Study some of the mechanical characteristics for polymer matrix composite reinforced by toner carbon nanoparticles TCNP

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دراسة بعض الخصائص الميكانيكية لمتراكبات بوليمرية مدعمة بدقائق احبار الكاربون النانوية

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المستخلص

تلعب المتراكبات النانوية دورا هاما كواحدة من اكثر التكنولوجيات الواعدة والمعروفة باسم تكنولوجيا النانو. بوليمرات الكاربون النانوية وفرت الكثير من الامكانيات في الحضارة الانسانية. وقد استخدم الكاربون المنشط منذ عصر ما قبل التاريخ وقد لعب ادوارا رئيسية في العديد من التطبيقات الصناعية. يركز هذا العمل على دراسة تأثير اضافة دقائق احبار الكاربون النانوية بحجم (89,77 nm) وبكسور وزنية مختلفة %(2,4,6)الى كل من راتنج البولي استر الغير مشبع وراتنج الايبوكسي لتحضير متراكبات بوليمرية نانوية. استخدمت طريقة القولبة اليدوية في تحضير عينات المواد المتراكبة النانوية, وتم اجراء الاختبارات الميكانيكية وتم حساب متانة الصدمة ومتانة الصلادة لعينات المتراكبات النانوية. بينت النتائج لهذه الدراسة ان عينات متراكبات البولي استر النانوية قد حققت اعلى قيمة من متانة الصدمه ($4.57\ KJ/m^2$) عند نسبة الاضافة 2% وكذلك حصلت عينات متراكبات الايبوكسي النانوية على اعلى قيمة من متانة الصدمة ($4.94\ KJ/m^2$) عند نسبة الاضافة 4%. كذلك بينت النتائج بان متراكبات الايبوكسي النانوية قد حققت اعلى قيمة لمتانة الصدمة مقارنة مع المتراكبات الاخرى عند نفس نسبة الاضافة 4%.في حين بينت النتائج لهذه الدراسة بان متراكبات البولي استر النانوية امتلكت اعلى القيم لمتانة الصلادة (85.40 H.NO.) مقارنة بمتراكبات الايبوكسي النانوية (84.00 H.NO.) عند نفس نسبة الاضافة (4%).

Abstract

Nanocomposites play a significant role in one of the most promising technologies, known as nanotechnology. Nanocarbon polymers provide enormous possibilities to human civilization. Activated carbons have been used since the prehistoric age and have been playing major roles in many applications industrial. This work focuses on studying the addition effect of the prepared Toner carbon nanoparticles TCNP with particles size of (89.77nm) as a nanoparticles with different weight percentages(2, 4, 6) % to unsaturated polyester resin (UPE) and epoxy resin (EP) as a matrix to prepare polyester nanocomposites and epoxy nanocomposites. The hand lay-up method was used to prepare neat polyester, neat epoxy and their nanocomposites sheets.

The mechanical properties were studied including impact strength and hardness strength for the samples. The results showed that the samples of UPE/TCNP nanocomposite gained highest values of impact strength ($4.57\ KJ/m^2$) at ratio percent

(2%) and the samples of EP/TCNP nanocomposite gained highest values of Impact strength (4.94 KJ/m^2) atratiopercent (4%). Also the results showed that the EP/TCNP nanocomposite gained highest values of impact strength (4.94 KJ/m^2) compared with UPE / TCNP nanocomposite (4.57 KJ /m^2) at the same ratio percent (4%).

Also the results showed that the samples of UPE/TCNP nanocomposite gained highest values of shore D number (85.40 H.NO.) at weight percentage (4%).While the samples of EP/TCNP nanocomposite gained highest values of shore D number (84.00 H.NO.) at weight Percentage (4%).

Keywords: - Carbon Nanoparticle, Unsaturated Polyester Resin, Epoxy Resin.

