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Carbon Fiber Reinforced Nano Composite-Synthesis, Characterization and Mechanical Properties

Shivraj Puggal, Novepreet Dhall
School of Mechanical Engineering, Lovely Professional University, Phagwara, India
shivraj.16125@lpu.co.in

Abstract

An economical and viable option to conventional and high cost materials is the use of carbon fiber but for strength to weight ratio application their tensile strength is still has to improve. The strength and other mechanical properties can be enhanced by adding small amount of CNTs (0.2%wt and 0.5%wt of weight of raisin). In present work composite sheet has been formed by mixing the CNTs at different weight ratio (0.0%wt, 0.2%wt and 0.5%wt of raisin) by hand layup method. To enhanced the dispersion of CNTs 0.5%wt CNTs are treated with polyelectrolyte. The cationic polymer used for treatment is Poly Diallyl Dimethyl Ammonium Chloride (PDAC). The nanocomposite has been characterized by SEM images and it can be seen that dispersion of CNTs is improved. Tensile and bending test has been performed as per the ASTM. The mechanical test characterized that 0.5%wt treated CNTs have the enhanced stress value among all the samples.

1. Introduction

1.1 Nanotechnology

Nanotechnology sometimes it is also called as nano tech is the changes which are done on the atomic, molecular and supra molecular level. Earlier the nano-technology was explained as the technique which always focuses on the manipulation done on atomic and molecular level to fabricate some macro scale product, and now this is called as molecular nano-technology. A further more brief and generalized description is given by the National Nanotechnology Initiative, in which nano-technology is defined the same as the change of material which have at slightest one dimension of size 1 to 100 Nm. This description defines that quantum mechanics plays a very important role at this quantum-realm scale, this is the main reason for the shifting

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this from particular technology goal to a investigate group comprehensive of all the type of study and technology in which the unusual property of material plays an important role which occur below the given size of the threshold. Nano technology found a broad range of impending application which include manufacturing and martial, due to which government have also invest billions of dollars in the area of investigate where Nano-technology is involved. From side to side its nationwide Nanotechnology proposal, the investment of USA is 3.7 billion dollars. The investment of European Union 1.2 billion and the investment of Japan are 750 million dollars.

The research which is associated with Nano technology and applications related to this are having a very broad range, it is range as of extension of the conservative mechanism physics to a very different approach which is based on the self-assembly of the molecules, by developing the new material which have Nano scale dimensions and they will control the matter on the atomic level.

Scientists nowadays have a new topic to discuss which “future implication of Nano-technology”. It has both positive and negative impact. Nanotechnology no doubt is able to create much kind of different material and devices which will have a wide range of application, for example in electronic, biomaterial, energy production and medicine. On a different aspect, it has a reverse effect on the environment. Nanotechnology started many issues to discuss because they are related with the impact of Nano material on the environment and it is also concerned about the toxicity, and their overall effects on the global economics.

2. Literature Review

Muhammad Kaleemullah*et al* [2012]

In this study, the polybenzoxazineNanocomposites are prepared by using multiwalled carbon nanotube with surfactant and then the mechanical and thermo mechanical properties are studied. The results obtained are then compared with the normal epoxy based composite. The CNT brings a improved change in many of the mechanical properties and characterization at the expanse of impact fracture toughness. These result are improved due to the dispersion of CNT in epoxy. The addition of CNT ameliorates the effect of lowering the thermal efficient coefficient of polybenzoxazine.

AbdolhosseinFereidoon*et al* [2012]

In this study mainly the concern is about the interaction of nanotube with epoxy by proposing the global local multiscale finite element method near the crack tip. The representative volume element at the crack tip is built with the 3D FE model. The chirality and length effect of single walled nanotube mixed with polymer matrix were studied in the presence of vander wall force. As the weight percentage of CNT is increased the fracture toughness is improved. The result shows that by increasing the length and chirality the crack resistance is improved.

