Effect of carbon nanotube and Zn particles addition on the some mechanical properties and thermal conductivity of unsaturated polyester resin

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Abstract

In this research work a composite material was prepared contains a matrix which is unsaturated polyester resin (UPE) reinforced with carbon nanotube the percentage weight (0.1, 0.2, 0.4.0.5) %, and Zn particle the percentage weight (0.1, 0.2,0.4,0.5)%. All sample were prepared by hand lay-up, process the mechanical tests contains hardness test, wear rate test, and the coefficient of thermal conductivity. The results showed a significant improvement in the properties of overlapping, Article containing carbon nano-tubes and maicroparticles of zinc because of its articles of this characteristics of high quality properties led to an, an increase in the coefficient of the rmalconductivity, and increase the hardness values with increased percentage weight when the wear rate increase with increased the applied load and percentage weight.

Key words

unsaturated polyester resin,
carbon nanotube,
zinc,
wear rate,
thermal conductivity

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تأثير انابيب الكاربون النانوية وجسيمات الخارصين المضافة على بعض الخواص الميكانيكية و معامل التوصيل الحراري لراتنج البولي استر غير المشبع

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الخلاصة

تم في هذا البحث تحضيرمادة متراكبة من راتنج البولي استرغير المشبع مقواة بانابيب الكاربون النانوية وجسيمات الخارصين وبنسب وزنية (0.2و0.4و0.8و1%)واستخدمت طريقة القولبة اليدوية في تحضير العينات واجريت اختبارات ميكانيكية تضمنت فحص الصلادة وفحص معدل البلى وقياس معامل التوصيل الحراري.

اظهرت النتائج تحسنا كبيرا في خواص المادة المتراكبة الحاوية على انابيب الكاربون النانوية وجسيمات الخارصين لما تتمتع به هذه المواد من خصائص عالية الجودة ادت الى زيادة في معامل التوصيل الحراري وزيادة قيم الصلادة بزيادة النسب الوزنية ومعدل البلى كان يزداد بزيادة الحمل المسلط وزيادة النسب الوزنية .

Introduction

Carbon nanotubes (CNTs) display a wide range of unique mechanical, optical, and electrical properties along with chemical stability. Their mechanical properties (especially tensile strength) considerably exceed those of currently available iber materials [1]. Recent research articles have reported the use of nanotubes in polymer[2], metal and ceramic matrix composites[3]. In the polymer field, epoxy resin is one of the most often used polymer matrix for advanced composite applications. The group of resins of this family presents good stiffness and speciic strength, dimensional stability, chemical resistance, and also strong adhesion to the embedded reinforcement [4]. The preparation of CNT-reinforced epoxies and any other kind of polymer, however, requires a homogeneous dispersion and a strong interfacial interaction between the nanotubes and the polymer [3].

Polymer matrix composites with carbon nanotube (CNT) reinforcement have become popular in structural applications because of unique atomic structure, very high aspect ratio and extraordinary properties like strength and flexibility of CNT (Wagner et al 1998; Dagani 1999). The high bond strength of the constituent carbon–carbon bonds of multi-walled carbon nanotubes (MWNTs) are the reason behind its outstanding mechanical properties[5].

Usually, composite materials will consist of two separate components, the matrix and the filler. The matrix is the component that holds the filler together to form the bulk of the material. It usually consists of various epoxy type polymers but other materials may be used. Metal matrix composite and thermoplastic matrix composite are some of the possibilities. The filler is the material that has been impregnated in the matrix to lend its advantage (usually strength) to the composite. The fillers can be of any material such as carbonfiber, glassbead, sand, or ceramic [6]. Hardness is the measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Macroscopic hardness is generally characterized by strong intermolecular bonds , however the behavior of solid materials under force is complex, therefore there are different measurements of hardness: scratch hardness, indentation hardness, and rebound hardness., Hardness is dependent on ductility ,elasticity , plasticity ,strain , strength, toughness viscoelasticity , and viscosity ,Common examples of hard matter are ceramics , concrete , metals , and super hard materials , which can be contrasted with soft matter [7]

Wear is the progressive loss of material due tointeracting surfaces in relative motion. It is quantitatively measured as the specific wear rate Ws (definedas volume loss per sliding distance and load [10–6 mm3/Nm]) of a material. Numerous distinct and independent mechanisms are involved in the wear of a polymer. These include:

• Abrasive wear – “cutting” caused by hard irregularities on the countersurface.

• Fatigue wear – failure of the polymer due to repeated stressing from hard irregularities on the counter surface.