Introduction

Nanoscience and nanotechnology refer to the understanding and control of matter at the atomic, molecular or macromolecular levels, at the length scale of approximately 1 to 100nanometers, where unique phenomena enable novel applications. Nanotechnologies are the design, characterization, production and application of structures, devices and systems by controlling shape and size at nanometer scale. Nanocomposites are composite materials in which the matrix material is reinforced by one or more separate nanomaterials in order to improve performance properties. The most common materials used as matrix in nanocomposites are polymers (e.g. epoxy, nylon, polyepoxide, polyetherimide), ceramics (e.g. alumina, glass, porcelain), and metals (e.g. iron, titanium, magnesium).

Nanomaterials are generally considered as the materials that have a characteristic dimension (e.g. grain size, diameter of cylindrical cross-section, layer thickness) smaller than 100 nm. Nanomaterials can be metallic, polymeric, ceramic, electronic, or composite. Nanomaterials are classified into three categories depending on their geometry:

1. Nanoparticles: When the three dimensions of particulates are in the order of nanometers, they are referred as equi-axed (iso dimensional) nanoparticles or nanogranules or nanocrystals.
2. Nanotubes: When two dimensions are in the nanometer scale and the third is larger, forming an elongated structure, they are generally referred as ‘nanotubes’ or nanofibers/ whiskers/ nanorods.
3. Nanolayers: The particulates which are characterized by only one dimension in nanometer scale are nanolayers/ nanoclays/ nanosheets/ nanoplatelets. These particulate is present in the form of sheets of one to a few nanometer thick to hundreds to thousands nanometers long. (1)

The transition from microparticles to nanoparticles yields dramatic changes in physical properties. Nanoscale materials have a large surface area for a given volume. Since many important chemical and physical interactions are governed by surfaces and surface properties, a nanostructured material can have substantially different properties from a larger-dimensional material of the same composition. In the case of particles and fibers, the surface area per unit volume is inversely proportional to the material's diameter, thus, the smaller the diameter, the greater the surface area per unit volume (2).

Thermosetting resins modified with inorganic particles such as carbon, Tio_2, Sio_2, Al_2O_3, clay. For inorganic or organic composites, the size of particles and the interfacial adhesion have great effect on the properties of the resin matrix. (3)

Polymer nanocomposites have attracted a lot of attention in the last few years due to their enhanced properties at low weight fraction of filler. Carbon nanomaterials are particularly interesting; as conductive fillers they allow the enhancement of multiple properties including mechanical, electrical and thermal properties. (4)

Conductive polymer composites are used in a wide variety of industrial application such as battery, fuel cell electrodes and corrosion-resistant materials. Consider, for example, the utility of Carbon Black particles, which have been routinely added to polymers over the past quarter, century for main purpose: improved electrical conductivity and mechanical properties. (5)The polymers, strengthened with very low percentages of nanometric particles (about 2–5%), offer (when compared to the base resin) enormous improvements in terms of thermo mechanical properties, barrier properties and fire resistance.

The advantage of nanocarbon was meant large industries in tires, cars, printing, pencils, laptops, computers, printers, photocopiers and laboratory tables.(6)

The present work focuses on the mechanical properties of nanocarbon filled polymer (epoxy resin, polyester resin) composites.

The aims of this work is to

1- Fabrication of UPE /TCNP and EP/TCNP nanocomposites.
2- Evaluation of mechanical properties of the nanocomposites.
3- Preparing of polymeric composites by mixing the resin with different percentages of Toner carbon nanoparticles so as to increase their toughness and impact strength in particular and to enhance the mechanical properties in general.

Experimental

Raw materials

The materials used to prepare the nanocomposites are unsaturated polyester (UPE) resin type (A-50) with the hardener MEKP and with accelerator cobalt naphthenate (having a symbol SIR SIROPOL) which was supplied from Saudi industrial resin CO. LTD, p.o.box 7764, Jeddah 21472, kingdom of Saudi Arabia, Epoxy resin (type Conbextra EP10) was used in this research; it is a liquid with moderate viscosity and capable to be converted to solid state by adding the solution (Metaphenylene Diamine, MPDA) as hardener. This hardener is a light liquid with yellowish color, the ratio of this hardener to the epoxy is about (1:3) and Toner Carbon nanoparticles

TCNP with particle size of (89.77 nm) was used in this work as a nano filler material as in Fig.1 and Fig.2.The compositions of this material are stated in the table (1).

