A Review Paper on Properties of Carbon Fiber Reinforced Polymers

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Carbon fiber reinforced polymers (CFRPs) are one the stiffest and lightest composite materials, they are much convincing than other conventional materials in many fields and applications. Use of composites is limited due to their higher rice and lower formability. Use of nanoparticles increases mechanical properties of these composites. As these composites are costly materials, Non Non-destructive testing (NDT) such as Eddy current pulsed thermography (ECPT) is used for studying properties against impact loading. Modifying composite papers with Hot Melting Fibers (HMF) shows increase in mechanical properties without considerable reduction in electrical properties.
Keywords: carbon fiber, CFRP, composite, material properties

I. Introduction

Fiber reinforced composites are considered to replace metallic components in many industries for past several years. Because, compared to conventional metals fiber reinforced composites have low density, high specific strength and stiffness, higher corrosion resistance and improved fatigue performance. Performance of these fiber reinforced composite under various loading condition; such as axial, torsion and impact loading is very crucial for the design of structural components. Mechanical properties of fiber reinforced polymer composites depend on the fiber, matrix and the interface between them. Among all fiber reinforced composites, carbon fiber reinforced polymers are emerging because of remarkable properties of carbon fibers and polymer matrix combination. Properties of these CFRP can be enhanced by using several additives.

II. Literature review

Carbon nanotubes (CNTs) are the strongest materials among the nanoparticles and are most widely used because of their strong interfacial interactions and excellent stress transfer properties. Uniform dispersion and proper interfacial adhesion between polymer and CNTs is most important hurdle for employing CNT as effective reinforcements in polymer composites. To increase compatibility of matrix with CNTs chemical fictionalization could be done which forms an interface with stronger interconnections and then increases compatibility.

Even if interface problem for CNTs is solved still CNTs are expensive and can be hazardous to health. Less expensive organic materials like nanoclays are also used for composite reinforcement. Nanoclays are layered structures capable of reinforcing the matrix to enhance mechanical properties. They act as thermal and moisture barrier to provide thermal stability and environmental degradation resistance as well[1]. As 2 wt.% addition of nanoparticles gives optimum results[1] the nanoclay used for experimentation was 2 wt.% I30E (Octadecylamine surface modified) Montmorillonite Nanoclay. 3 point bending (flexure) test, Dynamic Mechanical Analysis (DMA), and Low Velocity Impact (LVI) test have been conducted to characterize the modified composites and then compared with unmodified carbon/epoxy composites.

For experimentation nanoparticles were dispersed in CFRP, the dispersion technique used is shown in figure 1.

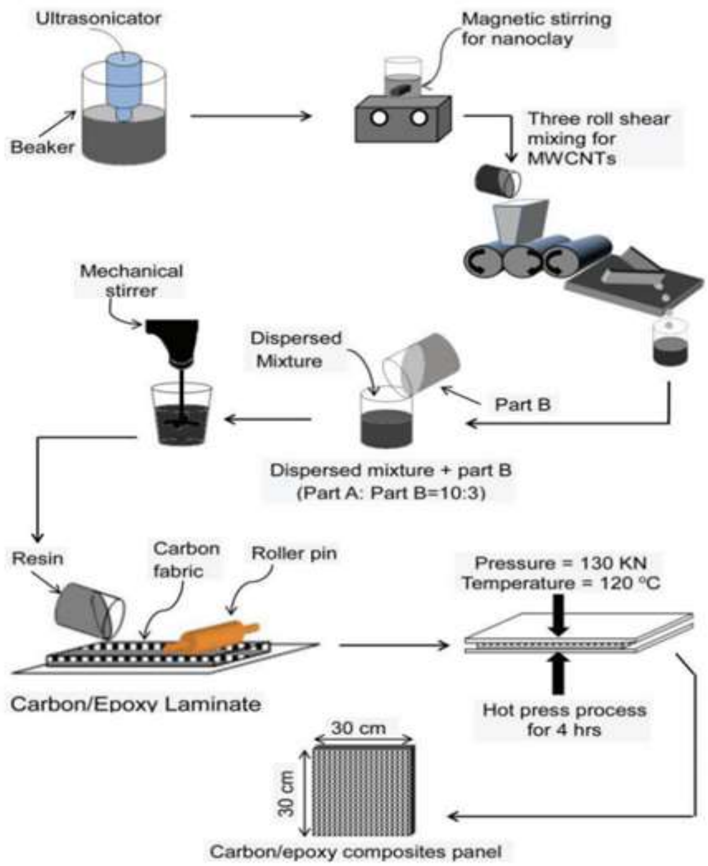


Fig. 1: Dispersion of nanoparticles and fabrication of laminates[1]

