# MECHANICAL BEHAVIOUR OF MWCNT REINFORCED POLYMER COMPOSITES: A REVIEW

Engineering

**KEYWORDS:** -Carbon nanotubes, polymers, young's modulus, strength

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## ABSTRACT

Modern day engine ering applications are highly dependent upon the type of material selection. Considering that wide variety of applications require a combination of properties, scientists prefer using various types of composite materials. Carbon Nanotubes have gained a lot of attention over the past few decades as an ideal filler material for polymer based composites which impact high strength, thermal stability without altering the weight of the composite material. In this paper, we present mechanical properties of various polymer composite materials like Ultra high molecular weight polyethylene, Nylon-610, Polyurethane, Nylon-6, Polycarbonate, Poly(methyl methacrylate), Polyethylene, Polypropylene etc. with small compositions of carbon nanotubes

## 1. INTRODUCTION

Carbon nanotubes (CNTs) were discovered in 1991 by Ijima and since then they are used as an ideal reinforcement for polymers because they have excellent mechanical properties and high aspect ratio. CNTs have strength 100 times greater than that of steel. They are tubular cylinders of carbon atoms that have brilliant mechanical, electrical, thermal, optical and chemical properties. CNTs are the stiffest and strongest man-made material. They have high flexibility, low mass density, high aspect ratio and very small size. CNTs have diameter ranging from less than 50 nm and have length of several microns. The properties of the material with which they are doped enhances if the proper dispersion of CNT into the polymer matrix takes place .CNTs consist of graphene sheets rolled into cylinders. CNTs are of two types: Single Walled Carbon Nanotubes (SWCNTs) and Multi Walled Carbon Nano Tubes (MWCNTs). SWCNTs have a single cylindrical wall. The structure of SWCNT can be visualized as a layer of graphite, called graphene which is rolled into a seamless cylinder. The diameter of SWCNTs is upto 1nm. The tube length may be thousand times longer. MWCNTs can are co-axial assembly of SWCNT similar to co-axial cable or as a single sheet of graphite rolled into shape of a scroll. The diameter of MWCNT is from 5nm to 50nm. MWCNTs have tensile strength upto 1000GPa and Young's modulus of elasticity upto 4000GPa.

Several methods have been used to fabricate polymer/CNT composites including electrostatic spraying technique ,twin screw extrusion, solution blending and compression moulding solution compounding, melt compounding, and in situ polymerization. But due to the high surface area and strong van der Waals forces, the complete dispersion of CNT into composite matrix is difficult.

The manufacturing technique and the processing conditions have a great effect on the mechanical properties of polymer composites because they decide degree of dispersion and distribution of filler in the polymer matrix. Chemical modification may improve the shear strength but that can introduce defects into CNT structure and can also degrade the property. Melt-mixing and injection molding is chosen as the baseline fabrication method due to its simplicity and widespread use in the polymer processing industry.

Study of CNT composites so far have largely focused on improving the homogeneous dispersion of CNT in polymer matrix and the strong interfacial interaction with the matrix so as to effect efficient load transfer from polymeric matrix to CNTs. CNTs in very small volume are used so that proper dispersion of CNT into polymer matrix takes place. Surface treatments of CNTs are commonly used to enhance interfacial adhesion between CNTs and polymer matrices.

## 2. LITERATURE SURVEY

Bakshi et al. Fabricated MWCNT reinforced ultrahigh molecular weight polyethylene (UHMWPE) composite by using the electrostatic spraying technique with 5wt% addition of MWCNT. They used MWCNTs of purity more than 94%. They used various test to investigate the surface and mechanical properties of composite material like XRD, DSC, SEM and Tensile test. The X-ray diffraction (XRD) results showed a decrease in crystallinity of UHMWPE film from 55% to 43% with incorporation of 5wt% MWCNT. Differential Scanning Calorimetry (DSC) results also showed a decrease in crystallinity from 58% to 48%. SEM images showed the pullout like regions and depression of cup shape in UHMWPE-5wt% MWCNT sample.