Table (1): Chemical composition for Toner Carbon Nanoparticles TCNP

Components	C	Fe	Mn	Cu
Weight%	75.2	19.72	0.061	0.0001

Figure (1): Toner carbon nanoparticles TCNP

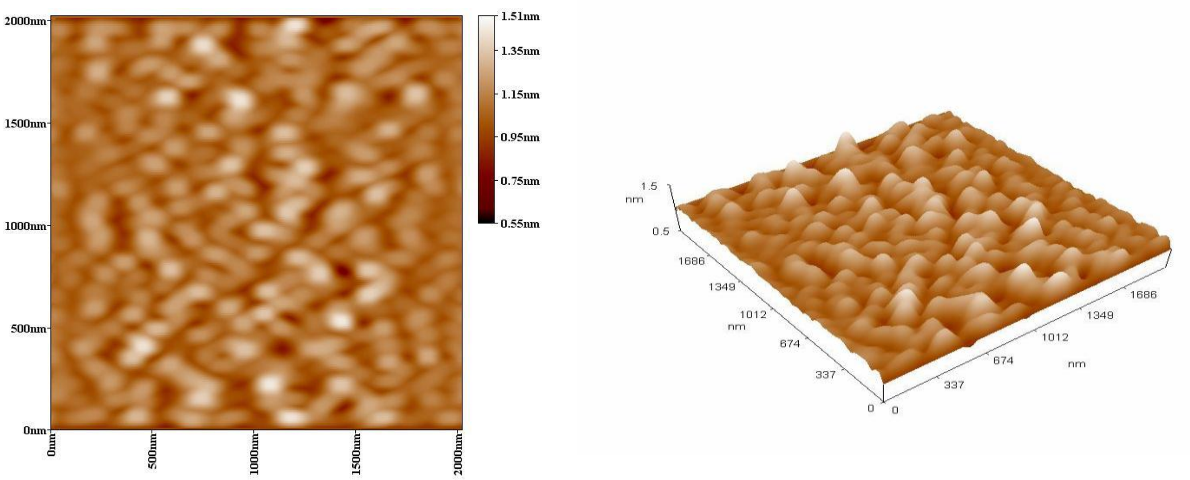


Figure (2): Scanning probe microscope SPM imager surface roughness analysis of toner carbon nanoparticles TCN.

Composites preparation

The preparation steps of the neat polyester, neat epoxy and their nanocomposites for mechanical tests were prepared by hand lay-up technique by mixing process which consists of three steps.

Neat epoxy preparation; firstly epoxy resin and hardener are weighted for suitable mixing ratio and then manually mixing then epoxy resin and hardener by shearing mixer at 800 rpm for 15 minutes to have good homogeneity between epoxy resin and hardener. Secondly, for better homogeneity ultrasonic homogenizer was used for 4 minutes. The third step was using vacuum system to remove the bubble before molding the epoxy. All the above steps were done for preparing neat polyester.

Epoxy nanocomposites preparation; firstly, the nanoparticles are weighted and manually mixed with epoxy resin under gloves box in nitrogen atmosphere. Interaction with water vapor specially increase particles agglomeration and decrease any interaction (chemical or physical) of particles with polymer chain in the matrix. Nanoparticles with epoxy resin were mixed by shearing mixer at 800 rpm for 15 minutes to have good distribution and less agglomeration.

The second step involves usage of ultrasonic homogenizer for 4 minutes to get good dispersion. The hardener was mixed with nanoparticles/epoxy resin for 4 minute by ultrasonic homogenizer. Using ultrasonic may cause to increase viscosity.

The third step was using vacuum system (10-2 bar) to remove the bubble before molding the composites in earlier prepared mold. All the above steps were done for preparing polyester nanocomposites.

Impact test sample cutting

The sheets of the nanocomposites are cutting into specimens, by using a circular iron saw, pluses from the samples were removed by using the iron rasp, the samples were polished by using abrasive emery papers of grade 400.The shape and dimension of the samples cut for impact test according to [ISO-179 TYPE D] shown at Figure (3) and Figure (4).

