Enhancing Thermal and Water Absorption Properties of Unsaturated Polyester and Epoxy by Nanocarbon Black Powder

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ABSTRACT

This paper covers the effect of nanocarbon black powder (N220) on the some physical properties (thermal conductivity and water absorption) of unsaturated and epoxy resins filled with nanocarbon black powder (N220). The polymer nanocomposites, were prepared with (1 to 10 wt%) of carbon black nanoparticles using ultrasonic wave bath machine dispersion method. The results had shown thermal conductivity of unsaturated and epoxy resins improved by (131.37% and 78%) respectively, at 10wt. %. The water absorption reduction by (55.41% at 4 wt.%, 51.76% at 6 wt.%) for unsaturated polyester and epoxy nanocomposite, respectively.

Keywords: Nanocarbon black powder, Physical Properties, Unsaturated Polyester and Epoxy.

تحسين الصفات الحرارية وامتصاصية الماءللبولي استرالغير مشبع والايبوكسي بمسحوق الكاربون الاسود النانوي

الخلاصة

هـذا البحـث يغطـي تاثيرمسـحوق الكـاربون الاسـود النانويـة (N220) فـي بعـض الخـواص الفيزائية(الموصـلية الحراريـة وامتصاصـية المـاء) لـراتنج البوليسـتر الغيـر مشـبع وراتـنج الايبوكسـي المـدعم بهمـا .تـم تحضـيرالمتراكبات النانويـة بنسـب وزنيـة مختلفـة (1-10 %) مـن الكـاربون الاسـود النانوي باستخدام طريقة التشتت بالموجات فوق الصوتية .وبينت النتائج ان الموصلية الحرارية لكل من راتنج البوليستر الغير مشبع وراتنج الايبوكسي على التوالي حسنت بنسبة (131.37% و78%) عند كسر وزنـي (10%).امـا امتصاصـية الامـاء فقد انخفضـت بنسـبة (55.41% عند كسر وزرنـي 4% و51.76% عنـد كسـر وزنـي 6%)لكـل مـن راتـنج البوليسـتر الغيـر مشـبع وراتـنج الايبوكسـي علـى التوالي.

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NOMENCLATURE

A	Cross sectional area	wt.%	Weight fraction
CB	Carbon black	W.R	Water absorption
d	Thickness of specimen (m).	m1	Mass before immersion in liquid
d1,d2&d3	Thickness of disks (m).	m2	Mass after immersion in liquid
e	Heat loss per unit time (sec.) through the cross sectional area (m^2) and temperature difference between the disc and environment.	Δm	Mass loss
I	Electric current (A)	PNCs	Polymer nanocomposite
r	Radius of disk (m).	T	Temperature (°K)
K	Thermal conductivity (W/m.°C)	T1, T2, & T3	The measured temperatures in disks no.1,2 and 3.(°K)

INTRODUCTION

Thermosets polymer such as epoxy and unsaturated polyester resins are the most commonly used in a variety of applications due to their excellent properties, such as thermal stability, mechanical response, low density and electrical resistance[1].These resins are inherently low in thermal and water absorption .For this reason application that require physical properties such as thermal and water absorption which could also benefit from the use of thermosets polymer because of their light weight, high strength/weight ratio, easy mold ability ,etc, cannot take advantage of this desired material [2,3].

A new approach aiming to overcome this basic problem is related to the nanotechnology and uses fillers in the nanometer scale. One aspect of nanotechnology is the possibility to design materials on a nanometer scale [4]. The new approach demonstrates the potential to change characteristics of thermosetting and thermoplastic polymers fundamentally, aiming to improve their general performance [5, 6].

Nanoparticles embedded in polymer matrix have attracted increasing interest because of the unique mechanical, optical, electrical, thermal, barrier and magnetic properties compared to neat polymers [4, 5]. Polymer nanocomposite materials possess two phases consisting of inorganic particles of nanometre scale in the range between 1 and 100 nm that are dispersed in a matrix of polymeric material .Due to nanometre size of these particles, nanoparticles demonstrate remarkable properties because of their comparative large surface area per unit volume. Such properties are the results of the phase interactions that take place between the polymer matrix and the nanoparticles at the interfaces since many essential chemical and physical interactions are governed by surfaces.The interest in polymer nanocomposites comes from the fact that the addition of nanosized fillers into a polymeric matrix would have a great effect on the properties of the matrix[5-8].