Naveed A. Siddiqui*et al* [2011]

A new method has been developed effectively for the production established on a solvent less prepregging route for prepreging of CFRP composites comprising of CNTs. The effort delivers an exclusive examination to date of the treating and gives remedy for the factors affected by the introduction of carbon nano tubes in CFRP prepreg production. It has been observed during the experimentation outcome that a reduction in viscosity of CNT/epoxy nano composites was evident by using high-speed shear mixing and functionalization of CNT. The rheological studies reveal that improved processing limits are chosen for lab-scale fabrication of CFRP composite prepregs. The influence of surfactant-treated CNTs on cure manner of CFRP and epoxy prepreg is calculated. The percentage of cure is lower for the prepregs covering 0.5–1.0 wt% CNTs in contrast to those comprising a negligible or lower level of CNT.

Toshiya Kamae*et al* [2011]

A new method has been developed for the fabrication of carbon nanotube over the carbon fiber, which permits the ascendable production of CNT comprising of epoxy/CF composites. In this technique, the carbon nanotube is treated with the cationic polymer then these treated CNTs are immersed in the CNTs/water suspension. Now repulsion between positively charged Carbon nano tubes aids good dispersion and also attractive action between positively charged Carbons obtained are then compared with the normal epoxy based composite. The CNT brings an improved change in many of the mechanical properties and characterization at the expanse of impact fracture toughness. These results are improved due to the dispersion of CNT in epoxy.

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The addition of CNT ameliorates the effect of lowering the thermal efficient coefficient of polybenzoxazine.

Joung-Man Park *et al* [2011]

The present work that the single carbon fiber specimens was having greater value of apparent modulus in CNT-phenolic nano composite in contrast to the single carbon fiber in neat phenolic resin and it is also shown that stress transfer also get better result. Also, the contact angle enhanced more than 90% on CNT-phenolic nano composites whereas somewhat less than 90% on neat phenolic resin revealed by water droplet contact angle measurements. This behavior is just only because of hydrophobic domains which is arbitrarily dispersed at the surface due to the of heterogeneous microstructure of Carbon nano tube. Furthermore, adhesive forces amid a CNT-phenolic nano composites and single carbon fiber also improved compared to neat phenolic resin that is credited to an upsurge in viscosity by addition of Carbon nano tube. The result of interface adhesion and Micro-failure patterns amid single carbon fibers and CNT-phenolic nano composites were constant with the last results.

Naveed A. Siddiqui *et al* [2009]

A concept of “healing” has been made in this approach. In this study the hard fiber’s surface was coated which diminished the stress concentrations and enhanced the strengthening efficacy of the composite. In this two types of coating is made. Firstly, neat epoxy is applied and secondly CNT strengthened epoxy nano composite was introduced on the different rovings and glass fibres. The outcome revealed that noteworthy improvement was evident in tensile strength of the single fibre for all gauge lengths when 0.3 wt.% CNT–epoxy nano composite coating was applied which inturn was better compared to the neat epoxy coating. Furthermore, the tensile strength was also improved for glass fibre roving with coatings of nano composite which revealed an extra distribution of strength in contrast to the neat epoxy. The variation in prevalent failure mechanisms influenced by nano composite and epoxy coatings was investigated.

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Joung-Man Park *et al* [2009]

The investigation of Interfacial evaluation and hydrophobicity of Carbon nano tubes and epoxy nano composites was conducted by wettability and micromechanical tests. In this the gradient specimen was used to examine the contact resistance of the CNT/epoxy nano composites which is having electrical interactions with spacing of gradual increments. Better outcomes could be achieved for evaluating the contact resistance of CNT/epoxy nano composites using two point methods. Tensile strength reduced radically for surface treated glass fiber, while tensile modulus had been altered to only some extent in spite of the existence of faults on surface of the etched fiber. Due to the improvement in surface energy and roughness, the shear strength at the interface between the CNT/epoxy nano composites and etched glass fiber improved. Due to the enhanced thermodynamic work of energy, the mechanical interfacial shear strength and the apparent modulus also augmented.