For impact testing however, Eddy current pulsed thermography was used as Eddy current pulsed thermography is a measurement technique, which induces eddy current in conductive material and detecting reflected thermal waves from boundaries of interfaces. There are two types of configuration reflection mode and transmission mode.

In reflection mode excitation and data acquisition is carried out on same side. In transmission mode specimen is stimulated from one side and data is recorded from other side. Eddy current pulsed thermography involves two heating modes according to different skin effect by eddy current induction; these are near surface heating and volumetric heating. Near surface heating is used when skin depth is very small and can be neglected. Whereas, volumetric heating is used when skin depth is much larger e.g. for CFRP with small conductivity it is about 50mm at 100kHz[2].

When impact energy increases more and more partial carbon structure will break down decreasing its conductivity therefore increasing resistivity. Therefore as impact energy increases electrical conductivity decreases.

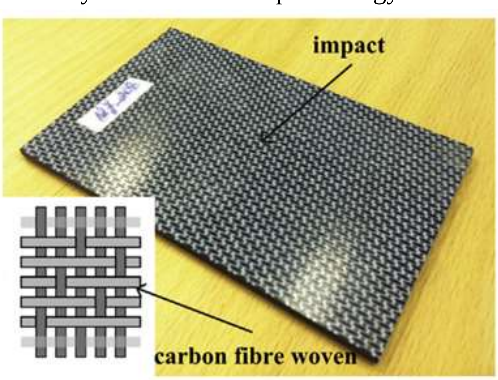


Fig. 2: Photo of CFRP impacted laminate [2]

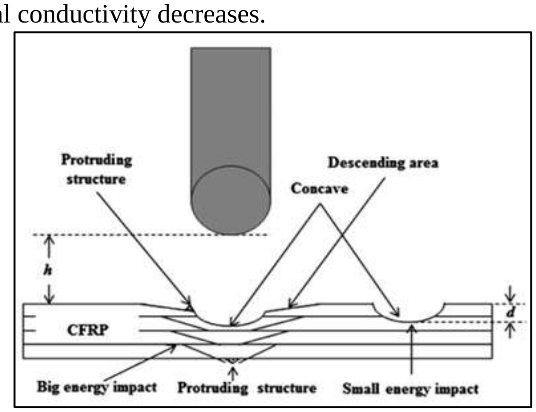


Fig. 3: General impact characteristics for CFRP structures.[2]

Since signal to noise ratio depends on heating of sample as heating increases ratio increases, but thermal diffusion process can lead to blurring of image therefore optimum heating time used to 50-200 ms For testing of modification in properties of composite paper testing specimen were prepared. In their experiment' Yunzhou Shi et.al. used chopped carbon fibers from Toray industries and unbleached softwood pulp from Weyerhaeuser. Hot-melting fibers (with an average length of 6 mm) provided by Danyang Shuguang fiber Co., Ltd were used for mechanical modification.

Unbleached softwood pulp was mechanically beaten for 40 min to acquire cellulose (CLS) aqueous slurries with a concentration of 0.1 wt%. Chopped carbon fiber were dispersed in water (0.1wt %), adding APAM (0.1 wt%) as dispersant. Both CL Sand CF slurries were mechanically stirred for 30min respectively before mixed together [3]. The well dispersed CLS and CF slurries were mixed together in different ratios and stirred for another 10 min to ensure both CLS and CF to distribute evenly. Dispersion of Hot melting fibers in water was made using APAM (0.1% wt), which was then mixed with slurries of cellulose and carbon fiber in different ratio as modification component then paper was made from it. Testing: composites produced were tested on universal testing machine. Ten samples of each concentration were tested and mean was taken.

Results: composites with added nanoparticles shows improvement in properties than that of parent composite.

