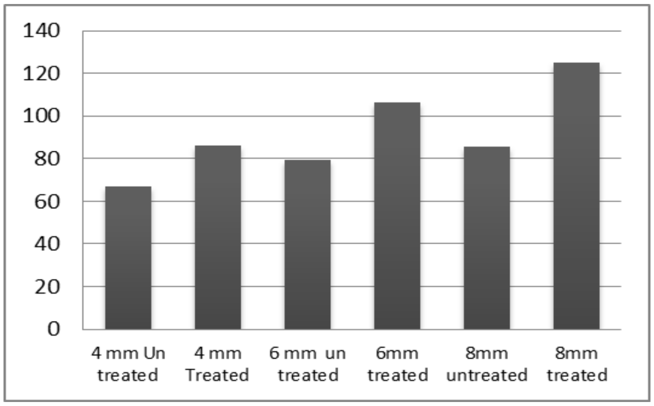

Figure 14 Flexural Strength for Different composites.

It is observed that 8mm fiber length composites were optimal flexural strength than 4mm and 6mm fiber length composites. Further it is observed that treated composites possess higher aforementioned properties than untreated. This is due to the alkali treatment improves the adhesive characteristics kenaf and thespesia fiber surface by removing hemicellulose and lignin. This surface offers the excellent fiber-matrix interface adhesion as a results improved mechanical properties.

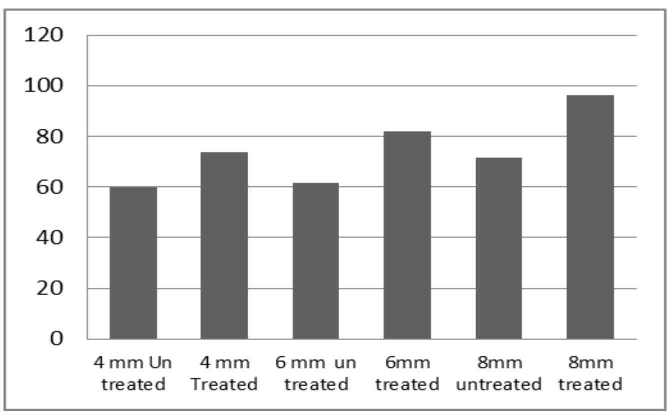

Figure 15: Specific Flexural Strength for Different composites.

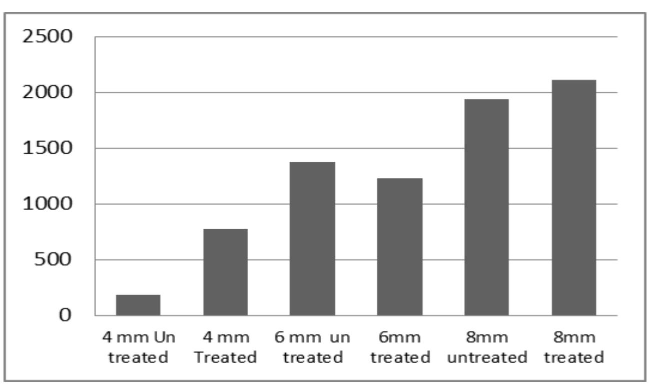

Figure 16: Flexural Modulus for Different composites.

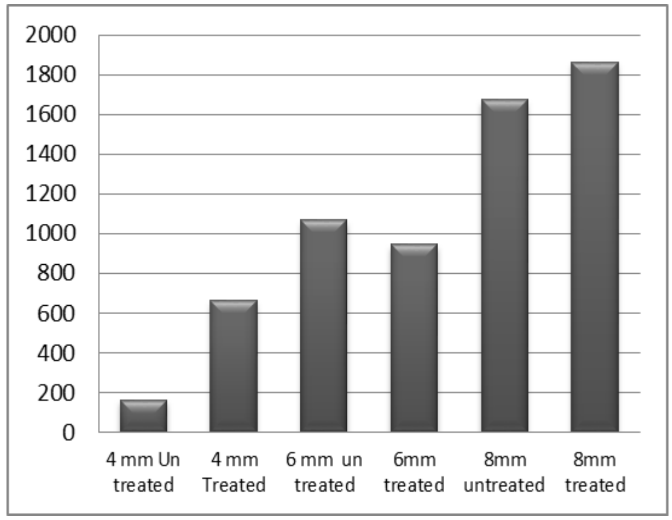

Figure 17: Specific Flexural Modulus for Different laminas.