• Adhesive wear – loss of polymer by transfer and adhesion to the countersurface.[8]

In physics, thermal conductivity, k, is the property of a material that indicates its ability to conduct heat. It appears primarily in fouriers law for heat conduction. Thermal conductivity is measured in watts per kelvin per meter ($W\cdot K^{-1}\cdot m^{-1}$). Multiplied by a temperature difference (in kelvins, K) and an area (in square meters, m2), and divided by a thickness (in meters, m). The thermal conductivity predicts the power loss (in watts, W) through a piece of material [9].

Balkas,M.T.and hoda,G.A.[10].a The research involves using Epoxy ,Unsaturated Polyester and Novolac resins;they were needed to prepare ternary polymer blends; wear resistance including change load applied, sliding velocity, using these resins with that ratios as 80%/10%/10%). Also hardness (shore) were study before and after immersing in (NaOH,HCl) solutions with(0.5) normality . In general the wear resistance was increased with the load applied (20N) and with immersion time. The effect of base solution was larger than that of the acid. Shore hardness was decreased after immersing in solution.

Fuji et al [11] measured the thermal conductivity of a single MWNT using a suspended sample-attached T-type nano sensor and found to be around 2000

W/m-K. They also showed that the thermal conductivity increased with decreasing diameter of nanotubes.

Frankland et al. [12] investigated the effect of cross-links on the interfacial bonding strength between a SWNT and polymer–matrix (crystalline or amorphous) with MD simulations. They found that even a relatively low density of cross-links could have a large influence on the properties of a nanotube–polymer interface. E. S. Choi et al. [13] showed that the thermal and electrical properties of single wall carbon nanotube (CNT) -polymer composites are significantly enhanced by magnetic alignment during processing. The electrical transport properties of the composites are mainly governed by the hopping conduction with localization lengths comparable to bundle diameters. The bundling of nanotubes during the composite processing is an important factor for electrical, and in particular, for thermal transport properties. Better CNT isolation will be needed to reach the theoretical thermal conductivity limit for CNT composites.

Materials and Methods

1- Polymer: An unsaturated polyester resin (UPE) thermosetting polymer is utilized as the polymer matrix, the density 1.2-1.5 gm/cm^3 the company (IPI) (Intermid Petrochemical Industrial.

2-Fillers: The materials used as filler throughout this study are carbon Nano tube (CNT) and Zn particles size (20µm), the density of carbon nanotube 1.3-2 gm./cm^3, the small size, high surface-to-volume ratios, and the stronger of C-C covalent bonds in carbon nanotubes.

Composite Specimen Preparation

A hand lay-up method was used to prepare the CNT/Zn/UPE composite sheets. Epoxy and hardener were used in this study in ratio of (3:1) for curing with-wall carbon nanotubes(MWNT CNT) (obtained by the Arc-Discharge Technique and diameter40-50 nm[14]. Five samples were prepared with average thickness of 3 mm and different weight fraction of carbon nanotube & Zn micro (0.2, 0.4, 0.8, 1) % according to table (1), out of composite weight. The composite samples were stored at room temperature for 24 h before use for complete curing and to eliminate the effect of moisture. The mechanical balance (mettle H35 AR) of accuracy10^{-4} was used to obtain a weight amount of unsaturated polyester resin and fillers (Carbon nanotube (CNT) + Zn micro particles).

Table1:Weight percentage the CNT and Nano

Carbon nanotube(CNT)	ZINC micro(Zn)
0.1%	0.1%
0.2%	0.2%
0.4%	0.4%
0.5%	0.5%

Wear test

Wear machine consists of an arm metal Flat containing the sample holder to install and a metal disk rotating motor connection Power, speed of disk (500 cycles /Minutes), and the hardness of disk made of iron 9269HBas shown in Fig.1

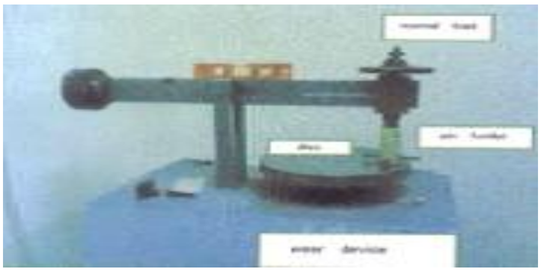

Fig.1: Wear test

And the rate of wear and tear of the mathematical relation, the following**:**[15]

Wear rate = $\Delta W / D_S$ (1)

(gm/ cm)

ΔW :- difference of the mass sample before and after test (gm)

$\Delta W = W1\text{-}W2$ (2)

Is calculated from the following relationship, distance Slide(S_D) (Cm)

$S_D = 2 \pi r n t$ (3)

r:- radius from the center of the sample to Center of the disc(Cm)

N:-Number of sessions of the disk (r/min). T: - Test time (minutes).