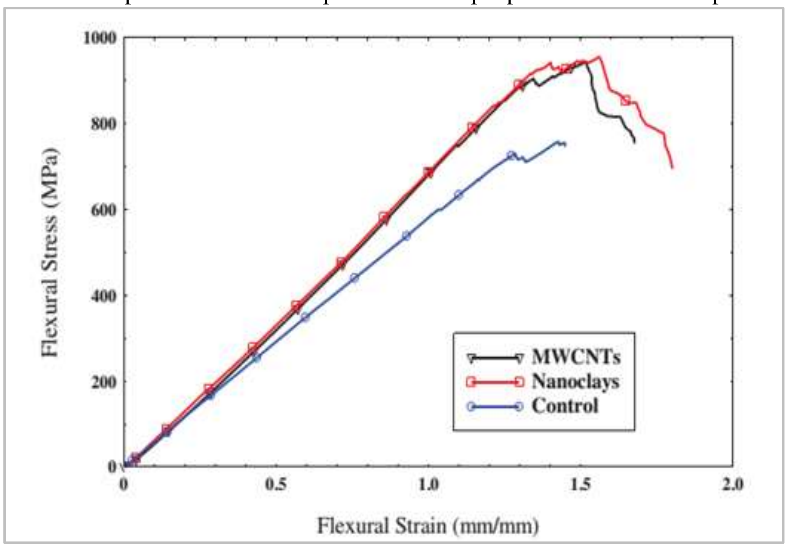
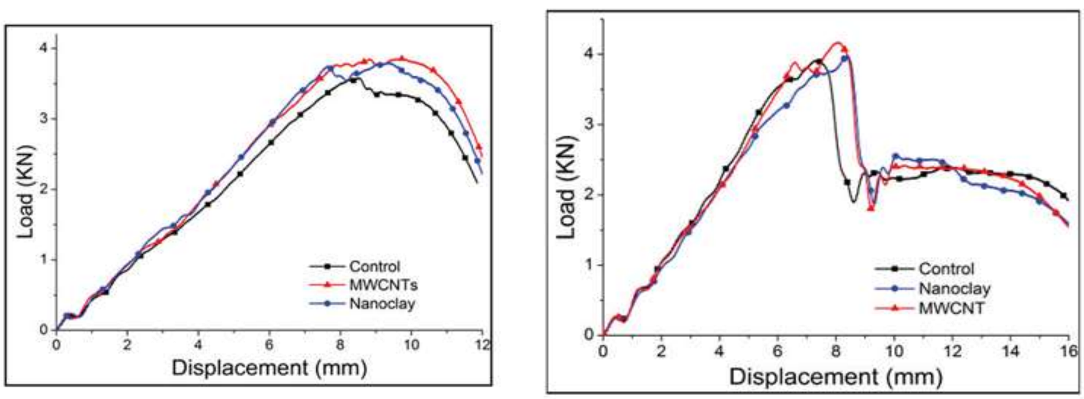


Fig. 4: Flexural Stress versus strain response of control and nanoparticles reinforced carbon fiber/epoxy composite samples [1]

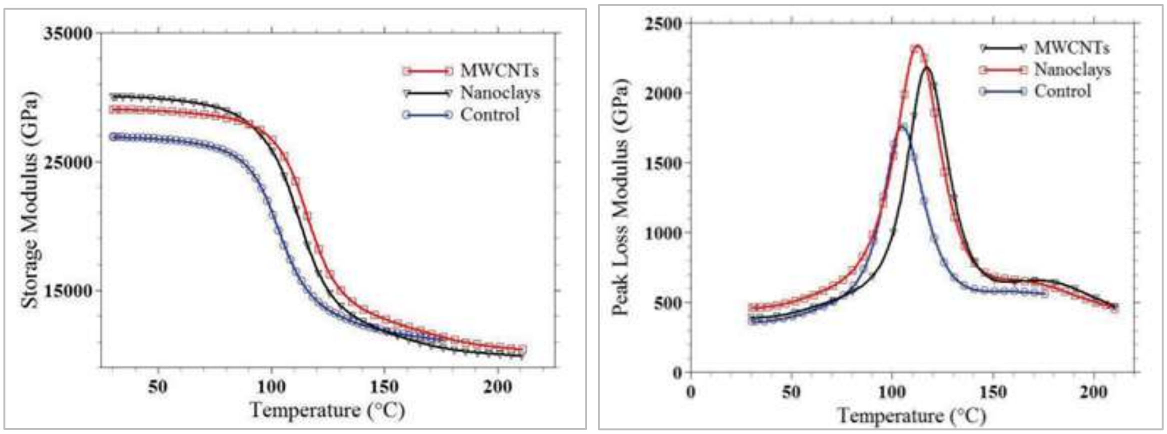
According to graph in figure.2, there is significant rise in flexural stress of the enhanced materials. Low velocity impact stress were conducted on 30J and 40J energy levels. At 30J energy level the load-displacement profile was very smooth for all samples. This smooth nature of graph implies that there is no sudden lamina failure. But, in case of graphs obtained at 40J energy levels there is sudden and significant drop of the profile for all samples.