Morphological Analysis

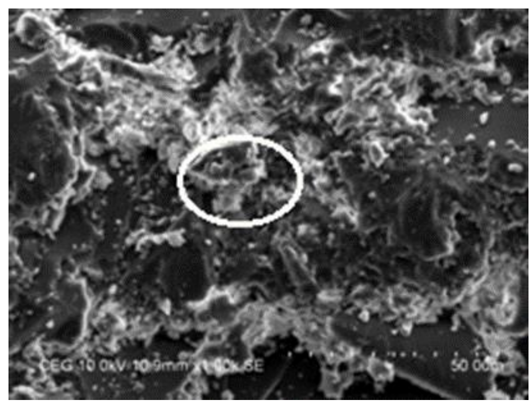

Figure 18 Micrograph of 4mm-UT Composite

Morphology of the composites is studied using EVOMA15 smart SEM micrographs. Figure 18 shows the untreated fractured surface of the composites. In case of untreated composite lamina, the fiber pullout can be observed in fractured surface due to poor bonding between fiber and resin.

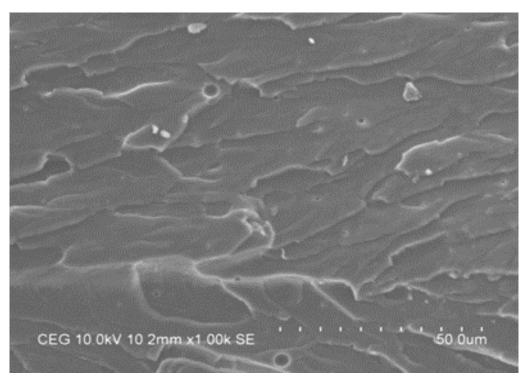

Figure 19: micrograph of 4mm-T Composite

Figure 19 shows the treated fractured surface of composite. For treated composite fiber surface treatment increased the bonding between fiber resin interfaces and the fracture of the fiber occurred instead of fiber pullout.

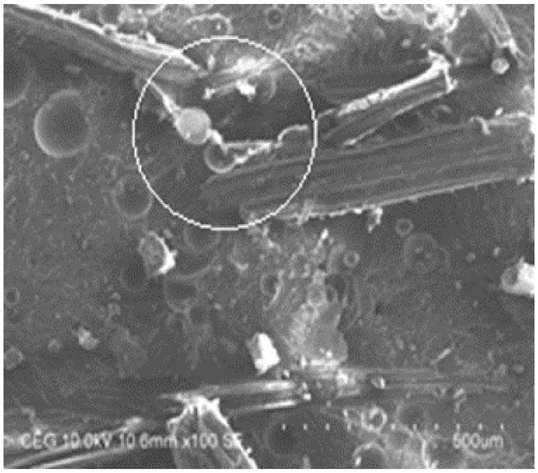

Figure 20 Micrograph of 6mm-UT composite

Figure 20 shows the untreated, fractured surface of composites. In this case the fiber pullout can be observed in fractured surface in figure 19 due to poor bonding between fiber and resin.

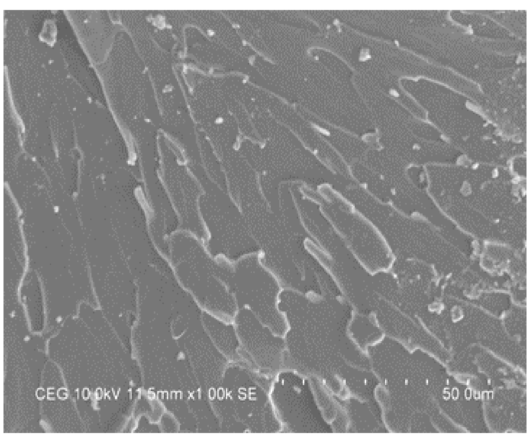

Figure 21: Micrograph of 6mm-T composite

Figure 21 shows the treated fractured surface of composites. For treated composite lamina the fiber surface treatment increased the bonding between fiber-resin interfaces and the fracture if fiber occurred instead of fiber pullout.

7. CONCLUSION

The kenaf and Thespisa lampas fibers was successfully used to fabricate hybrid natural composites with 30% fiber and 70 % resin, these fibers 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 in turn it would not induce any serious environmental problem like in synthetic fibers

The variation of mechanical properties like flexural test, and SEM analysis of Isopathalic based kenaf-Thespeisia lampas hybrid composites has been studied as function of fiber length. It is observed that 8mm fiber length hybrid composites are observed optimal flexural than 4mm and 6mm.

From SEM micrograph it is clearly visible that fiber is nicely embedded with matrix. These composites may find applications as structural materials where higher strength and cost considerations are important.

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