3. Experimentation

3.1 MATERIAL TO BE USED

CARBON NANOTUBE: The carbon nanotube is used here having 10 to 20 nm indiameter and 1.5 μm length and its item code is 280514-33. For having good result the purity of carbon nanotube is more than 95% which is supplied from **AutusNanolab Pvt.Ltd.**

Figure 3.1 carbon nanotubes supplied from Autus Nanolab Pvt. Ltd.

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CARBON FIBER: the carbon fiber used here is unidirectional fiber which is wovenwith a fiber thread so it will not displaced from the group of fiber.

Figure 3.2 Carbon fiber sheet roll

EPOXY: The epoxy which is used here is having two part one is base and other is aminehardener and the accumulative product quantity is 5 kg which is supplied by **BASFConstruction Chemicals (India) Private Limited**.

3.2 EQUIPMENT TO BE USED

Table 3.1: Equipment to be used

S.NO.	EQUIPMENTS		
1.	ULTRASONICATOR	5.	BARCOL HARDNESS TESTING MACHINE
2.	MECHANICAL STIRER	6.	SCANNING ELECTRON MICROSCOPE (SEM)
3.	UNIVERSAL TESTING MACHINE	7.	X-RAY DIFRACTION (XRD)

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3.3 FABRICATION OF SPECIMEN

i) Cutting of carbon fiber sheet

Carbon fiber sheet is been purchased from **BASF Construction Pvt. Ltd.**Its originally having the length of 5mts and width of 30 cm. this fiber sheet is cut into 40cm in length for bending and tensile specimen each.

ii) Mixing of carbon nanotube into epoxy

Varying percentage of carbon nanotube are mixed into epoxy with the help of homogenizer. Firstly, carbon nanotube is weighted and the some small fraction of CNTs is mixed into epoxy after that homogenizer is on having the shear mixing speed of 3000 to 4000 rpm. And then turn by turn small fraction is added followed by repeated process.

iii) Coating of carbon fiber sheet

Hand layup method is used to coat the carbon fiber sheet. Firstly the proper mixed epoxy is poured onto the fiber and the with the help of scrapper a uniform layup of sheet is prepared. One thing need to be take care that no air bubbles trapped into them. One side is placed for one to get settled and cure after that the opposite side is layup by applying the same process.

iv) Cutting of sheet into the sample specific dimension

Hand grinder machine is used to cut the sample in a precise dimension. Once the epoxy is cured for one week the sheet is marked by using marker and then grinder is placed over the sheet onto the appropriate marked line. This process is done in a very care full manner so the dust coming out from sheet doesn’t be inhale because its causes dizziness and harfull for health.

4. Results

4.1Expected Outcome

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I. Aggregates formation in the mixing of carbon nanotube in epoxy is improved to some extent because the treated carbon nanotubes with cationic polymer get the positive charge. When these treated CNT is mixed in epoxy they experienced the repulsive force among themselves which will enhanced the dispersion of CNT in epoxy.
II. The process of applying the CNT over the carbon fiber increases the attractive force between the CNT, epoxy solution and carbon fiber which ultimately increases the strength of the composite
III. Increasing the strength to weight ratio which hasmany applications.
IV. Hardness and flexural result will be improved.

4.2 Mechanical Characteristics

A series of experiment is performed and after complete accomplishment of project mechanical test is performed and these result are quite astonishing that there is a great improvement in the mechanical characteristics a treated CNTs have a strong tensile strength among them but the bending result are not so impressive dispersion of CNTs are also improved.

a) Tensile result of virgin samples

Table 4.1 Result showing maximum stress and maximum strain

Name	**Max_Force**	**Max_Disp**	**Max_Stress**	**Max_Strain**
Units	**N**	**Mm**	**N/mm2**	**%**
1	7120.63	4.18800	207.901	8.37600
2	2553.4	1.45200	92.8185	2.90400
3	3377.81	2.09700	101.497	4.19400
4	4622.34	3.12500	138.559	6.25000
5	5924.69	4.04200	200.837	8.08400
Mean	4719.78	2.98080	148.323	5.96160
Standard Deviation	1851.98	1.19610	54.0278	2.39220