(a) (b)

Fig. 5: (a) Load vs Displacement plot for control and modified carbon/epoxy composites impacted at (a) 30J; (b) 40J energy levels.[1]

When tested for Dynamic mechanical analysis to obtain viscoelastic properties (Viscoelasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation). It is as expected that nanoparticle reinforced carbon fiber/epoxy composites have higher glass transition temperature and higher storage modulus than parent material. Moreover loss modulus and damping properties are also higher in nanoparticle reinforced material than that of parent material.



(a) (b)

Fig. 6: (a) Storage modulus; (b) Loss modulus of modified and control carbon/epoxy composites.[1]

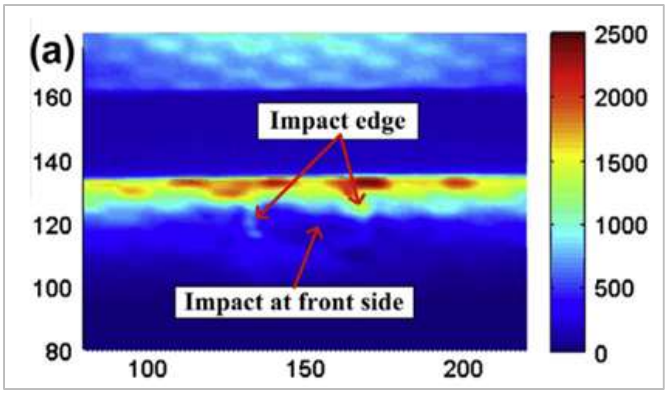


Fig. 7: Thermograms for front side side of 10 J impacted laminate at 200 ms under reflection mode.[2]

Fig.7 show thermogram for front side for 10J impact laminates at 200ms. There is a circle shape of higher temperature around impact. However, the middle area (concavity with thinner thickness) does not show the higher temperature. In the experiments under transmission mode, the front side and rear side of 10 J impacted laminate are tested, respectively. In order to let heat conduct from surface to rear side, the greater heating time (1 s) and cooling time (500 ms) are applied[2].

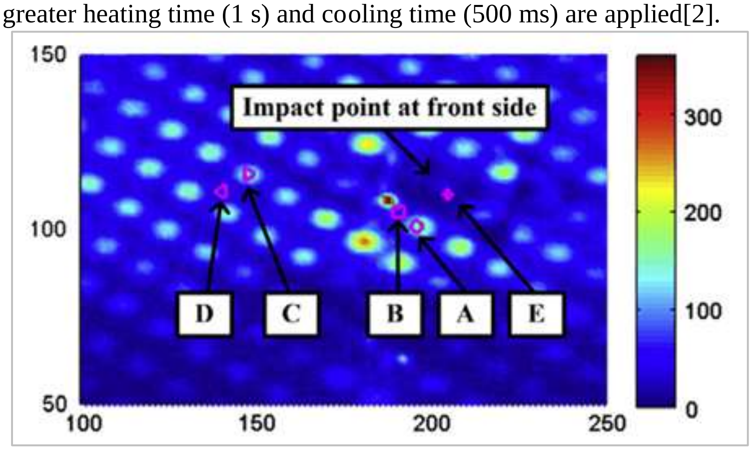


Fig. 8: Thermogram for front side of 10 J impacted laminate at 50 ms under transmission mode.[2]

Table – 1
The locations of points A, B, C, D and E on 10 J impacted laminate.