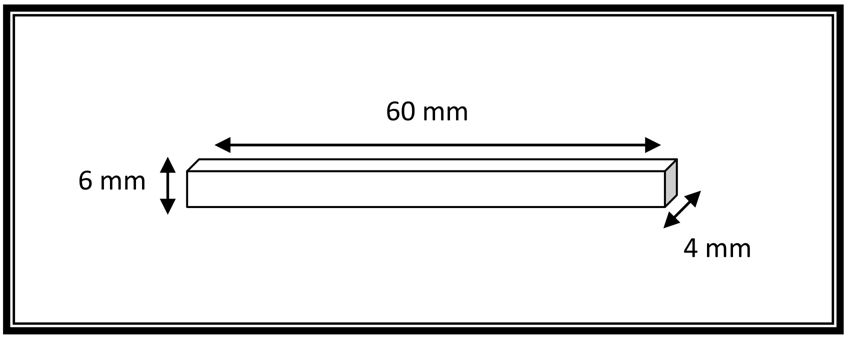
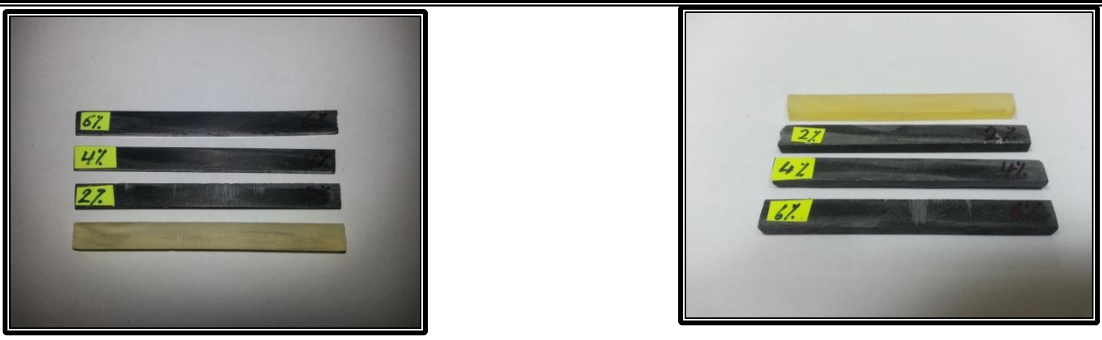


Figure (3): Dimensions of impact test specimens. [7]
[ISO-179 TYPE D]



(a) (b)

Figure (4): Photograph of impact test specimens before testing
(a) Pure polyester and UPE /TCNP nanocomposites samples
(b) Pure epoxy and EP /TCNP nanocomposites samples

Characterization techniques

Charpy impact test

This instrument consists mainly of pendulum and energy gauge. Charpy impact test consists of standard test piece that would be broken with one flow of a swinging hammer. The test piece is supported at both its ends in a way that the hammer strikes it at the middle.

The testing method of this instrument includes lifting of the pendulum to its maximum height and fixing it firmly. The specimen is fixed in its pertaining place, and then the energy gauge is initialized (on zero position), after that, the pendulum is freed whereas its potential energy would be changed to kinetic energy. Some of this kinetic energy is utilized to fracture the specimen, while the energy gauge reads the value of fracture energy (Uc) for the sample under test. Impact strength (I.S) is calculated by applying the relationship:(8)

I.S =Uc/A(KJ/m^2**)**

Where

Uc: is the fracture energy (Joule) which is determined from charpy impact test instrument.

A: is the cross-sectional area of the specimen.

Hardness test

Shore D Durometer Hardness instrument, fabricated by TIME GROUP INC Company, was used to carry out the hardness test by using pointed dibbing tool. The pointed dibbing tool penetrate the material surface by the pressure applied on the instrument where the dibbing tool head touching quite the surface of the samples then calculate the hardness values for the samples.