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Above table shows the outcome after testing samples. It can conclude from the above table maximum stress is ranging from 92 to 207 N/mm^2 having an average value of 148 N/mm^2 this shows that result are quite impressive and corresponding maximum strain % value are 2.90400 to 8.37600 %.

b) Tensile result of 0.2% weight of CNTs

Table 4.2 Result outcome of 0.2% weight CNTs

Name	Max-Force	Max_Disp	Max_Stress	Max_Strain
Units	**N**	**mm**	**mm**	**%**
1	3632.81	1.76400	147.699	3.52800
2	3789.84	1.80300	127.176	3.60600
3	6149.69	3.03400	267.331	6.06800
4	2703.75	1.60100	126.937	3.20200
5	2890.00	1.33600	92.9858	2.67200
Mean	3833.22	1.90760	152.426	3.81520
Standard Deviation	1375.99	0.65595	67.1675	1.31190

Above table shows result outcome of 0.2%wt CNTs. From above value we can conclude that max stress is varied between 92.9858 to 267.331 mm having an mean value of 152.426 mm. If we compare result of 0.2%wt CNTs from virgin sample we can found that there is an improvement in tensile strength.

c) Tensile result of 0.5%wt CNTs without treatment

Table 4.3 Result outcome of 5%wt CNTs

Name	Max_Force	Max_Disp	Max_Stress	Max_Strain
Units	**N**	**mm**	**mm**	**%**
1	6062.19	4.54000	175.593	9.08000
2	8446.88	4.46600	305.338	8.93200

3	8939.38	3.86100	250.108	7.72200
4	9275.63	4.20500	286.444	8.41000
5	7663.13	3.54500	187.491	7.09000
6	7077.50	3.04100	179.087	6.08200
Mean	7910.78	3.94300	230.677	7.88600
Standard Deviation	1215.01	0.57919	57.6586	1.15838

Above table shows that maximum stress value varied from 175.593 mm to 305.338 mm having a mean value of 230.667 mm as compared to the other outcome of above result this is quite impressive. Tensile result shows that there is a great improvement from the virgin samples and even from the 0.2%wt CNTs the maximum stress value jump from 148.323 mm to 230.667 mm in virgin samples and in 0.2%wt CNTs its jump from 152.426 mm to 230.667 which is also quite astonishing.

d) Tensile result of 0.5%wt CNTs with treatment

Expected outcome in this is really astonishing as compared to other cases. After the test has been conducted if we compared the result there is a great variation from virgin samples to this treated samples. The test result is jumped from 148.323 mm to 304.238 mm if we compared among virgin and treated samples.

Table 4.4 Tensile result of 0.5%wt treated CNTs

Name	Max_Force	Max_Disp	Max_Stress	Max_Strain
Units	**N**	**mm**	**N/mm2**	**%**
1	7488.13	3.89300	311.694	7.78600
2	7356.56	3.53000	292.391	7.06000
3	7525.63	3.76100	299.682	7.52200
4	9667.50	4.81300	400.476	9.62600
5	6125.31	2.98700	216.948	5.97400
Mean	7632.63	3.79680	304.238	7.59360
Standard	1276.84	0.66524	65.3797	1.33047

Deviation				

Above table shows that result came from this experiment are quite good and impressive as we seen that the maximum stress values are ranging between 216 to 400 mm and having a mean value of 304 mm which is greatest among all the samples tested under the same condition. So from this we can conclude treated CNTs have the highest tensile strength.

