Influence of surface activated carbon nano fibres on mechanical properties of poly ether ketone (PEK)

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Abstract. This investigation highlights different surface functionalization processes of Carbon Nano Fibres (CNF’s) and their effects on mechanical properties of Polyetherketone (PEK) nano composite. Surfaces of CNF’s were modified by low pressure plasma process. There is a significant change in physico-chemical characteristics of CNF’s after low plasma treatment as evident from Transmission Electron Microscopy (TEM) and Fourier Transform infrared Spectroscopic (FTIR) studies. Significant modification in surface morphology and oxygen functionalities are observed as a result of surface modification. There is a significant increase in mechanical properties of high performance polymeric nano composites when surface functionalized CNF’s are dispersed in polymeric matrix.

1. Introduction

Polymer matrix composites (PMC’s) are a judicious combination of matrix and reinforcement. The resistance of the PMC towards most of degrading environment is determined by the matrix. Few such processes include impact damage, delamination, water absorption, chemical attack, and high-temperature creep. Thus, the matrix is typically the weak link in the PMC structure. The reinforcement is responsible for providing high strength to the composites. The most common reinforcements presently in use are glass, graphite and aramid. In the last decade, extensive researches were carried out on the use of nano particles as reinforcements. The major issue pertaining to the use of nano particles is the interfacial adhesion and dispersion of the nano particles within the polymers. The interphase is the region between the polymer and reinforcement responsible for load transfer [1]. These problems can often be controlled by using an appropriate coating on the reinforcing fibers. This investigation highlights the effect of plasma modification of carbon nano fibres on the various properties of PEK high performance composites.

2. Experimental

In this investigation, two types of composites were prepared. PEK with unmodified CNF’s and PEK with plasma treated CNF’s subjected to mechanical testing. CNF’s were dispersed in PEK matrix with 2% weight ratio. The matrix and reinforcement were compounded in a twin screw extruder at a
temperature of 400 °C. The compounded material was fed into a 1500Bar injection molding machine. Two kinds of samples were developed from injection molding machine. FTIR spectra were recorded by an apparatus developed by Nicolet iS10 spectrometer. FTIR was performed to find the presence of new functional groups due to the exposure to plasma. Transmission spectra in the range of 4000–400 cm⁻¹ were studied with a resolution of 4 cm⁻¹. Transmission electron microscopy was to study the dispersion of modified and non modified CNF’s in the polymeric composite samples.

3. Results and Discussion

3.1 FTIR results
Fourier Transform Infrared Spectroscopy (FTIR) is a method to obtain an infrared spectrum of absorption or emittance of solid or liquid. The FTIR spectrum reveals significant information on the formation of new functional groups in CNF’s as a result of the interaction with plasma. The FTIR images of unmodified and modified CNF’s is as shown in Figure 1 and 2.

![Figure 1. FTIR plot for unmodified CNF.](image1)

![Figure 2. FTIR plot for modified CNF.](image2)
The above FTIR figure shows that there is a significant change in the oxygen functional groups when exposed to oxygen plasma. This clearly indicates that the surface of CNF is being modified. Therefore, by functionalizing the nano particles, the dispersion and interfacial bonding between CNF’s and polymers can be enhanced [10]. Many studies have been reported using Single Wall Carbon Nanotubes and Multi Wall Carbon Nanotubes as reinforcements for polymeric composite materials to improve the properties of the material [2-4].

3.2 Tensile strength

The polymeric composites reinforced with unmodified and modified MWCNT’s were subjected to tensile test. The specimens were tested on a ZWICK ROELL machine with a capacity of 10KN. The results of composites with unmodified and modified CNF are as shown in Figure 3.

![Figure 3. Mechanical strength of composites.](image)

Figure 3 clearly indicates that there is a significant increase in the mechanical strength of composites on reinforcing modified CNF. This increase in the mechanical strength is attributed to the high interfacial adhesion developed between polymer and reinforcement. It is also observed that there is an increase in the tensile strength of PEK composites due to the influence of carbon nano fibre. CNF when reinforced in PEK gives increased strength due to the exceptional modulus of the nano filler combined with the large surface area [5-6]. In this context, research on PEK reveals that the backbone of PEK is especially rigid because of dominant phenyl groups. The side groups and the regularity of the polymer are basically semi crystalline in nature. This semi crystalline structure of PEK, coupled with the presence of dominating phenyl functional groups in the polymeric chain, provides PEK with exceptional resistance to radiation similar to that of PEEK. The energy of the radiation is thus dissipated within the crystallites through a phenomenon known as the “cage effect” and within the many aromatic structures of the phenyl groups, thus avoiding damaging the structure and the bonds of the molecules [7-8]. Therefore, it can be concluded that the presence of a strong and rigid backbone may explain why the mechanical properties are not affected after exposure to the aggressive environments [9].

3.3 TEM analysis

TEM is performed on the composite samples to study the effect of modification of nano particles in the dispersion of nano particles in composites. Figure 4 and Figure 5 shows the TEM micrographs of polymeric sample.
Figure 4. TEM of unmodified CNF composite
Figure 5. TEM of modified CNF composite

Figure 5 clearly shows that there is a better dispersion of CNF’s in polymers when CNF’s are functionalized. This is also attributes to the enhanced mechanical strength when plasma modified CNF were reinforced in the composites.

4. Conclusion

It has been noted that there is appreciable changes in the mechanical properties of composites after reinforcing modified CNF. TEM results also show that there is better dispersion of nano fibres in polymers after modification. FTIR results conclude significant enhancement in oxygen linkages after modification. These studies make it evident that modification of nano particles enhances the dispersion and interfacial adhesion.

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