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An Investigation on Mechanical, Wear and Morphological Properties of Areca Leaf Fiber-CNT-Epoxy and Eupatorium Fiber-CNT-Epoxy Reinforced Hybrid Polymer Composites

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ABSTRACT

In recent years, due to environmental concern the use of renewable materials have been gaining importances in various fields. In this regard the proper utilization of natural fiber in composites material is one of the advanced technologies improved in engineering and industries. Therefore, we have adopted areca leaf and eupatorium fibers to incorporate in epoxy resin-CNT mixture. This method of fabrication implies the formation of hybrid polymer composites. In this work, areca leaf, eupatorium fiber and multiwall carbon nanotube were considered as reinforcement material and epoxy resin as matrix phase. The prepared composites were tested for tensile, flexural, compression, impact strength and wear rate. The surface morphology was analyzed through Scanning electron microscope and decomposition profile of material was characterized by thermo gravimetric analysis. The results revealed that, the incorporation of CNT as second reinforcement material enhanced the properties of the composites. This gives an insight that hybrid composites shows better properties than primary composites.

KEY WORDS: Natural fiber, MWCNT, Epoxy resin.

1. INTRODUCTION

In recent years, the proper utilization of natural fibers over synthetic fiber is gaining more importance in various fields (Layth Mohammed, 2015). This trend is may be due to some advantages of natural fiber over synthetic fiber such as low cost, bio degradability, wide spread over earth, light in weight, easy availability, cellulose content etc. (Saba, 2016). The composites of natural fibers have the advantages which may dominate over shortcomings of the composites of the synthetic fiber. There are many natural fibers are used to make composites, some are combined in two or more form and some natural fibers are incorporated with synthetic fibers to give hybrid composites (Paul Wambua, 2003).

Now a day's this type of fabrication of hybrid composites trending more superiority non hybrid composites (Atiqah, 2014). Some reports said, natural fibers such as flax, sisal, coir, hemp, jute, pineapple leaf, kenaf, banana, bamboo etc. have been utilized for the preparation and characterization of composites (Libo Yan, 2016; Ratna Prasad, 2011). The use of these natural fibers in composites accepting various applications like construction field, automobile, packaging and transport, medical, defense, food storage etc. (Jinchun Zhu, 2013; Pravin, 2015).

Hybrid composites are developed by the combination of more than two different types of fibers with matrix (Irina, 2015; Asim Shahzad, 2016). This is significant technique to maintain shortcomings of the fibers used (Begum, 2013). The mechanical property such as strength, stiffness, moisture absorption of composites depends on fiber strength, length, orientation of fibers, dispersion of fibers, interfacial bond length etc. (Chandramohan, 2013; Lippo Lassilaa, 2013).

In composite materials, use of well-defined matrix play an important role in enhancement of the materials. In such a case, the commonly used thermosetting resins like epoxy acquire higher performing applications (Bongarde, 2014). An epoxy resin indicates low fracture toughness, low impact strength which can overcome by hybridization technique (Naheed Saba, 2015). In this work, the composite undergo hybridization by incorporating natural fibers with multiwalled carbon nanotube and epoxy resin. The excellent usage of carbon nanotube (CNT) showed considerable attention and high strength and modulus to the material (Kenan Song, 2013; Shivakumar Gouda, 2013).

The dispersion of CNT in resin is more challenging. If it is dispersed properly their properties such as length to weight ratio improves the property of material significantly (Ayesha, 2016). There are many methods adopted to disperse CNT in resin, among those the ultra-sonication technique is the common method widely used (Byung Gil Min, 2009).

In this work, two different types of composites were fabricated, one is combination of Areca leaf-CNT-Epoxy composites (ACE) and another type is Eupatorium-CNT-Epoxy composites (ECE). Here the areca leaf fiber and the eupatorium fiber are considered as first reinforcement material in the different composites. Multiwall carbon nanotube is taken as second reinforcement material and also common in both the composites. These two reinforcements are mixed with epoxy resin results in the formation of hybrid composites. The composites were prepared by hand layup technique and so that fibers are oriented randomly (Gupta, 2016).