Point name	*Location (carbon fiber of matrix)*	*Location (defect or good part)*
A	*Carbon fiber*	*Impact edge*
B	*Matrix*	*Impact edge*
C	*Carbon fiber*	*Defect free*
D	*Matrix*	*Defect free*
E	*matrix*	*Impact middle*

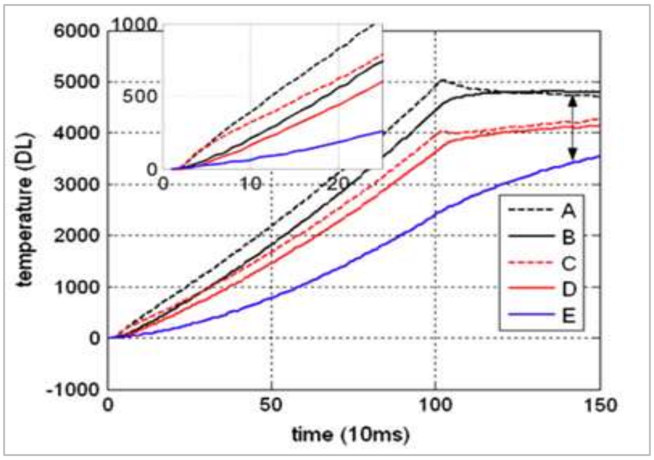
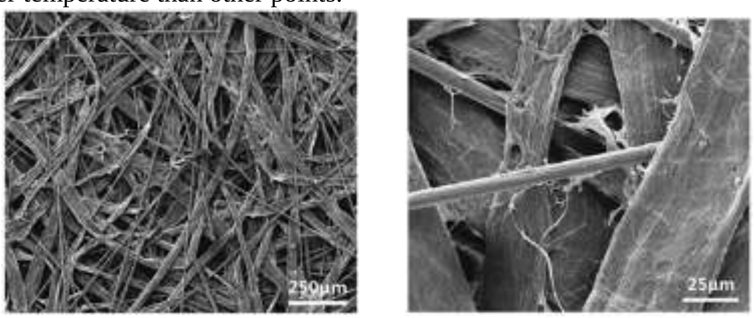


Fig. 9: Temperature responses for different points on 10 J impacted laminate under transmission mode.[2]

The fiber structure and polymer matrix will show the different transient temperature responses as they have different specific electric and thermal properties.In heating phase point A and C have almost similar temperature in early stage, showing higher temperature than B and D since both are of conductive carbon fiber however after 500ms A and B shows higher temperature. While cooling, A and B shows higher temperature than other points.

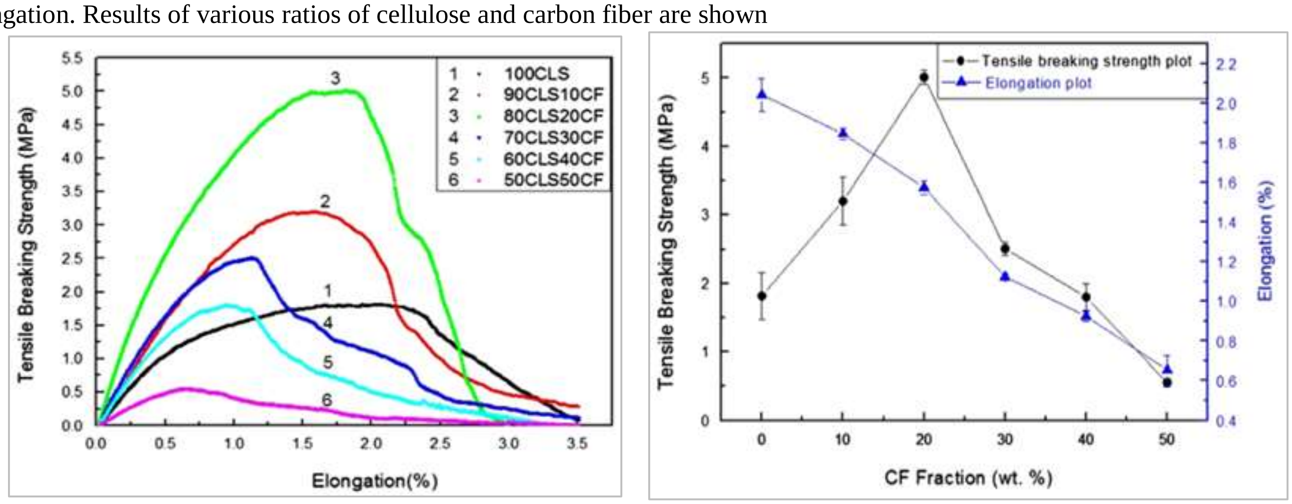


(a) (b)