Table 4.5 Comparison of result of all the different types of tensile samples

Name	Max_Force	Max_Disp	Max_Stress	Max_Strain
Units	**N**	**mm**	**N/mm2**	**%**
0.0%wt CNTs	4719.78	2.98080	148.323	5.96160
0.2%wt CNTs	3833.22	1.90760	152.426	3.81520
0.5%wt CNTs	7910.78	3.94300	230.677	7.88600
0.5%wt treated CNTs	7632.63	3.79680	304.238	7.59360

From above table we can clearly conclude that the maximum stress value is increasing as we increase the % of CNTs because the stress value is distributed among the dispersed CNTs which enhanced the overall tensile strength of the samples but the treated CNTs have quite astonishing result among all which shows that the CNTs among the epoxy is uniformly distributed. Maximum force and Maximum displacement are fluctuating according to the overall stiffness variation.

e) Result of Scanning Electron Microscope of virgin samples

SEM was used to determine the size and distribution of particles in the samples in different types of samples. The main concern is to use SEM to see the particle dispersion. The basic use od SEM is to get the high magnification image so it can be relate to the properties of the samples. The images obtain here are ranging from 100X to 1000X

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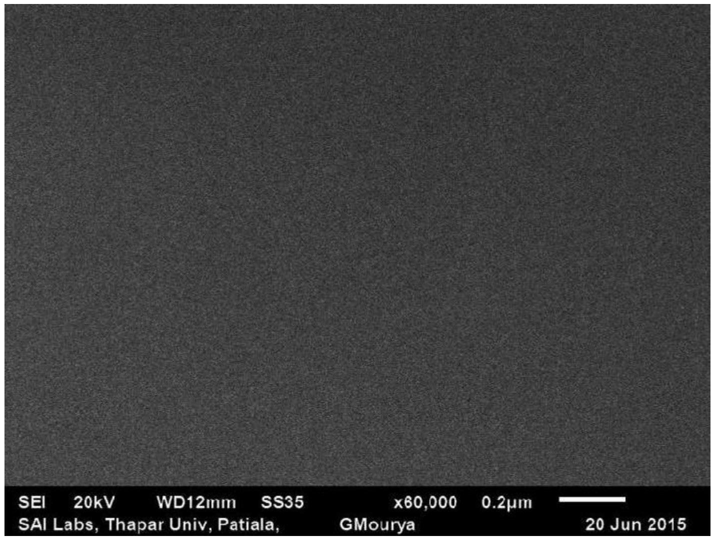

Figure 4.1 SEM images of virgin samples

In figure 4.1, the SEM images of virgin samples have been shown. In comparison to pure epoxy, different ratio of weight percentage of CNTs image has been observed at different magnification. It can be observed in figure 4.3 and 4.4 at different magnification that cluster of particles can be seen.