Jayachandran (2016), studied the mechanical properties of hair and coir fiber epoxy resin. It is noticed that when content of hair and coir increased tensile strength is increased but flexural strength is decreased. It was also showed that individual hair composites gives higher flexural strength and combination of coir and hair makes hybrid composites has higher tensile strength. Anoop (2015), showed the improvement in compressive strength by the addition of carbon fiber and nanoclay to the epoxy resin by 27.3 MPa when compared with individual glass fiber and epoxy resin. Hardik studied the modification of woven glass fiber by introducing CNT. It was observed that limited increase in modulus of the woven glass fiber. Srinivasa Rao (2016), conducted experiments on sisal/hemp fibers and concluded that more tensile and flexural properties than sisal/coir and sisal/flax hybrid composites. This can be exhibited that sisal fiber has some influence on mechanical property than coir or flax.

2. MATERIALS AND METHODS

Materials: Areca leaf fiber which is extracted from the areca leaf of tree widely distributed in coastal areas of South India. The advantage of choosing this fiber is they are cost free and which is also can be extracted from the source easily.

Figure.1. Extracted Areca leaf fiber

Eupatorium fiber is obtained from the species Eupatorium odoratum found in large areas of coastal Karnataka. It is a thin fiber extracted from the stem of the Eupatorium plant. They are also easily available and cost free fiber.

Figure.2. Extracted Eupatorium fiber

The above two different types of fiber were extracted and cut into appropriate size 4mm to 6mm. These are considered as short fiber reinforcement material and then introduced into the matrix phase.

Multiwall carbon nanotube (procured from Sigma Aldrich, purity >95%, length 0.5 nm) is the second reinforcement phase added directly into matrix initially. Both natural fiber and CNT are considered as fillers during the preparation composites.

Figure.3. Multiwall carbon nanotube

Epoxy (LY 556, Density 1-1.5 g/cm^3, procured from the Zenith industrial supplies Bangalore, India) is a thermosetting resin and taken as matrix phase. Hardener (HY 951 procured from Zenith industrial supplies Bangalore, India) used to quick setting of composites.

Methods:

Preparation of areca leaf-CNT-epoxy polymer composites: The extracted areca leaf fiber cut into 4-6 mm dimensions. They are washed with water to make dust free fiber. It is then dried in sunlight for a day and later in the oven at the temperature 45-50^{0}C for about an hour. The required amount of fiber and MWCNT were calculated in terms of total percentage and both these are considered as fillers or reinforcement phase. Within that total percentage, the amount of leaf fiber and CNT were varied up to 5 compositions. At the beginning the weighed amount of CNT

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was mixed with calculated amount of epoxy resin. The dispersion of CNT in the epoxy resin was carried out by the ultra-sonication technique. The dispersion process was conducted for about 8-10 hours in order to get uniform mixing of CNT in epoxy (Gryshchuk, 2016; Sui, 2008). The well dispersed mixture of CNT and epoxy was mixed with weighed amount of areca leaf. They are stirred well for 3 minutes. The hardener was added to above uniform mixture and stirring continued for 2 minutes. It was then moulded in Teflon or mild steel mould as per ASTM standards. It is kept for 24 hours after applying load on moulded composites. The fabrication of composites was proceeding through hand lay-up technique (Madhukiran, 2013). After proper curing, the composites were cut into required size for various tests. Hence various volume content of fillers like 6%, 8%, 10%, 12%, 14%, 16% fractions of composites have been prepared.

Preparation of Eupatorium-CNT-Epoxy polymer composites: The similar methods were used for the preparation of Eupatorium-CNT-Epoxy polymer composites. Instead of areca leaf fiber, the eupatorium fiber was used as reinforcement material and they were distributed randomly in the matrix. Later process is same as that of method used for the fabrication of areca leaf-CNT-composites.

The various percentage compositions of composites were prepared for both eupatorium and areca leaf fibers. For eupatorium composites, 2%, 4%, 6% of fillers were introduced. Above 6% it is difficult to incorporate, due to improper mixing of fiber in the resin matrix. The areca leaf composites were prepared for the percentage of 6, 8%, 10%, 12%, 14%, and 16%. Here the mixing started from 6% due to lower distribution range of leaf fiber volume in the resin matrix below this compositions.