Hardness test:-It was measured hardness of the samples in a manner shore(D) and the device used for this test type(shore D Hardness tester TH 210) that is a tool that stitches in needle the surface of the sample and then register the number which comes out on the screen of the device.

Thermal conductivity:-The method of measuring thermal conductivity can be divided in to two categories, static and dynamic, depending on whether the temperature distribution within the sample is time dependent Lee's disc method, which was the method of choice in this work, belongs to the static category in which the equation (1) can be applicable

$$J_Q= - K\, dt \backslash dx \qquad (1)$$

where J_Q is the flux of thermal energy transmitted across unit area per unit time [16].

For the material which has low thermal conductivity, Lee's disc method was adopted. This method is applicable over a wide range of temperature. The arrangement is shown in Fig.2, the sample S was contained between two copper blocks or discs A and B (each 3cm diameter and 13 mm thickness) and there is a heading coil between B and a third copper block C which is of the same dimensions. Temperature of disc A, B, and C are determined using thermometer. The heating coil provides current I = 0.25A and D.C voltage V = 6 v which are held constant for all samples. The following equation was used for calculating the heat received per second (e) by S and passed on to A [17]

$$IV=\pi r^2 e(T_A+T_B)+2\pi re\{d_A T_A+ds.1/2(T_A+T_B)\} +d_B T_B+d_c T_c \qquad (2)$$

where r is radius of the disc and d_s is sample thickness. The thermal conductivity then calculated by

$$K(T_B T_A/d_s)=e\{T_A+2/r(d_A+1/4d_s)T_A+1/2rd_sT_B\} \qquad (3)$$

Fig.2: Lee's disc

Results and Discussion

Wear rate

The applied load was very important parameter which effected on the fraction between the surface of sample and disc will increase the temperature between them. Table 2 shows the values for the wear rate for CNT and Zn particle additives in general; all samples appear increase in wear rate with increase applied load. So that the hardness for their samples will decrease and the fraction will increase.

Both surfaces get between them fraction consists of bumps and grooves and the beginning of contact between the surfaces happens when bumps acute or large size (Zn) of and under the influence of applied load show Fig.3, the stress is concentrated on the bumps acute (Zn), which lead to a distortion born to these bumps, and increasing the load leads to an increase Deformation happening when tops bumps and the region near the surface will become more drilling as a result of the impact of Particle resulting of the from the crash crust surface so that the small cracks with each leading to a removal of layers the surface is composed of debris in the form of particle thin for this Plastic deformation increases with increasing the load[18]

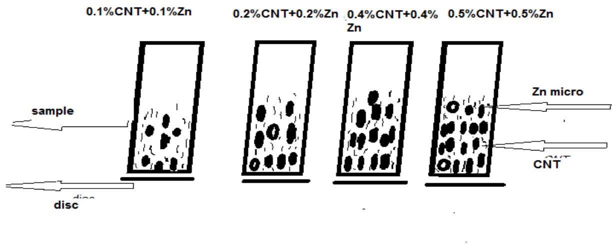

Fig. 3: The fraction between sample and disc

Table 2: The wear rate values as a function applied load

Sample	Wear rate at load 5N	Wear rate at load 10N	Wear rate at load 20N
UPE	1.06*10-8	2.65*10-8	5.3*10-8
UPE+(0.1 %CNT+ 0.1%Zn)	1.59*10-8	4.77*10-8	7.43*10-8
UPE+(0.2% CNT+ 0.2%Zn)	2.6*10-8	5.3*10-8	7.9*19-8
UPE+(0.4%CNT+ 0.4%Zn)	3.1*10-8	6.3*10-8	10*10-8
UPE+(0.5%CNT+ 0.5%ZN)	3.7*10-8	7.9*10-8	12.7*10-8

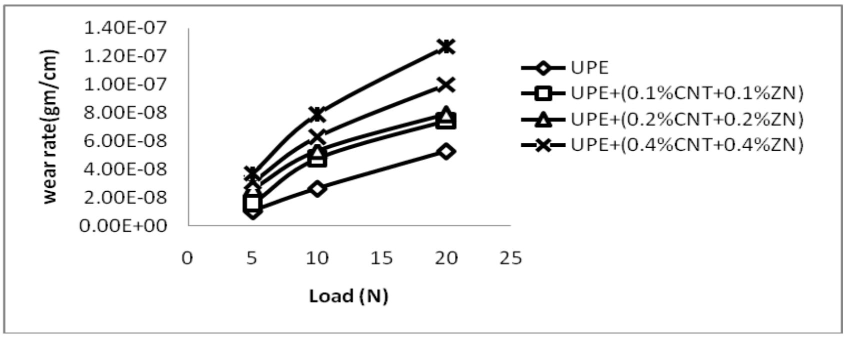

Fig .4: Wear rate as a function load of unsaturated polyester resin filled with carbon Nano tube and Zn.