f) Result of Scanning Electron Microscope of 0.5%wt CNTs without treatment

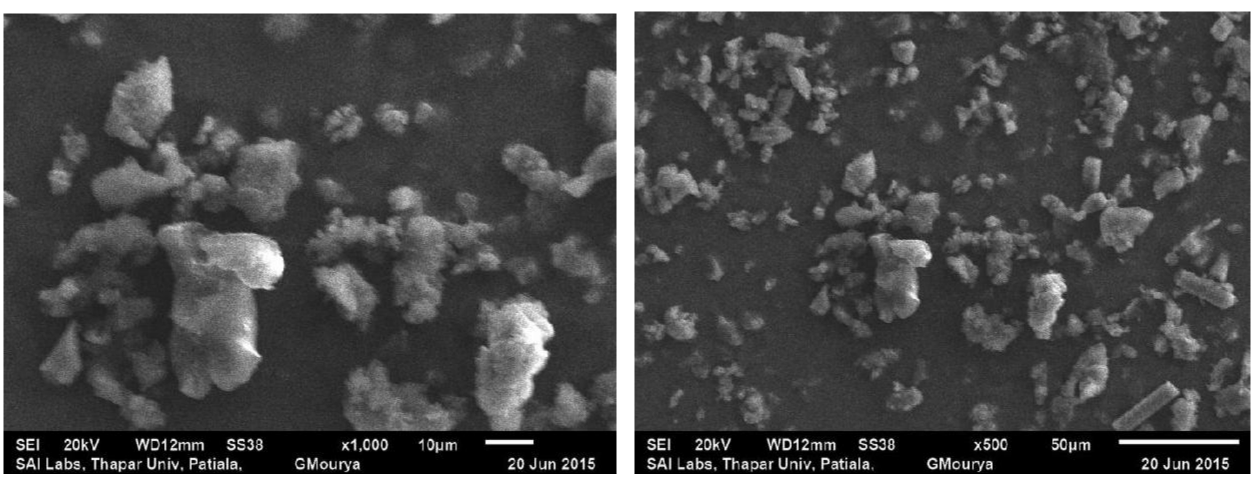

Figure 4.2 SEM images of 0.5%wt CNTs without treatment

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In figure 4.2, SEM images of 0.5%wt CNTs without treatment can be seen at 1000X and 500X. It can be observed that there is a cluster of CNTs are observed which shows that dispersion is there but not as improved as treated CNTs. In 1000X it is clearly visible that CNTs formed agglomerate.

g) Result of SEM of 0.5%wt CNTs with treatment

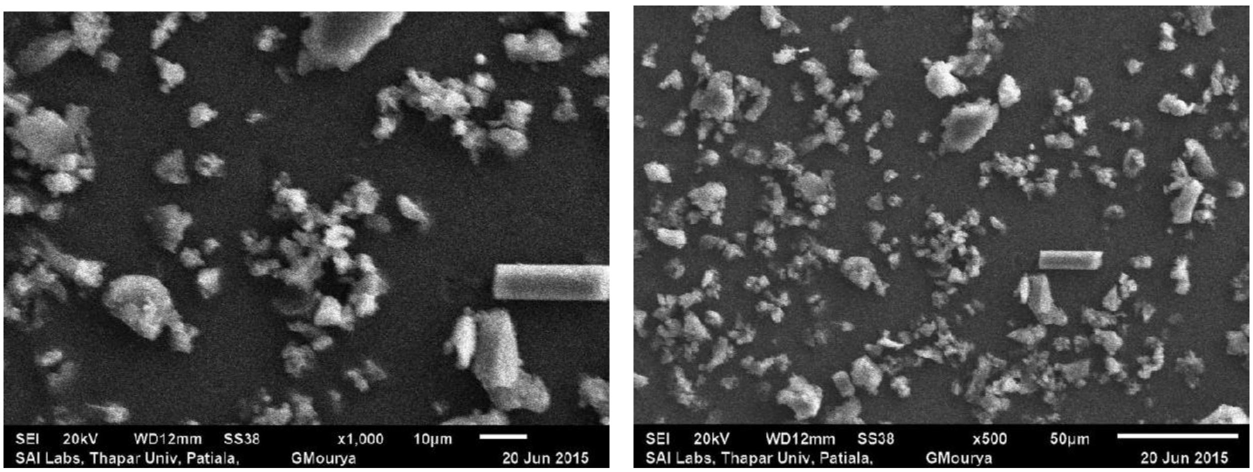

Figure 4.3 SEM images of 0.5%wt CNTs with treatment

In figure 4.3, SEM images has been developed at 1000X and 500X magnification. In the first image it can be seen that CNTs dispersion are improved as comparison of 4.3 images where a cluster of CNTs particle are visible.

6. CONCLUSION

Carbon fiber reinforced composite has been formed by using carbon fiber as reinforcement and epoxy mixed with CNTs as a matrix. CNTs are mixed into epoxy in different weight percentage (0.0 wt%, 0.2 wt% and 0.5 wt % of weight of epoxy). For the processing of composite sheet shear mixing by homogenizer and then sonication is done. Better result can be seen when the percentage of CNTs are increased and among all the samples treated CNTs have the highest bending and tensile strength. Tensile test has been performed as per the ASTM standard. The result outcome shows that 0.5%wt CNT have the highest stress value among the untreated samples which can be taken further to demonstrate by increasing percentage of CNTs to optimal limit. SEM images have been developed at different magnification and from that image it can conclude that after treatment of CNTs dispersion of CNTs particle is improved.

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