Carbon materials, such as graphite, carbon black (CB) and carbon

nanotubes (CNTs), are widely used as fillers in conductive polymer nanocomposites due to low density and high conductivity, Recently carbon conductive filler in polymer matrices have emerged as another promising because of high aspect ratio, low cost, easy production and low resistance[9,10].

A major aim of the this work was to improved physical properties (thermal conductivity and water absorption) of the unsaturated polyester and epoxy via adding the reinforcing nanocarbon black (N220) at different loading levels and to optimize the effect of loading level of carbon black (N220) as well as economic efficiency via using low cost nanoparticles.

EXPERIMENTAL WORK

Materials

Unsaturated polyester a trade mark (TOPAZ-1110TP) is a liquid viscose resin and convert to soled stat by added a curing catalyst, methyl ethyl ketone peroxide (MEKP) at a concentration of 2% of the matrix, Catalyst accelerator cobalt is added to matrix resin at percentage 0.5g for 100 gm of resin. All these material Supplied by (ICR) Saudi Arabia Company.This resin system was chosen for its low viscosity, low shrinkage and for general applications purpose .Table (1) showed the important properties of unsaturated polyester used in this work according to the properties of Product Company.

Epoxy resin of a trade mark (Euxit 50 KI) is a liquid of low viscosity resin and its converted to solid stat by adding hardener (Euxit 50 KII) at ratio of (1:3),which were Supplied by Egyption swiss chemical industries company . The properties of epoxy resin used in this work is shown in Table (2) according to the properties of Product Company.

The carbon black (N220) used in this work was obtained from Korea Carbon Black Company. The properties of carbon black shown in Table (3) according to the properties of Product Company.

Preparation of Polymer Nanocomposite Specimens

The moulds of specimens used in this work are fabricated from carbon steel. The internal base and internal walls of the mould were coated with thin layer of release agent to avoid sticking between cast material and the mould wall.

Five samples were prepared as disks with about (40 mm) diameter and (4 mm) thickness for each weight fraction (1, 2,4,6,8 and 10 wt. %), the same thermal conductivity specimens were used for water absorption test. The procedure of specimens fabrication can be described as follow:

A. Drying of nanocarbon black powder in an electric oven at a temperature of (200°C) for (12) hrs.
B. The weight of nanocarbon black was calculated according to the required weight fraction (1, 2,4,6,8 and 10) wt. % of matrix resin.
C. Nanocarbon black manually mixed with matrix resin for about 15 minute at room temperature continuously and slowly to avoid bubbling during mixing until a homogeneous sate of the mixture.
D. Intermingling the mixture by ultrasonic wave bath for (45) minute to avoid heat generated during mixing which is affect on the properties of polymer resin and to disperse the nanoparticles homogeneously.
E. Adding of hardener to the mixture with gentle mixing, and then mixture was poured into the mould and the uniform pouring is continued until the mould is filled to the required level. The mixture was left in the mould for (24) hours at room temperature to solidify.

F. The cast is placed inside a drying micro wave oven (post curing) at (60) °C for one hour and at (90) °C for two hours , respectively for unsaturated polyester and epoxy nanocomposite, this step is important to accomplish complete polymerization, best coherency, and to relieve residual stresses.

PHYSICAL PROPERTIES

Thermal conductivity

The measurements of the thermal conductivity (k) were performed by (Lee's disc apparatus) type (Griffin and George) and some accessories to measure the temperature of both sides of the PNCs specimen in order to calculate the thermal conductivity.

The exposed side-wall of the specimen is chosen to be small relative to that area in contact with brass discs. The heater is switched on from the power supply with (V = 6 V and I = 0.2 A) to heat the brass disks and the temperatures of the all disks increased in nonlinear relationships and at different rates with time according to its position from the heat source. The temperatures were recorded every (5 minutes) until the equilibrium temperature of all disks was reached .The thermal conductivity value is calculated using follow equations[11]:

Input energy = Output energy

$$\mathbf{i \times v = \Pi r}^2 . e\,(T_1+T_3) + 2\Pi . r . e\,[\,d_1T_1 + d\,(\frac{\mathbf{T_1 + T_2}}{\mathbf{2}}) + d_2\,T_2 + d_3T_3] \qquad ...\ (1)$$

From the above equation, the value of (e) obtained is applied in equation (2) to compute the coefficient of thermal conductivity (k)[11].

$$k\frac{(T_2 - T_1)}{d} = e.[T_1 + \frac{2}{r}(d_1 + \frac{d}{2})T_1 + \frac{1}{r}dT_2] \qquad ...(2)$$

Water Absorption

This test is performed according to (ASTM D 570- 98), to estimate the water absorption percentage, the specimens were dried for 24 hrs at 45°C.Conditioned specimens were then immersed in distilled water at room temperature. Specimens were taken out of the water after 24 hours and wiped with a cotton tissue to remove surface water. They were then weighed to the nearest 0.0001gm.