Results

Impact strength of composites

The conventional charpy impact test is used to evaluate the impact strength of the composites that have (2, 4, 6) % of TCNP and in either of EP and UPE. The results of this test are shown in Fig. (5) and Fig. (6), which show the effect of TCNP content on the impact strength values of the prepared composites.

The results showed that the samples of UPE/TCNP nanocomposites gained highest values of impact strength (4.57 KJ/m^2) at ratio percent (2%) and the samples of EP/TCNP gained highest values of impact strength (4.94 KJ/m^2) at ratio percent (4%).

Also the results showed that the EP /TCNP nanocomposites gained highest values of impact strength (4.94 KJ/m^2) at ratio percent (4%) compared with UPE / TCNP nanocomposites (4.57 KJ/m^2) as shown in Fig. (5) and Fig. (6).

It should be noted that the interface between the polymer and the filler particles is crucial in determining the properties of the composite because at the interface the stress is transferred from the polymer to the filler and has a reinforcement role in the composites. (5)

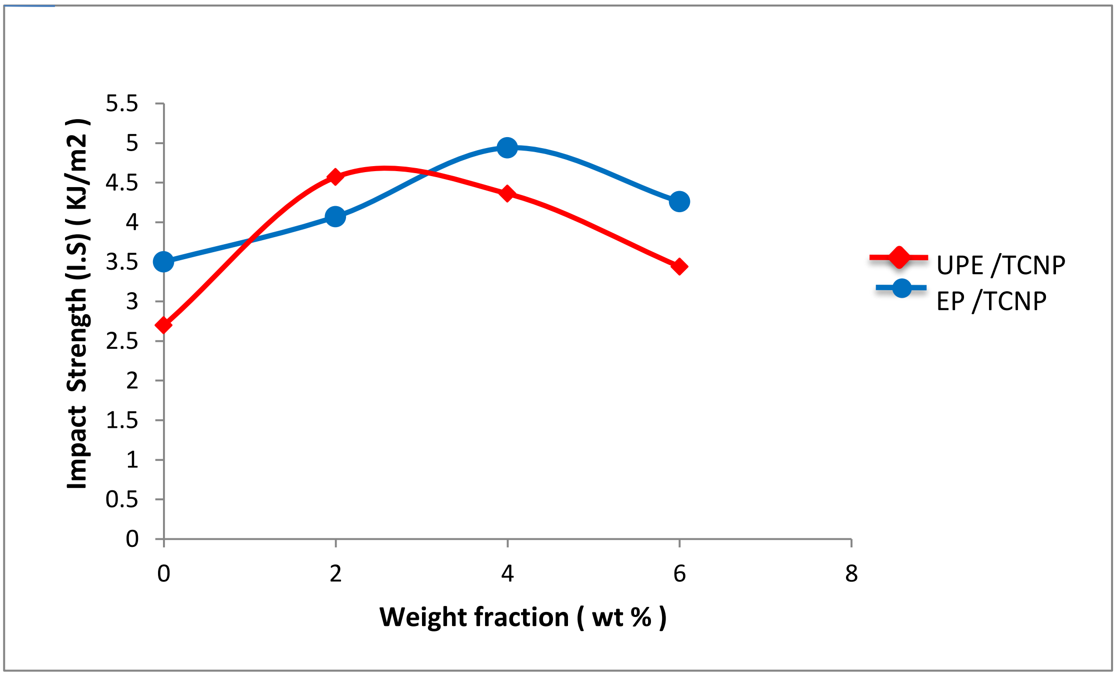


Figure (5): Charpy impact strength variation with TCNP content in UPE and EP resins