Mechanical testing:

Tensile test: The tensile strength of prepared composites was tested according to the ASTM standard D-638. The composites were cut into dog bone shape. Theoretically the tensile strength can be calculated by using the formula (Ajith, 2014),

$$T = P/bh$$

Where, P= ultimate load on the specimen; b= initial width on the specimen; h= thickness on the specimen.

The ability of the material to elongate without breaking is coined as tensile strength. The tests were carried out in Universal testing machine (Capacity 100 KN, Kalpak instruments, Pune-India) at the loading rate of 5mm/min. Minimum four specimens were subjected to test and average values were taken for Ultimate tensile strength. It was recorded as function of load v/s length. The tension was applied on specimen and breakage takes place at the expected area. The appropriate breakage appeared due to the proper mixing of fiber and resin, uniform distribution of fillers and absence of air gap.

Figure.4. Specimen for tensile strength

Flexural test: It is the measure of force required to fracture the specimen through 3 point loading process with testing speed 2mm/min. It was done as per ASTM standard D-790. A rectangular shaped composite specimen of minimum 4 samples was subjected to flexural test. The specimens were tested under same machine at cross head position with large span length to thickness ratio (16:1).

The flexural strength can be calculated by the equation given below (Ajith, 2014),

$$\sigma = 3FL/2bt^2$$

Where, F= maximum load on the specimen; L= span length; b= width of specimen; t= thickness of specimen.

Figure.5. Specimen for flexural strength

Compression test: The compressive strength was carried out as per ASTM standard D-695. The specimens were tested under the same UTM at the speed of 2mm/min. It involves the placing the specimen on the flat surface in the machine and subjecting into compression until it fractures. It is recorded as compressive force as a function of displacement.

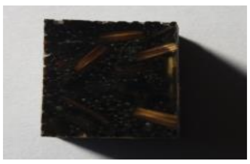


Figure.6. Specimens for compressive strength

Impact strength: It is the ability of the material to resist applied force. The test measures the kinetic energy required to cause the fracture and continues until the breakage of specimen. The specimen was kept vertically and the pendulum was made to hit from one side. The energy absorbed by the specimen before it and fracture was calculated. It gives toughness, resistance of the material towards applied load and ductility. The test was carried out in izod impact testing machine (Advance Equipments, Thane-India) as per ASTM standard D-256.

Figure.7. Specimens for impact test

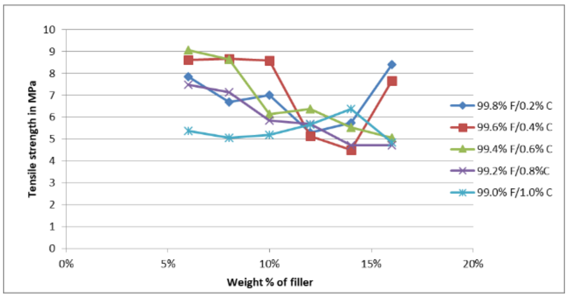
Wear behavior: The wear is formed by the surface contact between 2 materials. The wear friction was conducted in pin on disc system (Ducom Instruments, Bangalore-India) as per ASTM standard G-99. The specimen weighed before the test and placed vertically into gripper with uniform surface contact between base and specimen. The rotating disc speed was taken around 750 RPM, sliding distance 500m, sliding diameter of 130mm with varying weight at 20N, 40N, and 60N.

Figure.8. Specimen for wear test

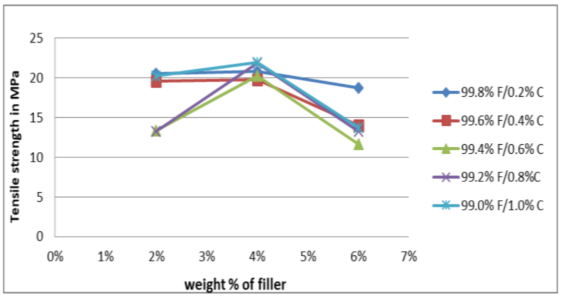
Scanning electron microscope (SEM) and Thermogravimetric analysis (TGA): The scanning electron microscope gives evident about distribution of fillers, surface morphology of the material. It was carried out for the flexural fractured specimen of hybrid materials of areca leaf-CNT-Epoxy and Eupatorium-CNT-epoxy and also for non-hybrid composites of Areca leaf-epoxy, Eupatorium-epoxy and CNT-epoxy. TGA was carried out in the instrument TGA Q-50 V20. TGA used to determine degradation behavior of the fiber composites at high temperature under air and nitrogen atmosphere.