By immersion of the specimen in water, the water absorption (change in mass) can be calculated according to equation[11]:-

$$\text{Water absorption\%} = \frac{w_2 - w_1}{w_1} * 100 \qquad \dots (3)$$

RESULTS AND DISCUSSION

The variation of thermal conductivity with carbon black for unsaturated polyester and epoxy nanocomposites are shown in Figure (1). This figure shows that the thermal conductivity is increase with increasing weight fraction of nanocarbon black particles in nonlinear relationship. Carbon black improves the thermal conductivity of polymer nanocomposite due to the greater thermal conductivity of nanocarbon black than the thermal conductivity of unsaturated polyester and epoxy. In the dispersion system with low loading level of nanocarbon black, few particles contribute to form conductive chains, and at this time the matrix polymer is almost continuous. Thus, the contribution of fillers to the thermal conductivity of a polymer nanocomposite seems to be higher than that of the matrix. On other hand, at low loading levels of nanocarbon black the thermal conductive particles are insulated by the polymer from each other. With the increasing of nanocarbon black loading, many nanocarbon black particles touch each other (the distances between agglomerated particles are within several nanometres) and begin to form carbon conductive chains, which greatly contribute to the thermal conductivities of polymer nanocomposites.

The maximum improvements percentage of thermal conductivity for unsaturated polyester and epoxy reinforced with 10wt.% nanocarbon black, respectively are 131.37% and 78% .The result of epoxy nanocarbon black composite is in a good agreement with Abdul Razak study[2] , but in this work, the improvement of thermal conductivity is higher with less nanocarbon black weight fraction (less 50% of wt.%) due to nanocarbon black and good dispersion vie ultrasonic wave bath machine as compared with his study which used micro carbon black and manual mixing instead.

Figure (2) show the water absorption percentage for unsaturated polyester and epoxy at different weight fraction of nanocarbon black. From these figures it can be noted clearly that the water absorption percentage for PNCs shows a non-linear decrement as the weight fraction of nanocarbon black increases, and reaches its maximum amount (0.1277% and 0.1024%) by adding weight fraction of 4% and 6% nanocarbon black compared to water absorption percentage of the both neat polymer which is equal to (0.2864% and 0.2123%) for unsaturated polyester and epoxy, respectively. After this percentage of weight fraction, the water absorption value increase but remain lower than the neat matrices (unsaturated polyester and epoxy). This phenomenon can be attributed to the presence of nanocarbon black filled polymer which acts as a barrier medium that hinders the water flow into the composites. On other hand, the high aspect ratio of nanofillers can create a tortuous pathway for water molecules to diffuse into PNCs.

In general, for all nanocomposites, water absorption decreases with increasing filler content. This can be attributed to the increase in the tortuosity effect with increasing filler content.

CONCLUSIONS

1. Thermal conductivity of unsaturated polyester and epoxy nanocompsites is increased with the addition of nanocarbon black (N220). The maximum improvement percentage of this property is (131.37% and 78%) at 10 wt% for unsaturated polyester and epoxy nanocompsites, respectively.
2. The water absorption is reduction by (55.41% at 4 wt.%, 51.76% at 6 wt.%) for unsaturated and epoxy nanocomposite, respectively.

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Table (1) the properties of unsaturated polyester used in this work according to the properties of Product Company.