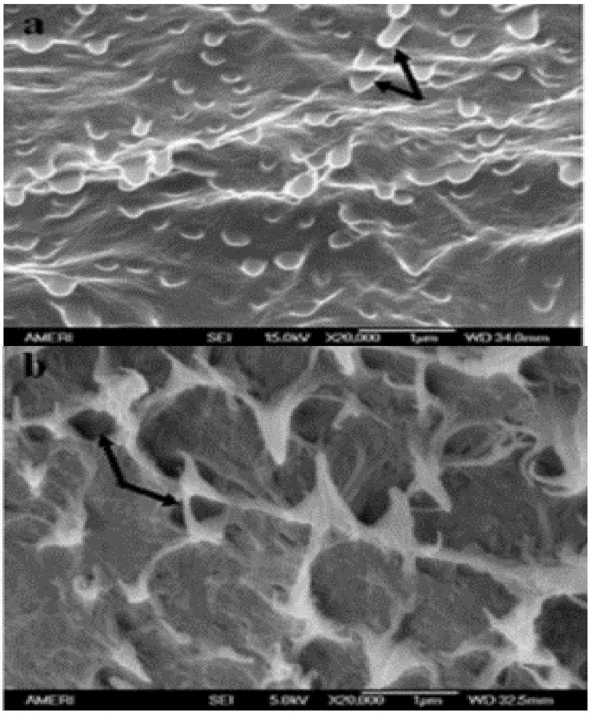


**Fig.1 SEM images of the fracture surface of MWCNT reinforced UHMWPE film showing (a) pullout like regions and (b) regions from where pull-out occurred.**

Tensile test showed an increase in Young's modulus by 82%, but the stress and strain at which failure occurs decreases from 14.3MPa to 12.4MPa and 3.9% to 1.4% respectively.

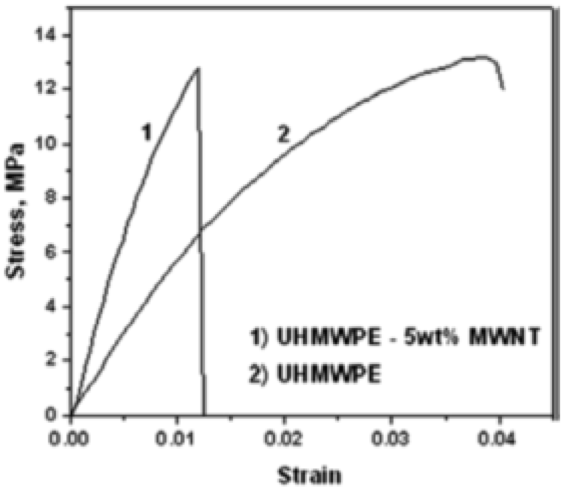


**Fig.2 Stress-strain curves for UHMWPE and MWCNT reinforced UHMWPE**

Kim et al. Fabricated MWCNT reinforced Nylon 610 composite by in situ interfacial polymerization by 0.1wt% addition of MWCNT. The purity of MWCNT used was more than 95%. SEM results showed the nascent morphology of the MWCNT in Nylon 610 matrix. TEM results showed the dispersity of MWCNT in the composite. The tensile test showed increase in strength and Young's modulus from 33.5MPa to 43.9MPa and 886MPa to 1352MPa. But the elongation at which break occurs decreased from 11.9% to 4.5%.

