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Fabrication and characterization of carbon nanotubes-based Polymer nanocomposites

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ABSTRACT

Polymer nanocomposites are used in different application such as load bearing, aerospace and biomedical etc. Present work describes the fabrication and preparation of carbon nanotubes based polymer nanocomposites by an injection molding machine. Multi walled carbon nanotubes reinforcement was mixed with pure polymer (high density polyethylene) of injection moulding grade matrix. The resultant matrix shows remarkable strength as compare to pure material due to material behaves like as composites. The carbon nano fluid was mixed with HDPE pellets for CNT coated HD PE pellets. This coated pellets used as raw material for an injection molding to form "dog bone shaped" CNT/HDPE tensile specimens of dimensions 120 mm long, 2 mm thick according to ASTM. Different weight fractions of CNT were mixed with pure material and improvement in the strength, toughness, young modulus, stiffness etc. were studied using universal testing machines, Scanning electron microscopy and optical microscopic. It was concluded that the composites have higher mechanical properties compared to pure material.

Keywords: A.CNT, B. PE, C. Injection molding machine, D. Instron UTM

INTRODUCTION

Nanotechnology has impacted research in many areas from materials to biology.[1]Nanomaterials are at the leading edge of the rapidly developing field of nanotechnology.Nanocompsites can be defined as multiphase solid material where one of the phase has one ,two or three dimensions of less than 100 nanometers(nm) or structure having nano-scale repeat distances phases that make up the material.[2]In mechanical terms, nanocomposites differ from conventional composer material due to the exceptionally high surface to volume ratio of the reinforcing phase or its exceptionally high aspect ratio.[2] The polymer nanocomposites properties related to local chemistry, degree of thermoset cure, polymer chain mobility,polymer chain conformation, degree of polymer chain ordering or crystallinity can all vary significantly and continuously from the interface with the reinforcement into bulk of the matrix. Polymer matrix can enhance its performance by simply capitalizing the nature and properties of nanoscale filler.[3] A nanometer Carbon nano tubes(CNTs)[4] are allotropes of carbon with a cylindrical nanostructure.[5] CNT significantly larger than any other material. These cylindrical carbon molecules have novel properties that make them potentially useful in many applications in nanotechnology, electronics, optics and other fields of materials science, as well as potential uses in architectural fields. They exhibit extraordinary strength and unique electrical properties, and are efficientthermal conductors[6] Their final usage, however, may be limited by their potential toxicity. Their name is derived from their size, since the diameter of a nanotube is on theorderof a few nanometers (approximately 1/50,000th of the width of a human hair), while they can be up to several millimetres in length.Nanotubes are categorized as; single walled nanotube (SWT), and multi walled nanotube(MWT).Carbon nanotubes are 1000x tubes thinner than an average human hair and 200x stronger than steel. The first synthetic material to have greater strength than spider silk. Excellent conductors of electricity and heat. It have huge potential for product development. Strongest known material. 200 times stronger than steel 40 times more conductive than aluminium.[7]

Table 1: Comparision of mechanical and thermal properties of CNTs to other conventional

Material	Young's modulus (E)	Tensile strength	Thermal conductivity
Aluminium	72GPa	676MPa	222W/m.K
Copper	128GPa	130MPa	393W/m.K
Steel	200GPa	1,965MPa	52 W/m.K
Cabon nano tubes	1,250GPa	3000MPa	6,000W/m.K

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MATERIALS AND METHODS:

PE material had provided by Haldia.Helene is the registered trade mark of high density polyethylene. FR5400 is a film grate HM-PE and it has excellent mechanical strength. Barrel temperature of melting point inside injection moulding machine is 220-50°C.[6]Carbon nano tubes(CNT) purchased from china. The specification of multiwalledcarbon nanotubes are as follow;[8] Range of diameter: 80 nm, length of tube 12 µm, Purity : 97%,density of MWCNTs are: 2.16 gm/cm.[9]

Preparation of CNT-HDPE pellets .

The nanofluid, which was prepared with equired quantity of CNT, was mixed with PE pallets. This mixture was heated andstirred continuously to have a uniform coating on the PE pallets. Once the fluid was evaporated, these pellets were kept in an oven for 4 h at 100° C to evaporate addition moisture present on the CNT coated pallets (Figure – 1).[10-16]

Figure 1:CNT coated HDPE pallets

PREPARATION OF TENSILE SPECIMEN

The CNTs coated PE pallets used in raw material of an injection moulding machine PE was melted in injection moulding machine which was kept at 220 ºC to induce sufficient softening of polymer to mix with CNTs and this mixture injected into a tensile specimen mould the sample was prepared at 0.04% CNT in PE. The injection moulding machine used for plastic manufacturing process like injection or blow moulding unit. The test specimen has the shape of a tensile dog bone shape of a tensile dog bone, 100mm long, with the centre section 10mm wide by 2mm thick and 50mm long.[17,18] Specification of moulding machine (Figure – 2) used in this study is given below:[9-12]

Model no *Tex air JTS – 40*
Barrel temperature *180-360ºC*
Pressure *32-100 bar*
Injection shot capacity 100 gm/cm²

RESULTS AND DISCUSSION

The dog bone shaped tensile specimen (Figure – 3) according by ASTM tested on instron UTM (Figure – 4) and carried the mechanical properties modulus of elasticity, tensile strength,peak stress and ultimate strength of the material.