3. RESULT AND DISCUSSION

4.1 Tensile strength: The dumb bell shaped specimens were tested under Universal Testing Machine (UTM) for the evaluation of tensile strength. The specimens were made to break till the Ultimate tensile strength (UTS) occurs. Minimum 4 samples were taken from each composition and mean value is adapted to the UTS. The results were plotted below in the graph,



Graph.1. Tensile strength v/s weight % of filler in areca leaf-CNT-epoxy composites



Graph.2. Tensile strength v/s weight % of filler in eupatorium-CNT-epoxy composites

(In the entire plotted graph, F is abbreviated as Fiber and C as Carbon nanotube)

The above graph shows the UTS of areca leaf-CNT-Epoxy (ACE) and Eupatorium-CNT-Epoxy (ECE) polymer composites. In ACE polymer composites, at 6% weight of filler content gains highest strength when it is compared with 8%, 9%, 10%, 12%, 14% and 16% filler weights. At the mean time hybrid ACE composites of 6% fillers gains more strength than 6% non-hybrid areca leaf-epoxy composites. This may be due to the addition of carbon nano tube which elevates the strength of leaf-epoxy composites. The uniform distribution of CNT in the resin gives strong interfacial adhesion between matrix and fillers.

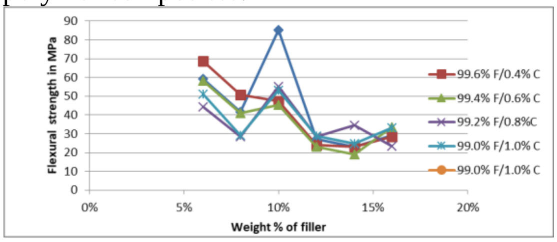
The same trend is appeared in the ECE polymer composites. The highest strength is observed in 4% of filler weight when compared with 2% and 6% fillers. It is seen that UTS is 28.15 MPa for ECE composites which is more than same volume of non-hybrid Eupatorium-epoxy composites and CNT-epoxy composites of 11.55 MPa and 16.63 MPa respectively.

In ACE composites, the tensile strength decreases when increase in filler content. This may be due to the random incorporation of fiber into resin leads to improper distribution of fiber. Therefore at 6% of filler, it was observed that proper dispersion of fiber and hence gains highest strength. When the ECE of 2%, 4%, 6% fillers where compared, the 4% ratio fillers gains highest strength. This may be due to the aspect ratio of eupatorium fiber in matrix phase.

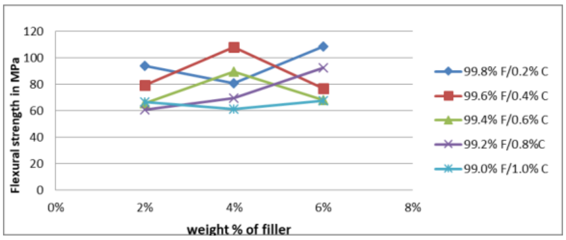
Flexural strength: The rectangular shaped specimens were undergone bending for the flexural strength. The graph shows that 10% volume of filler is gaining highest flexural strength of 85.09 MPa for ACE composites. It is greater than non-hybrid areca leaf epoxy composites of 59.57 MPa. But quite lesser than non-hybrid CNT epoxy composites of 91.79 MPa.

Meanwhile, the ECE composites of 6% fillers have more flexural strength of 120.02 MPa. In this composite, the hybrid ECE composites get highest strength than non-hybrid eupatorium epoxy (62.01 MPa) and non-hybrid CNT epoxy (115.38 MPa) composites. It has been observed that the flexural strength has been increased in 2%, 4%, 6% when increase in filler volumes.