Fig. 10: SEM images of the CF/CLS composite papers (20 wt% of CF).[3]

As we can see from images in Fig.10 the cellular structure of cellulose was squashed after mechanical beaten, providing larger superficial area. The flexible cellulose fibers with large superficial area can offer sufficient frictional force and entanglement.

Results of testing material on universal testing machine are shown if Fig.11 as graph of tensile strength versus percentage elongation. Results of various ratios of cellulose and carbon fiber are shown



(a) (b)

Fig. 11: CF/CLS composite papers of different CF fractions: (a) tensile test average curves and (b) tensile breaking strength and elongation values as a function of CF fraction.[3]

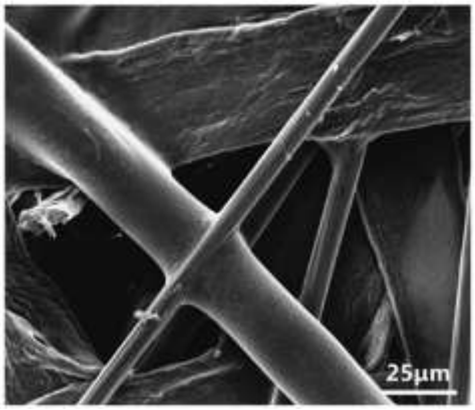


Fig. 12: SEM images of the CF/CLS/HMF composite papers (5 wt% of CF, 57 wt% of CLS and 38 wt% of HMF) at 1000X[3]

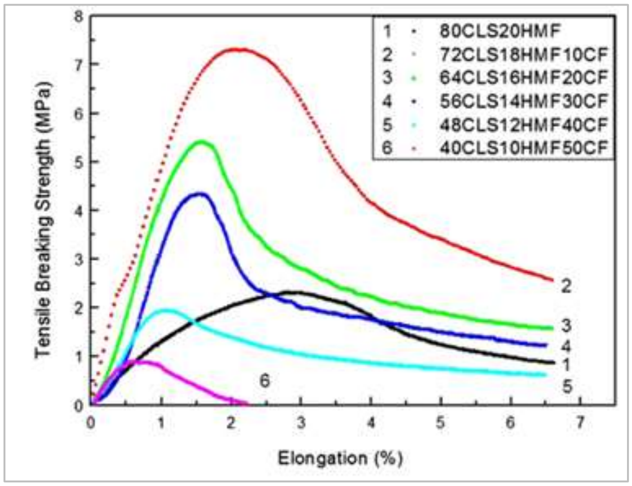


Fig. 13: CF/CLS/HMF composite papers of different CF fractions: tensile test average curves[3]

When compared, modified CF/CLS paper shows enhancement in mechanical properties than that of unmodified, this has occurred due to binding forces provided by hot melting fibers. These contribute to the stress transfer and dispersion. However, the modified papers show an earlier decline in breaking strength with the addition of carbon fibers. This is mainly caused by the reduction of binding joints formed by hot-melting fibers, as well as the reduction of inter-fiber forces provided by cellulose fibers.

III. CONCLUSION

From various experimentation done by research team it is clear that addition of CNT or nanoclay which in this case is montmorillonite Nanoclay properties of CFRP are showing promising increase and enhancement. As well as for NDT testing the early stage of heating phase is suitable for carbon fiber mapping and that both latter heating phase and cooling phase can be used for impact characterization. Both results under reflection mode and transmission modeillustrate that the detection of impact is mainly based on the carbon structure broken and conductivity change but not the thickness change using eddy current pulsed thermography.

Composite papers which are modified, shows better mechanical properties than unmodified. Tensile strength for both modified and unmodified papers first increases then decreases with increase in carbon fiber fraction.

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