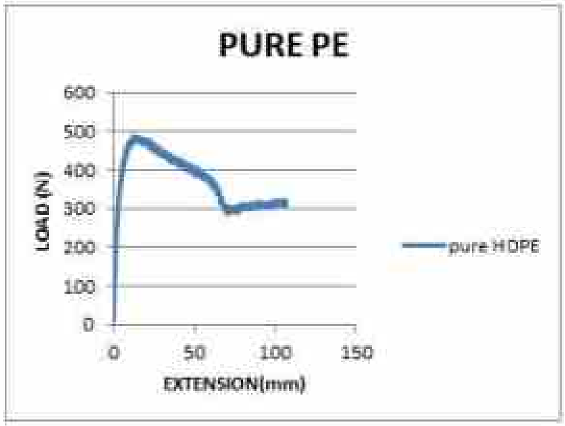
Tensile test on instron UTM

Tensile test of the specimen was carried on instron UTM.The elastic,modulus ,ultimate, strength, Peak stress and Fracture were measured. Figure – 5 (A) and (B) shows the laod vs extension curve of CNT/HDPE composite and pure HDPE sample[8].The cube type 0.04wt % of CNT-HDPE sample gripped of instron UTM.The carbon nano tube added in pure material HDPE to decreases the wear properties due to increase the mecahnical properties. Various properties of Pure and 0.04wt % CNT added on PE polymer compared and summerized in Table-2.

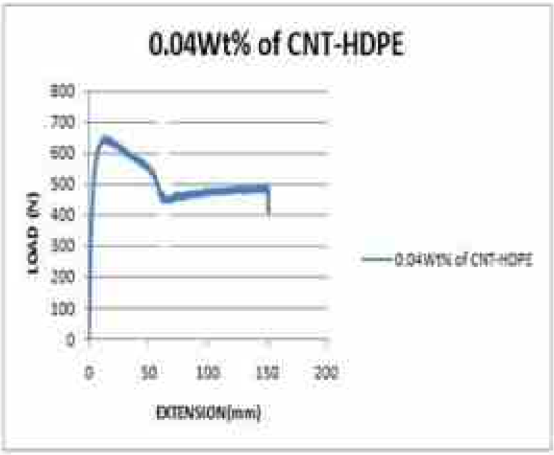
Figure 2: Injection moulding machine

Figure 3:Tensile specimen of pure and 0.04 wt % of CNT by using injection moulding machine.

Figure 4: Instron Universal testing machine



(A) Load vs extension curve of PURE PE



(B) Load vs exteusion curve of 0.04

Figure 5

Optical Microscopic Studies

After performing the punch tests the polymer samples and CNT polymer were studied under Optical Microscope for good homogeneous mixture of CNT and PE material before and after fracture (Figure – 6 and 7).

Table 2 Comparison of Pure and 0.04wt % CNT added on PE polymer

WT% of CNT	Modullus of Elasticity (Mpa)	Load (N)	Tensile stress	Elongation of %
0.00-I	141.63	483	12.33	Up to 100mm
0.00-II	141.93	484	12.34	Up to100mm
0.04-I	162.23	612	13.14	Up to 100mm
0.04-II	162.28	614	13.18	Up to 100mm

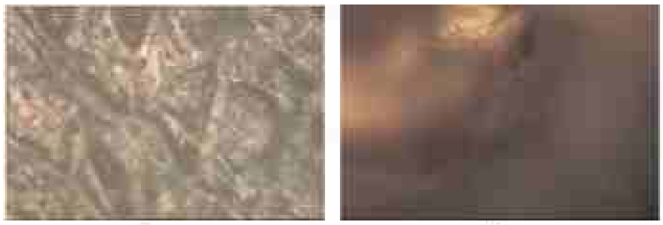
Scanning Electron microscope Studied

Scanning electron microscope analysis

Gold coated PE-CNT polymer nanocomposite sample to keep inside SEM for morphological image of the sample and carried the good homogeneous dispersion of CNT and PE matrix as shown micrographs image CNT/PE composites at 1kx magnification (Figure – 8).

CONCLUSION:

If volume fraction of cabon nano tube is increased with the material reduce volumetric wear of the material as well as improvement on young,s modulus, stiffness,toughness,wear resistance and rigidity with an addition of CNT. The carbon nano tube (CNT) have been used with polymer to make composite having remarkable properties .A considerable improvement on mechanical properties.



A B

Figure 6: Optical microscopic image of Pure polymer before fracture (A), and after (B)

A B

Figure 7: Optical microscopic image of 0.04wt % of CNT/PE nanocompositesbefore fracture (A), and after (B).

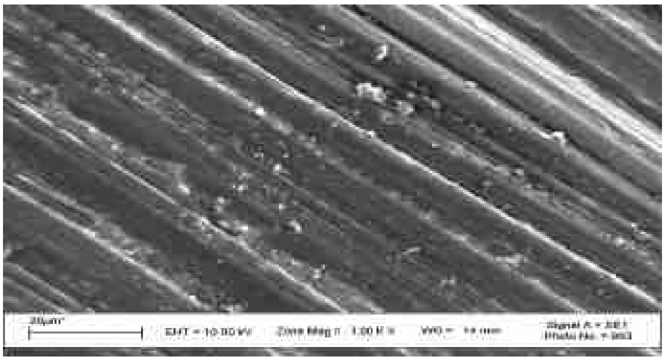


Figure 8: EM image of PE-CNT polymer nanocomposites sample

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