Generally, in homogeneous mixture of composites the flexural strength will be merely equal to tensile strength of material. But in heterogeneous composites, the material acquires some defects which vary the results. The fiber at the extreme concentration gets more strength; hence the flexural strength will be higher as that fiber resists the rupture. Where as in tensile strength, equal load is applied in all the fibers as a result even fibers at the weaker region can initiate a crack which will results in fracture of material. Therefore flexural strength is mostly greater than Tensile strength. This type of trend appeared in the tensile and flexural strength results of both ACE and ECE polymer composites.



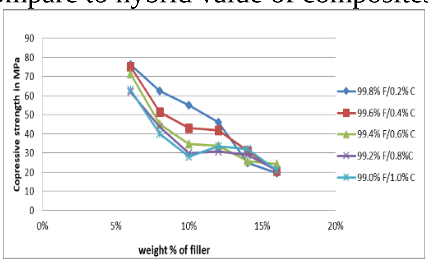
Graph.3. Flexural strength v/s weight % of filler in areca leaf-CNT-epoxy composites



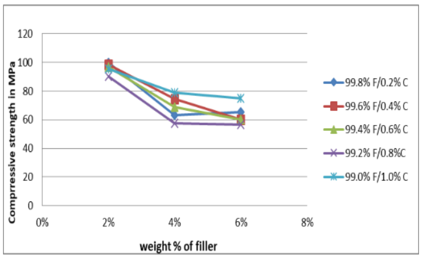
Graph.4. Flexural strength v/s weight % of filler in eupatorium-CNT-epoxy composites

Compression strength: The behavior of specimen under compression are shown in the below graph. In the ACE composites the specimen of 6% volume fraction has resulted with highest compressive strength of 76.37 MPa. It is greater than non-hybrid areca leaf epoxy composites and lower than non-hybrid CNT epoxy composites. Then compressive strength have been decreased when filler volume increases from 6%, 8%, 10%, 12%, 14%, 16%. In longitudinal compressive test, the strength is influenced by the intensity of resin. In case of 6% filler the intensity of resin is more and when it comes to higher filler volume fraction intensity of resin has been decreases and fiber volume increases.

In the case of ECE composites similar results were obtained. The compressive strength decreases when it move from 2%, 4% and 6% volume fraction. 2% filler composites are gaining highest compressive strength (106.51 MPa). Non hybrid areca leaf epoxy composites and non-hybrid eupatorium epoxy composites gaining lesser strength compare to hybrid value of composites.



Graph.5. Compressive strength v/s weight % of filler in areca leaf-CNT-epoxy composites



Graph.6. Compressive strength v/s weight % of filler in eupatorium-CNT-epoxy composites

Impact strength: The strength of the vertically placed material is given by the impact strength. It is calculated as absorption of energy by the sample when it hit by pendulum. The results of impact strength are presented below in the graph. In case of ACE composites, the 8% volume fraction of material gaining highest impact strength that is

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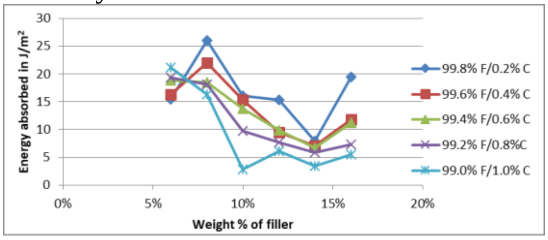
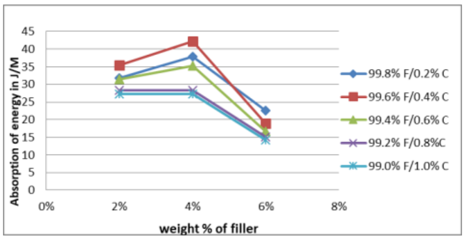
25.96 J/M and it is then decreased. In case of ECE composite the 4% filler material has highest impact strength at around 42.63 J/M. When both these hybrid composites are compared with non-hybrid composites the impact strength is greater in hybrid material.