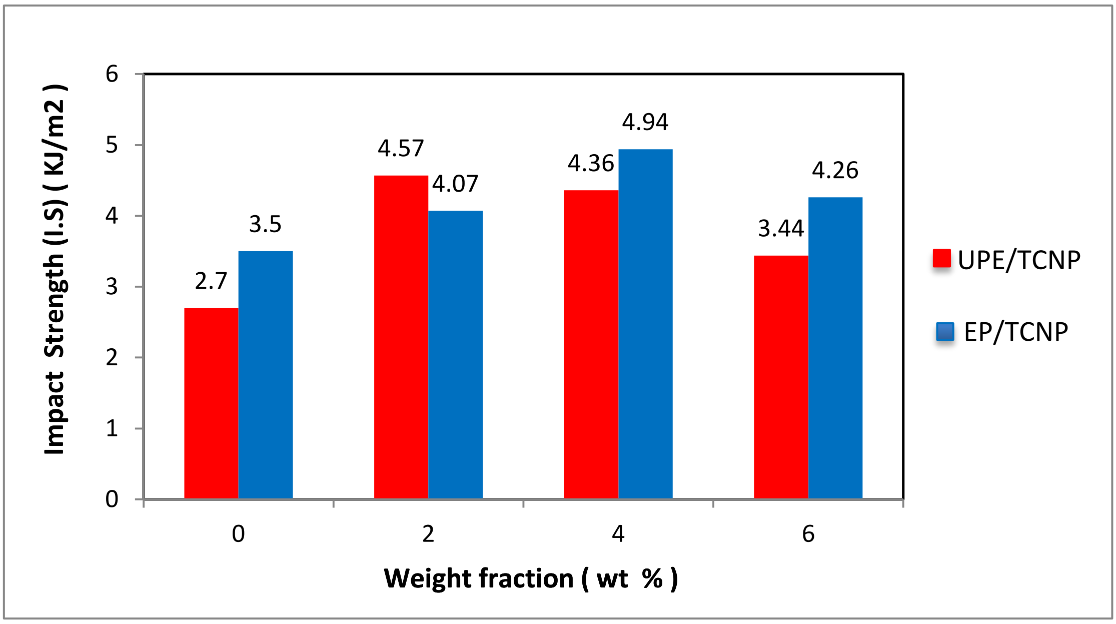


Figure (6): Charpy impact strength variation with TCNP content in UPE and EP resins

Hardness test

The hardness is a measure of resistance to indentation and, hence, will not be greatly influenced by the matrix (9).

The shore D hardness values indicate that the best results were achieved for the particle composite material consisting of unsaturated polyester resin, epoxy resin reinforced with Toner carbon nanoparticles compared with UPE and EP pure. The explanation of that as follows:
The results showed an increase in the value of shore D number for all the samples of UPE / TCNP nanocomposite compared with UPE pure, where the samples of UPE / TCNP nanocomposite gained the highest values of shore D number(85.40 H.NO.)at ratio percent (4%)as showed in the Fig. (7) and Fig. (8).
Also it showed an increase in the value of shore D number for all the samples of EP / TCNP nanocomposite compared with EP pure, where the samples of EP / TCNP nanocomposite gained the highest values of shore D number (84.00 H.NO.) at ratio percent (4%).