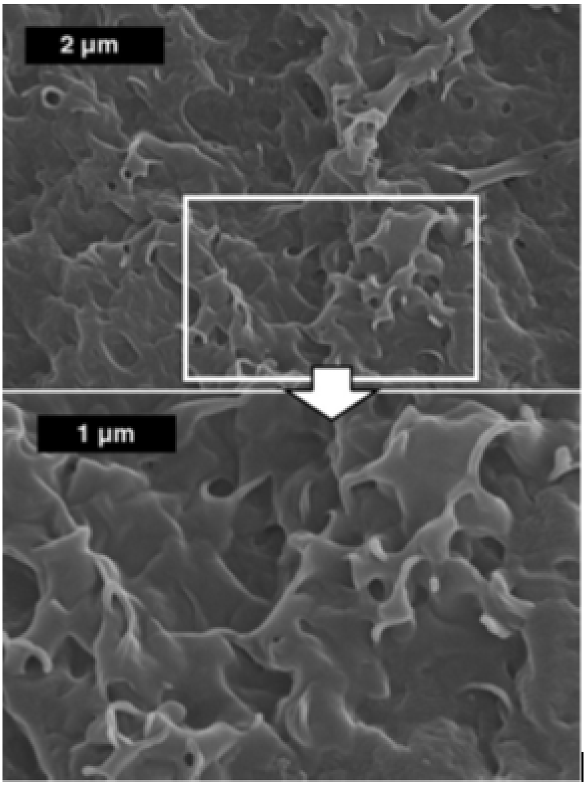


**Fig.3 SEM images of fractured surface of MWCNT reinforced Nylon 610**

X. Wang et al. used the drawing and stretching technique to fabricate the CNT/Nylon composites to improve CNT alignment. The strength increased by 50%, 150% and 190% by stretching 2%, 4% and 7% respectively. The Young's modulus increased by 50%, 200% and 290% by stretching 2%, 4% and 7% respectively

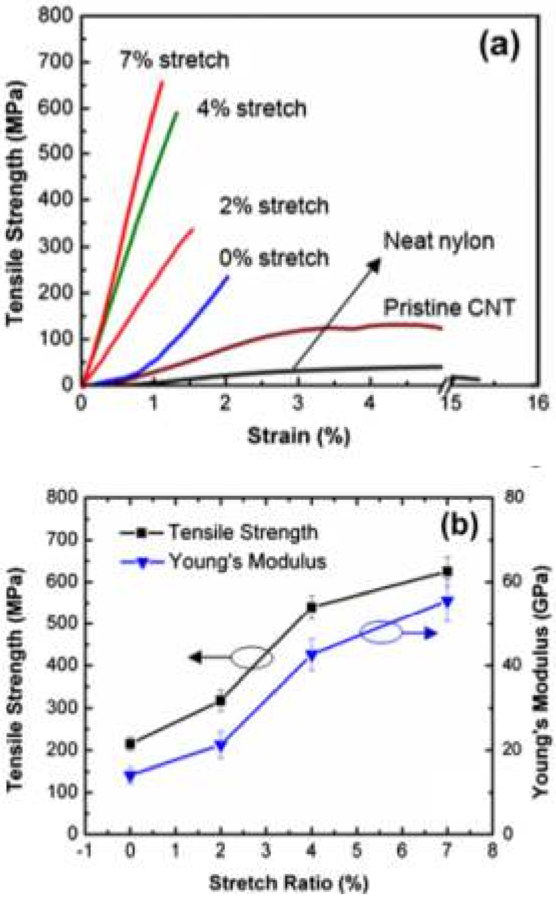


**Fig.4 (a) Stress-strain curve for different stretch ratio of composites (b) Comparison of Young's modulus and tensile strength of CNT reinforced Nylon composites with different stretch ratios**

SEM images indicated that the after stretching CNTs were much straighter and better aligned than the CNTs in as drawn ribbon

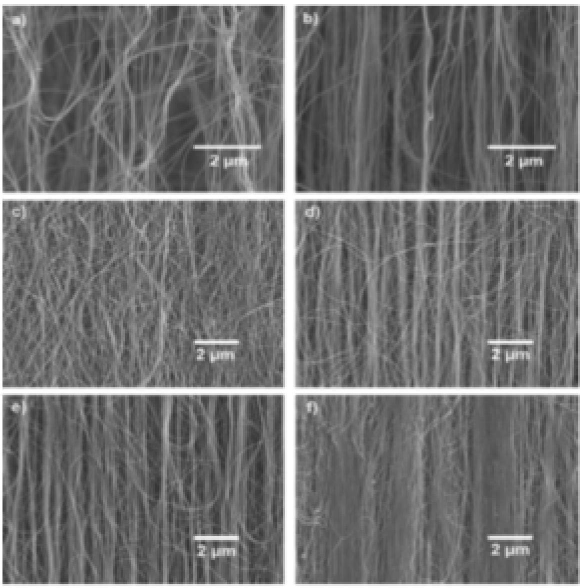


**Fig.5 SEM images of (a) as-drawn CNT (b) stretched CNT (c) non-stretched CNT/Nylon composite (d) 2% stretched (e) 4% stretched ( f ) 7% stretched**

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Chen et al.[9] Fabricated CNT reinforced polyurethane (PU) composite by twin-screw extrusion method. SEM results showed that embedded MWCNT were wrapped by the PU matrix. TEM images showed no aggregation and uniform dispersion of MWCNT in PU matrix took place.