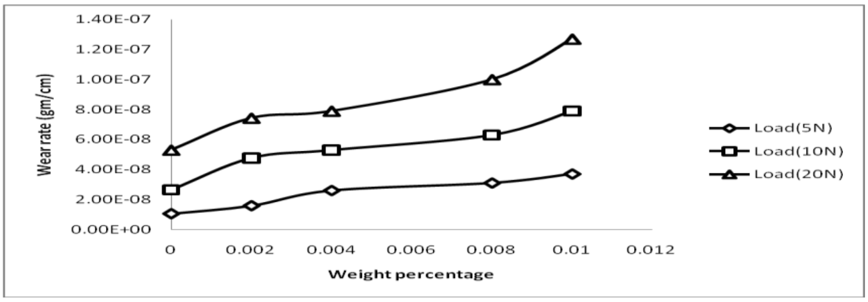

Fig.5: Wear rate as a function weight percentage of unsaturated polyester resin filled with carbon Nano tube and Zn.

Hardness test

The values of hardness increase with increased percentage weight because the metal Zn very hard and carbon Nano tube small size and high surface –to-volume ratios of one –dimensional nanostructures endow for CNTs variety of interesting and useful mechanical properties as well as, The stronger of c-c covalent bonds in carbon nanotube make them one of the strongest in nature and gives carbon nanotube their unique strength, and thus, carbon nanotube are one of the stiffest and most robust synthesized structure.

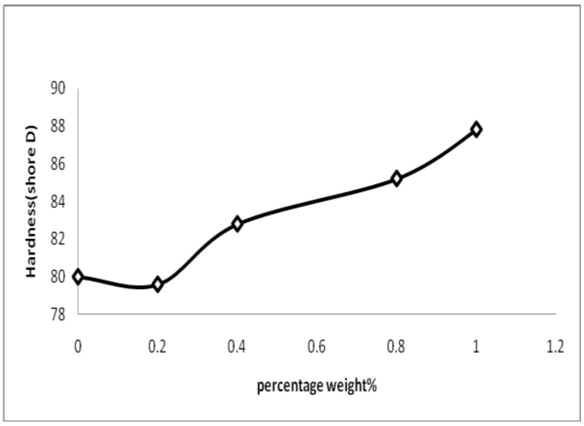

Fig.6: Hardness values of epoxy composites as a function of percentage weight

Thermal Conductivity

The thermal conductivity (k) measurements performed according to the lees disc method .the values of thermal conductivity (k) are calculated according to eq.(2) and (3) ,experimental values of k for pure UPE at room temperature 0.24w/m.k,while the theoretical values are between 0.2-0.32 w/m.k[19]. Fig.6 shows the effect of different CNT+Zn wt.% addition on the thermal conductivity of UPE-(CNT+Zn) composites. The thermal conductivity increased with CNT+Zn wt.% addition because the CNT+ZN is homogeneous in the dimensions this homogeneity reduce the number of contact point between CNT+ZN and the polymers which increases the phonon scattering and grading the mechanisms of heat transfer[20]. The modification of unsaturated polyester resin matrix might be caused the decreasing in the mean distance between neighboring chains and, hence, to increase the elastic constants caused by the intermolecular interaction as a result, thermal resistant is decreased and hence thermal conductivity increased .this explanation is based on the liquid state theory. Another explanation is based on solid state theory deals with the cooperative motion of monomers and the phenomenon a of phonon scattering which limit the region of energies of transfer [21]

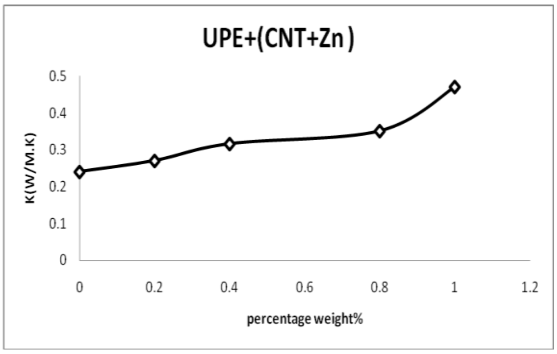

Fig.7: Thermal conductivity of epoxy composites as a function of CNT+Zn weight percentage.

Conclusions

1-Wear rate increase with value percentage weight.

2-Hardness test increase with value percentage weight.

3-Thermal conductivity increase with value percentage weight

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