Graph.7. Energy absorption v/s weight % of filler in Areca leaf-CNT-epoxy composites



Graph.8. Energy absorption v/s weight % of filler in Eupatorium-CNT-epoxy composites

Wear behavior: The samples were subjected for sliding to measure wear rate and frictional force (F.F) as per ASTM standard. In the results it is noted that when the applied load increases on the sample the wear rate also increases with frictional force. The wear behavior of areca leaf-CNT-Epoxy and eupatorium-CNT-epoxy composites are presented in the below tables.

In ACE composites, the maximum frictional force is 41.9 N at 60 N for 10% of filler load and wear rate about 271 mm at the weight of 60N for 16% of filler. In case of ECE composites the maximum wear rate is found to be 981 mm at the weight of 60N for 2% of filler content. The increase in wear rate is due to deformation of sample when the load is applied on the material. After increasing the load causes penetration between material and disc. Hence the surface of the material gets worn out, this increases the wear rate.

Table.1. Wear rate and frictional force for 6% Areca leaf-CNT-Epoxy composites

% of Fiber + % CNT	20 N		40N		60N	
	Wear in mm	**F.F in N**	**Wear in mm**	**F.F in N**	**Wear in mm**	**F.F in N**
99.8%+0.2%	49	5.7	48	17.4	111	36.0
99.6%+0.4%	52	5.6	45	17.1	42	40.7
99.4%+0.6%	10	3.6	20	8.7	53	26.7
99.2%+0.8%	53	5.1	38	18.6	32	31.4
99.0%+1.0%	87	8.3	134	28.8	128	39.4

Table.2. Wear rate and frictional force for 8% Areca leaf-CNT-Epoxy composites

% of Fiber + % CNT	20 N		40N		60N	
	Wear in mm	**F.F in N**	**Wear in mm**	**F.F in N**	**Wear in mm**	**F.F in N**
99.8%+0.2%	08	2.8	09	8.2	34	18.6
99.6%+0.4%	15	4.8	22	11.2	32	19.1
99.4%+0.6%	05	2.3	9.0	5.4	22	14.5
99.2%+0.8%	04	4.2	12	9.6	97	24.1
99.0%+1.0%	06	4.4	25	10.5	129	19.8

Table.3. Wear rate and frictional force for 10% Areca leaf-CNT-Epoxy composites

% of Fiber + % CNT	20 N		40N		60N	
	Wear in mm	**F.F in N**	**Wear in mm**	**F.F in N**	**Wear in mm**	**F.F in N**
99.8%+0.2%	60	8.3	135	22.9	175	41.9
99.6%+0.4%	04	3.6	08	9.5	28	14.5
99.4%+0.6%	42	3.9	134	15.2	151	25.3
99.2%+0.8%	11	4.6	29	14.9	49	25.0
99.0%+1.0%	14	4.1	28	10.2	157	26.0

Table.4. Wear rate and frictional force for 12% Areca leaf-CNT-Epoxy composites

% of Fiber + % CNT	20 N		40N		60N	
	Wear in mm	**F.F in N**	**Wear in mm**	**F.F in N**	**Wear in mm**	**F.F in N**
99.8%+0.2%	34	5.4	21	13.9	23	21.5
99.6%+0.4%	14	6.9	22	14.7	73	24.0
99.4%+0.6%	49	8.3	91	19.5	102	28.8
99.2%+0.8%	16	5.6	29	9.1	194	24.9
99.0%+1.0%	58	5.4	39	11.9	54	22.7

Table.5. Wear rate and frictional force for 14% Areca leaf-CNT-Epoxy composites

% of Fiber + % CNT	20 N		40N		60N	
	Wear in mm	**F.F in N**	**Wear in mm**	**F.F in N**	**Wear in mm**	**F.F in N**
99.8%+0.2%	27	7.0	109	21.3	51	24.0
99.6%+0.4%	14	4.9	35	9.1	46	24.2
99.4%+0.6%	94	4.6	13	11.0	12	14.0
99.2%+0.8%	04	4.2	30	8.8	54	16.8
99.0%+1.0%	54	6.3	51	11.4	93	17.4