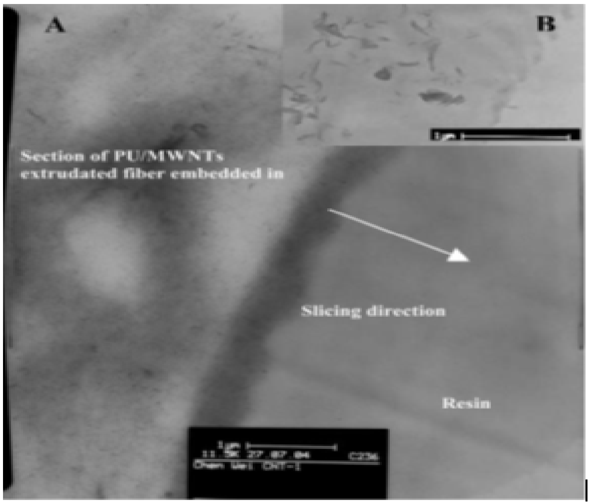



**Fig.6 (a) TEM images of PU containing 9.3 wt% of MWCNT**

Mechanical test showed that compared with pure Thermoplastic polyurethane(TPU), the tensile modulus and tensile strength are improved without decreasing high elongation at break by incorporating MWCNTs less than 9.3wt%

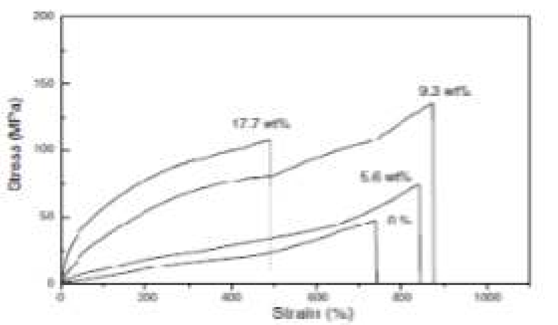



**Fig.7 Stress-strain diagram for MWCNT reinforced PU composite**

Liu et al. Fabricated MWCNT reinforced Nylon-6 composites with different percentage of MWCNT by melt compounding method. TEM results showed the homogeneous dispersion of MWCNT in the composite matrix. SEM results showed that uniform dispersion of MWCNT and strong interfacial adhesion with the Nylon-6 matrix

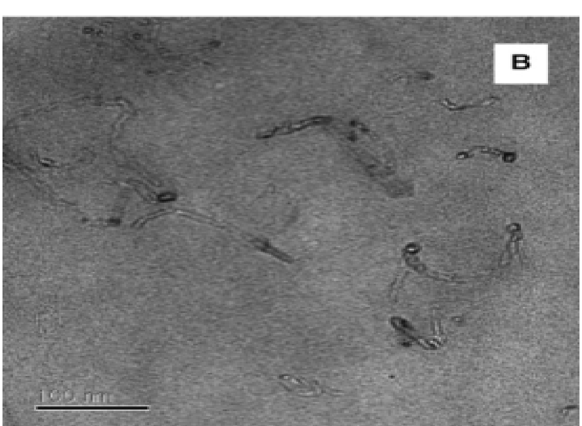



**Fig.8 TEM image of MWCNT/Nylon-6 composit**

Mechanical test showed that Young's modulus, yield strength and hardness increased by 214%, 162% and 83% with incorporation of less than 2wt% MWCNT. But the elongation at which break occurs decreased slightly.e