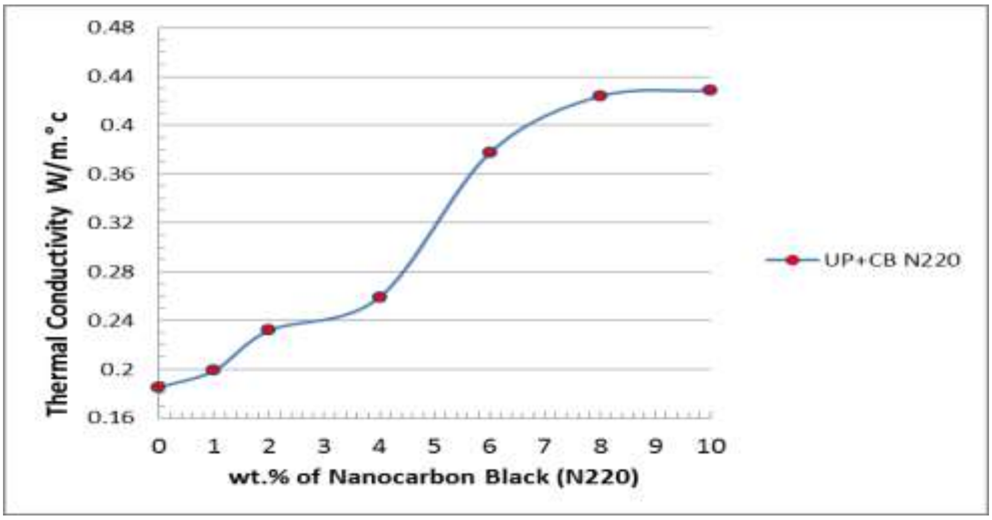
Density gm / cm3	Thermal conductivity w/m. °c	Specific Heat J/ kg. k	Coefficient of thermal expansion 10-6(co)$^{-1}$	Tensile strength MPa	Percent Elongation (EL%)	Modulus of elasticity GPa
1.2	0.17	710-920	100-180	41.4-89.7	<2.6	2.06-4.41

Table (2) the properties of epoxy used in this work according to the properties of Product Company.

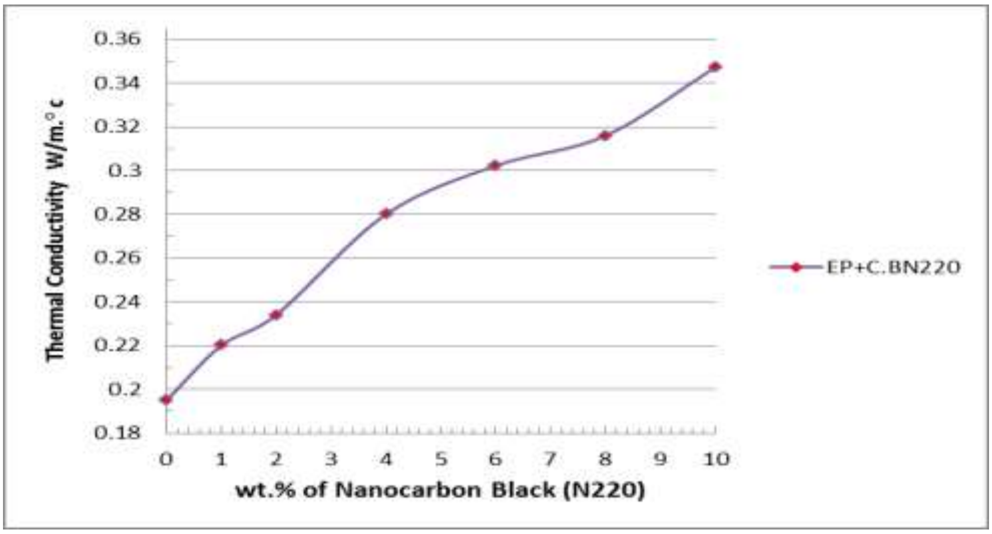
Density gm / cm3	Thermal conductivity w/m. °c	Compression strength/ Mpa	Flexural Strength	Tensile strength MPa	Percent Elongation at break (EL%)	Modulus of Elasticity (MPa)
1.05	0.18-0.195	70	63	27	<6	2800

Table (3) The properties of nanocarbon black (N220) used in this work according to the properties of Product Company.

Property	Ash content, %, max.	Iodine adsorption, g/kg	PH	Pour density, kg/m3	Sulfur content, %, max	Mean Particle diameter /nm	Surface Area m^2/g
Value	106-116	24-26	1.5	355 ± 20	6 - 9	20-25	117±5