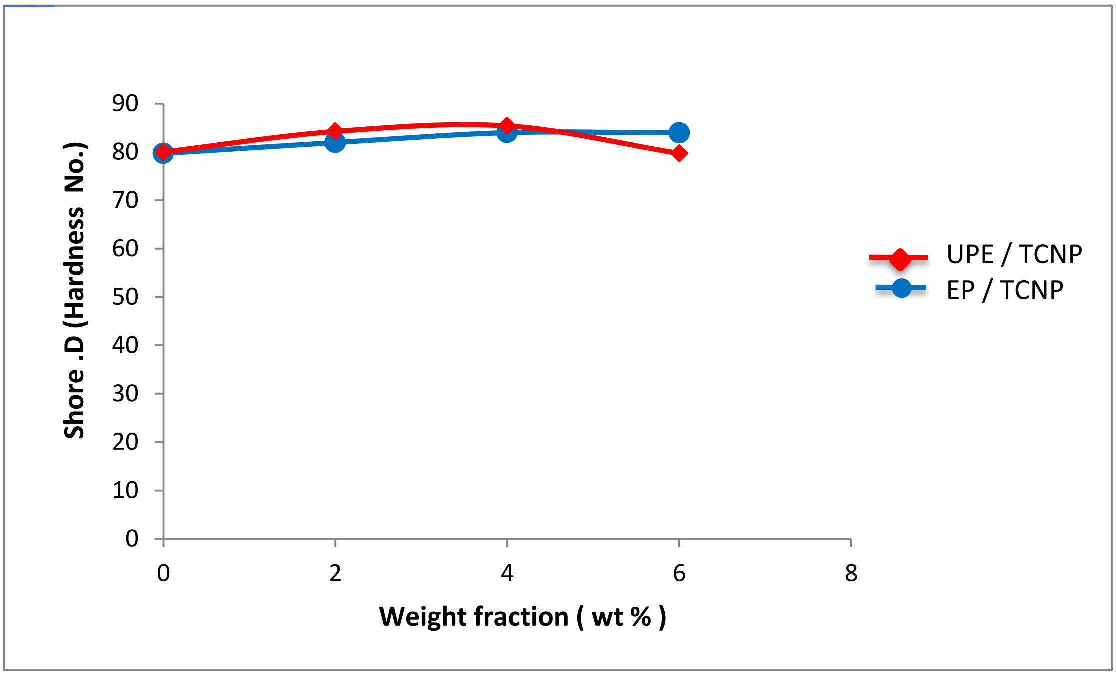


Figure (7): Shore D (Hardness No.) variation with TCNP content in UPE and EP resins

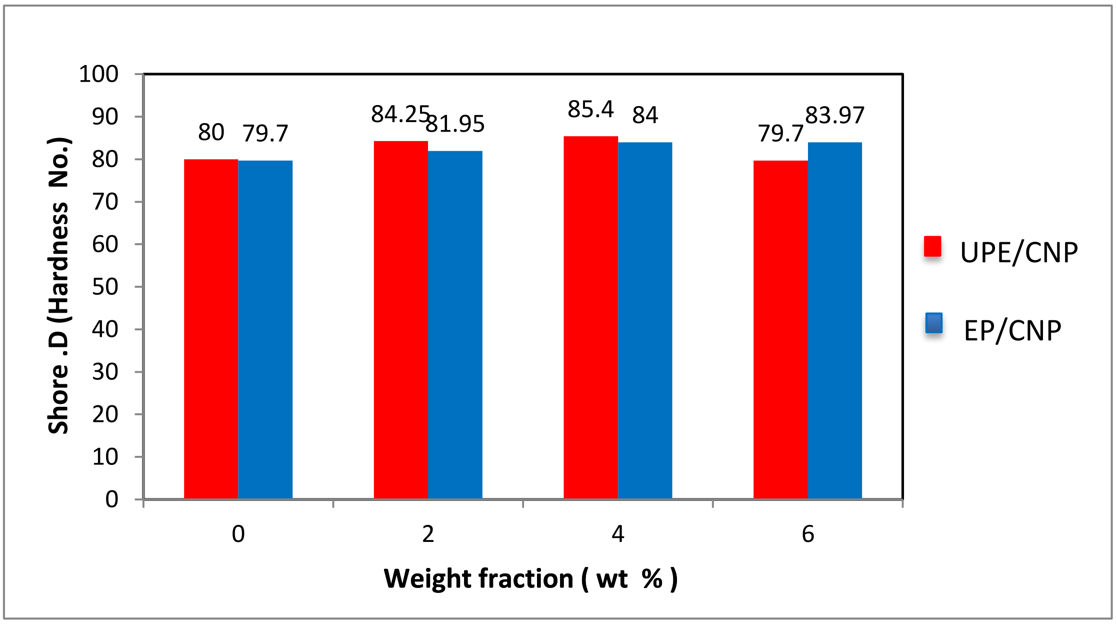


Figure (8): Charpy impact strength variation with TCNP content in UPE and EP resins

Conclusion

1-Polyester and epoxy resins are a good adhesive materials which can use as a matrix with Toner carbon nanoparticles.
2-The above experimental results indicate that this Toner carbon nanoparticles may be a good filler material for polymer nanocomposite materials.
3-We can produce a composite hard, strong by use small particle size of Toner carbon as fillers.

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