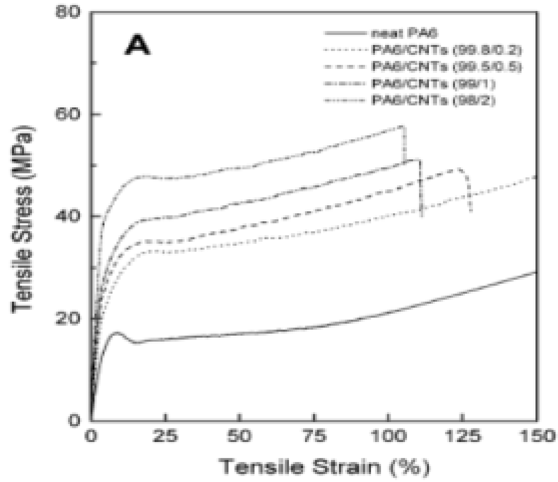



**Fig.9 Stress-strain diagram**

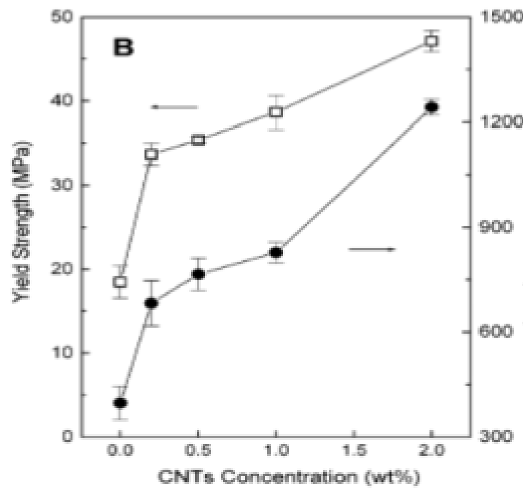



**Fig.10 Tensile stress and tensile modulus for Nylon-6 composite with different concentrations of MWCNT**

Jindal et al. Fabricated MWCNT-Polycarbonate (PC) composites by solution blending and compression moulding technique. The MWCNT content was varied from 0.5 to 10wt%. SEM images show the extent of dispersion of MWCNT in PC.

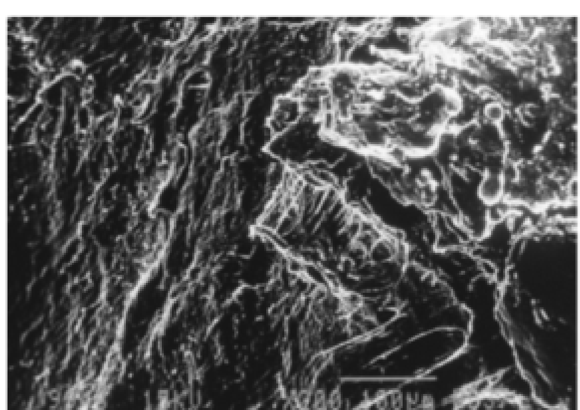


**Fig.10 SEM image for PC containing 5wt% MWCNT**

They used nano indentations techniques for evaluating elastic modulus and hardness. The results showed an increase in elastic modulus and hardness by 95% and 150% respectively by incorporating MWCNT upto 2wt%.

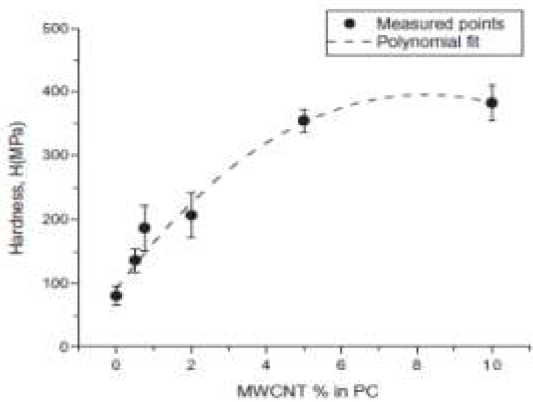



**Fig.11 Hardness as a function of MWCNT content in PC composite**

S. Jindal and P. Jindal have done some mechanical test for computing the hardness and tensile strength of CNT reinforced Poly methyl meth acrylate (PMMA). TEM image showed good dispersion of MWCNT in PMMA polymer matrix.