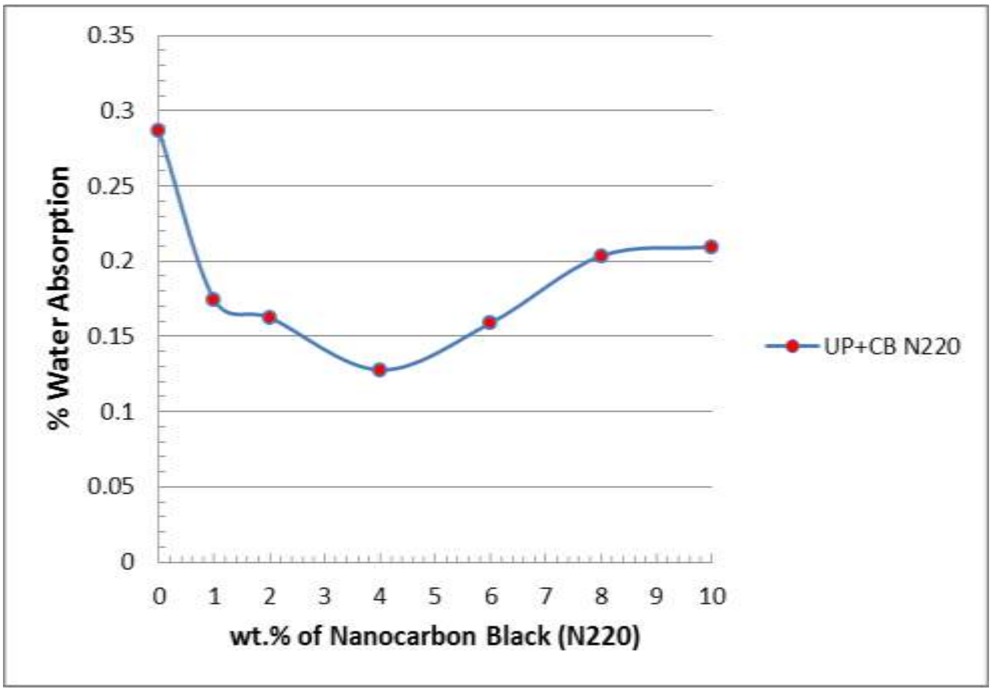


(a)

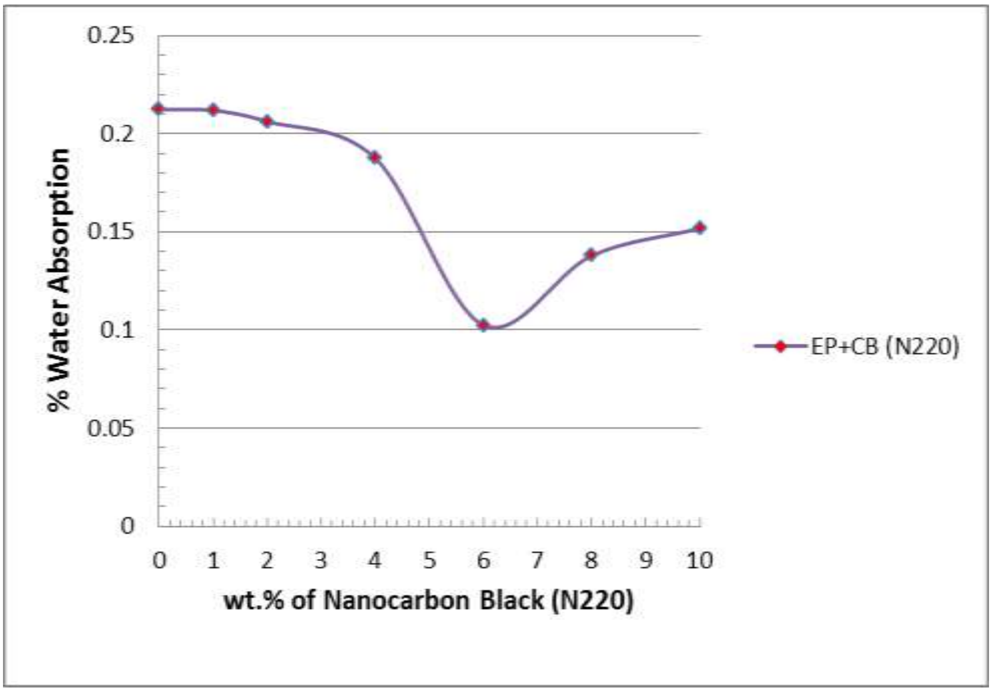


(b)

Figure (1) Thermal conductivity at different weight frication of nanocarbon Black (N220) (a) unsaturated polyester (b) Epoxy.



(a)



(b)

Figure (2) the effect of nanocarbon black (N220) on Water absorption (a) Unsaturated polyester and (b) Epoxy.