Table.6. Wear rate and frictional force for 16% Areca leaf-CNT-Epoxy composites

% of Fiber + % CNT	20 N		40N		60N	
	Wear in mm	**F.F in N**	**Wear in mm**	**F.F in N**	**Wear in mm**	**F.F in N**
99.8%+0.2%	32	5.0	48	9.8	67	15.3
99.6%+0.4%	08	3.9	28	12.7	51	22.1
99.4%+0.6%	31	5.1	73	21.3	207	25.6
99.2%+0.8%	50	5.8	221	21.9	271	30.3
99.0%+1.0%	80	8.9	104	16.3	153	29.3

Table.7. Wear rate and frictional force for 2% Eupatorium -CNT-Epoxy composites

% of Fiber + % CNT	20 N		40N		60N	
	Wear in mm	**F.F in N**	**Wear in mm**	**F.F in N**	**Wear in mm**	**F.F in N**
99.8%+0.2%	34	6.3	58	23.8	119	12..0
99.6%+0.4%	48	7.1	163	24.8	233	27.2
99.4%+0.6%	71	8.8	186	25.3	272	31.0
99.2%+0.8%	62	8.7	101	21.8	535	29.8
99.0%+1.0%	44	7.0	97	20.6	981	30.0

Table.8. Wear rate and frictional force for 4% Eupatorium -CNT-Epoxy composites

% of Fiber + % CNT	20 N		40N		60N	
	Wear in mm	**F.F in N**	**Wear in mm**	**F.F in N**	**Wear in mm**	**F.F in N**
99.8%+0.2%	45	9.4	95	21.4	195	120
99.6%+0.4%	104	9.0	193	27.7	253	36.9
99.4%+0.6%	69	8.3	287	24.6	224	28.7
99.2%+0.8%	67	9.8	163	25.7	218	29.9
99.0%+1.0%	60	7.0	140	28.3	145	39.7

Table.9. Wear rate and frictional force for 6% Eupatorium-CNT-Epoxy composites

% of Fiber + % CNT	20 N		40N		60N	
	Wear in mm	**F.F in N**	**Wear in mm**	**F.F in N**	**Wear in mm**	**F.F in N**
99.8%+0.2%	53	7.2	210	18.1	206	30.4
99.6%+0.4%	54	7.1	218	21.6	231	39.3
99.4%+0.6%	98	8.2	275	20.7	197	36.1
99.2%+0.8%	122	7.8	173	18.4	114	39.5
99.0%+1.0%	50	9.3	63	15.1	124	38.1

Scanning Electron Microscope: The following microstructure of the materials are shows the morphological factors for various composites. In Eupatorium-CNT-Epoxy, the SEM images were analyzed for 4% of filler content composites. The cracked samples were selected from flexural strength and compressive strength tested composites. The images show the orientation of areca leaf and eupatorium fibers in the resin-CNT matrix. There are cracking and surface damage in the material where fiber content is high. There is only longitudinal breakage on applying load in compression tested sample. The agglomeration of CNT with epoxy in the figure.12, shows improper dispersion of CNT if it undergoes sonication process below 5 hrs. Microstructure of the figure.10, gives information about uniform dispersion of CNT in epoxy resin.