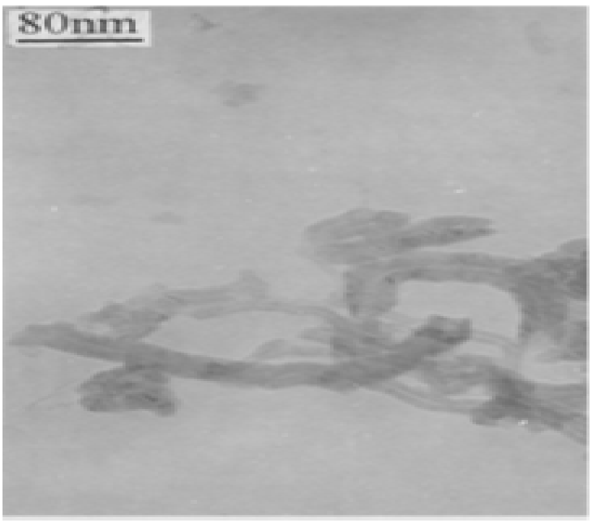
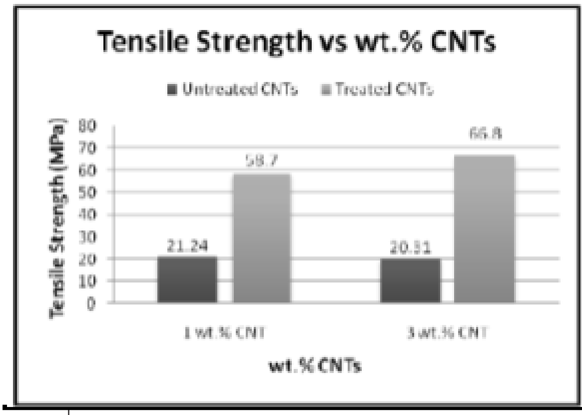



**Fig.12 TEM image of MWCNT reinforced PMMA**

Mechanical test showed an increase in tensile strength and hardness by 176% and 95% by adding 1wt% MWCNT respectively. By adding 3wt% MWCNT tensile strength and hardness increased by 230% and 158% respectively



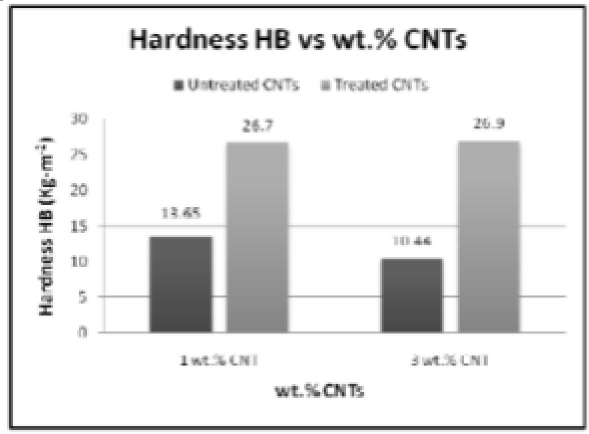




**Fig.14 Hardness comparison**

Xiao et al. Fabricated MWCNT reinforced Low density polyethylene (LDPE). TEM images showed the proper dispersion of MWCNT into polymer matrix

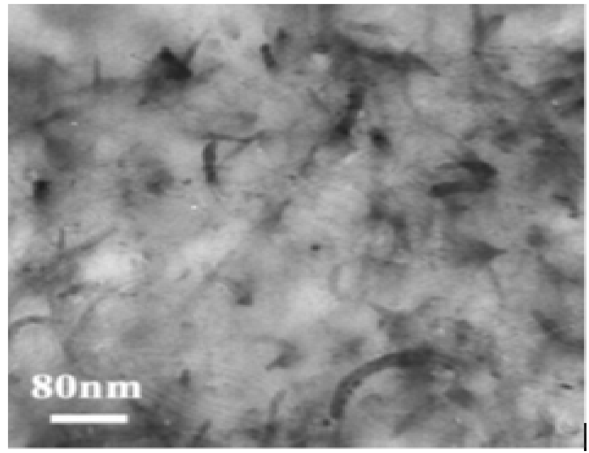
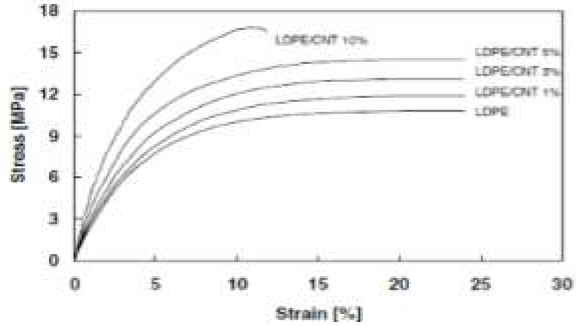



**Fig.15 TEM image of 3wt% MWCNT LDPE composite**

Mechanical test showed that Young's modulus and tensile modulus increased by 89% and 56% by adding MWCNT upto 10wt% but the strain at which failure occurs decreases



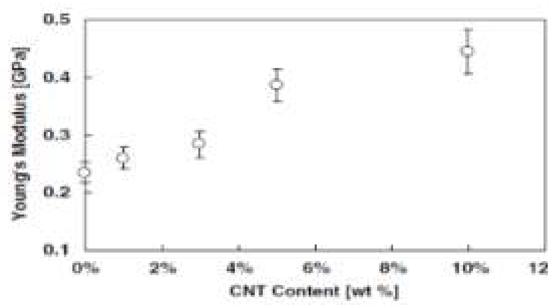




**Fig.17 Young's modulus as a function of CNT content**

There is a sudden increase in Young's modulus when content of CNT is increased from 3wt% to 5wt%.

Prashantha et al. Fabricated MWCNT reinforced Polypropylene (PP) using melt compounding technique. TEM images showed good dispersion of MWCNT in PP matrix.

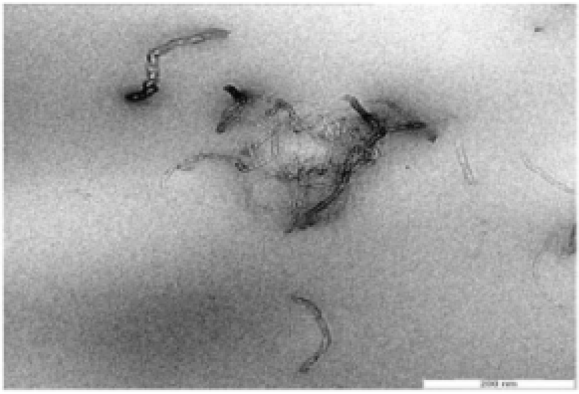


**Fig.18 TEM image of MWCNT-PP composite**

Stress-strain diagram showed that a ductile behavior of MWCNT-PP is observed for 1-2wt% of MWCNT whereas for 3-5wt% of MWCNT brittle behavior.

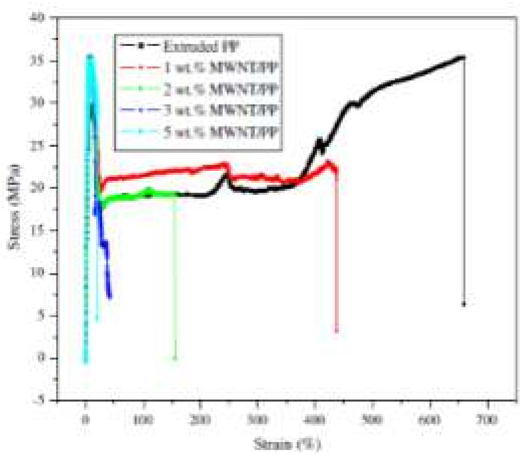



**Fig.18 Stress-strain curve for MWCNT-PP**

Young's modulus also increased with incorporation of MWCNT into the matrix.

## CONCLUSIONS

It was observed that the young's modulus, tensile strength, hardness increased with incorporation of small wt% of MWCNT into the polymer composites but the elongation at which fracture occurs decreases.

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