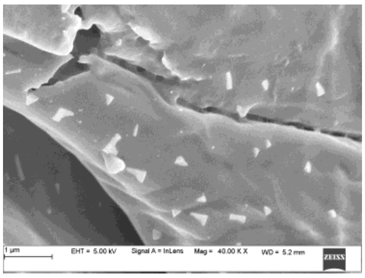


Figure.9. 10% ACE of flexural test

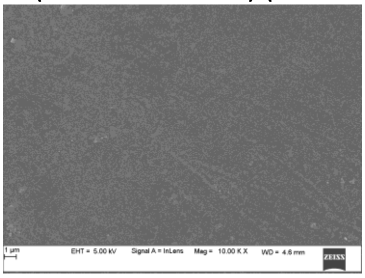


Figure.10. Non hybrid CNT-Epoxy mixture

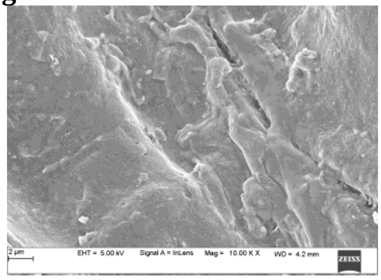


Figure.11. 4% ECE of flexural test

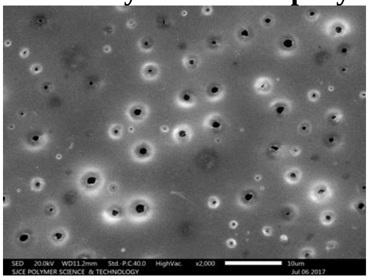


Figure.12. Agglomeration of CNT in epoxy

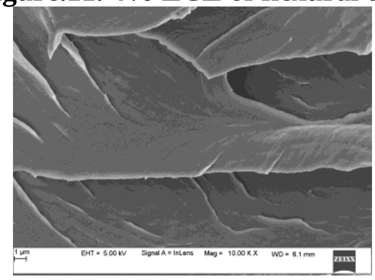


Figure.13. 4% ECE of compression test

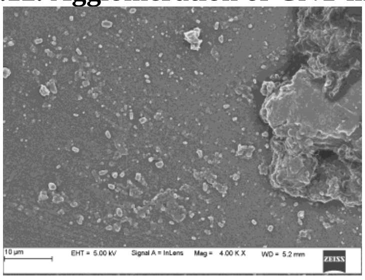


Figure.14. 10% ACE of compression test

Thermogravimetric analysis (TGA): The TGA curves for 6% eupatorium filler and 10% areca leaf filler reinforced composites are shown below figure.15 and 16 respectively. There is a peak at 100^0C indicating the removal of moisture for both

Eupatorium and areca leaf fiber composites respectively. The eupatorium fiber and areca leaf fiber composite shows thermal decomposition at 350^0C and 320^0C respectively. Thus from the above results Eupatorium fiber composites had highest thermal stability than areca leaf fiber polymer composites.

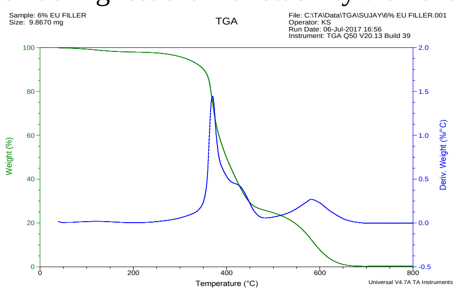


Figure.15. TG graph for 6% Eupatorium-CNT-Epoxy polymer composites

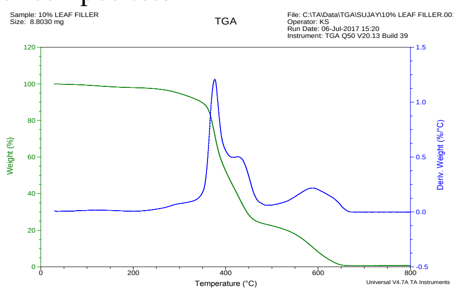


Figure.16. TG graph for 10% areca leaf -CNT-Epoxy polymer composites

4. CONCLUSION

The mechanical, wear and morphological properties of hybrid polymer composites have been investigated. An attempt made to incorporate two different types of natural fibers such as Areca leaf and Eupatorium in CNT-Epoxy mixture. It was prepared separately and undergone for various tests. The tensile strength of areca leaf composites have been decreased when the fiber load increased from 6% to 16% weight percentage. But when it is compared with non-hybrid areca leaf composites the hybrid composites shows better tensile strength.

Similar trend observed in eupatorium fiber composites. The flexural property is more in 10% weight of fiber in areca leaf and then it is decreased. The compression strength is more in 6% fillers of areca leaf and CNT. In ECE composite, 2% fillers gains higher strength and later it decreased. The impact strength is more in 8% of fillers in ACE composites where in ECE, 4% filler gains higher strength.

The wear rate and frictional force has been increased when the load applied on sample increased. The areca leaf-CNT-epoxy composites degrade at lower temperature when compared to eupatorium-CNT-epoxy composites.

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The mechanical and morphological properties are more in eupatorium-CNT-epoxy polymer composites than areca leaf-CNT-epoxy composites.

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