Study of SWCNT Effect on Some Mechanical Properties of Epoxy Nanocomposites

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DOI: https://dx.doi.org/10.24237/djps.16.02.523C

Received: 11 December 2019 **Accepted: 8 January 2020**

Abstract

In this work, we successfully prepared single wall carbon nanotubes (SWCNTs) / Epoxy polymer nanocomposites with different volume fraction ratios of SWCNTs (0, 0.2, 0.4, 0.6, 0.8, 1, and 1.5%) using mixing method in order to examine and study some of their mechanical properties (impact strength, hardness, creep). The Creep test result showed that the creep rate decreases gradually as the weight ratio of the SWCNTs reinforcement material increases in polymer. Impact strength and hardness values of samples were increased by increasing volume fraction of SWCNT reinforcement material in polymer compared with pure epoxy.

Keywords: Nanocomposites, Single wall carbon nanotubes (SWCNTs), Epoxy, Creep, Impact strength, Hardness.

دراسة تأثير الأنابيب النانوية الكربونية أحادية الجدران على بعض الخواص الميكانيكية للإبوكسي المتراكبات النانويية

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Diyala Journal for Pure Science

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الخلاصة

في هذه الدراسة، نجحنا في تحضير متراكبات من الانابيب الكاربونية احادية البعد / الابوكسي بوليمر مع نسب حجمية مختلفة من الانابيب الكاربونية (0, 0.2, 0.4, 0.6, 0.8, 1, 1.5%) بطريقة الخلط من اجل اختبار ودراسة بعض الخواص الميكانيكية (مقاومة الصدمة، الصلابة، الزحف). نتائج اختبار الزحف اظهرت ان معدل الزحف يقل بشكل تتدريجي مع زيادة النسب الوزنية المضافة للمادة المدعمة من الانابيب الكاربون النانوية في المادة البوليميرية. قيم مقاومة الصدمة والصلابة للعينات المحضرة كانت تزداد بزيادة النسب الحجمية لمضافة للمادة المدعمة من الانابيب الكاربون النانوية في المادة البوليميرية النقية.

الكلمات المفتاحية: متراكبات نانوية، الانابيب الكاربون النانوية احادية الجدران، الايبوكسي، الزحف، مقاومة الصدمة، الصلابة.

Introduction

Carbon nanotubes (CNTs) have many very unique properties such as (mechanical, optical, electrical and chemical stability) [1]. Many research articles have used carbon nanotubes as mechanical reinforcement material in different polymer, metal and ceramic matrix composites [2]. The epoxy resin material can be considered as one of the best polymer matrices used for sophisticated composite applications. The resin polymer group offers well stiffness and specific strength, dimensional stability, chemical resistance, and strong adhesion [3]. In order to make good preparation of CNT-reinforced epoxies or any other types of polymers, it needs to make good homogeneous dispersion of carbon nanotubes and strong interaction with polymer matrix. One of these good dispersions is addition of solvents to thermoset resins. This solvents addition to polymer leads to decrease the resin viscosity, allowing better distribution of nanomaterials such as SWCNTS fillers in epoxy matrices [4].

Epoxy resin can be considered as viscoelastic material. During a curing process under continuous stresses or strains, its viscoelastic characteristics change, which is reflected in the variations of the viscosity η. In the early cure stage, the epoxy resin is in a liquid state. Cure reaction takes place in a continuous liquid phase. With the advancement of the cure process, a crosslinking reaction occurs at a critical extent of reaction. This is the onset of formation of networking and is called the gel point [5]. At the gel point, epoxy resin changes from a liquid to a rubber state. In this study, the samples of single wall carbon nanotubes (SWCNTs)/Epoxy polymer nanocomposites with different volume fraction ratios of SWCNTs (0, 0.2, 0.4, 0.6, 0.8, 1, and 1.5%) using mixing method were prepared in order to examine and study some of their mechanical properties (impact strength, hardness, creep).

Samples Preparation Method

The preparation steps of the clean epoxy and epoxy/SWCNTs nanocomposites for all mechanical tests were carried out by pointer layup method by straight mixing procedure which consists of three steps. For pure epoxy preparation; the sample of pure epoxy was used us reference (the ratio of resin to hardener was 3:1). The required amounts of resin and hardener for the preparation of samples were accurately weighted using (Digital balance (d=0.1mg) made in Germany). The resin and hardener were mixed in a beaker using magnetic stirrer –bar equipment for (20-30) minutes to get a homogenous mixture. Finally, the mixture was left in vacuum oven to remove the bubbles before pouring it in to the prepared mold. The samples were left for (48 hours) before pulling it out from molds and left in vacuum for (15 days) before any test.

SWCNTs were used as reinforcements to improve the properties of epoxy polymer. Direct mixing process method was used to prepare nanocomposite samples, SWCNTs were weighted and manually mixed with epoxy resin. To ensure good dispersion of SWCNTs in epoxy resin, an ultrasonic bath for (30 minutes) was used, then the mixture was stirred at room temperature using magnetic stirrer–bar for (2 hours), followed by sonication in ultrasonic bath for (30 minutes) to get better homogeneous for SWCNTs in epoxy resin. For degassing, the mixture of (SWCNTs/epoxy) was left in a vacuum oven at (70℃) for (30 minutes). The hardener was added after the mixture getting cold at room temperature, and mechanically stirred for (10 minutes) to get better homogenization mixture. The final mixture was put for 5 minutes in vacuum oven to remove its bubbles from it, and the final mixture was poured in the prepared molds and the samples were left for (48 hours) before pulling it out from molds and left in air for 15 days before testing it. The volume fractions of SWCNTs to epoxy resin were (0, 0.2, 0.4, 0.6, 0.8, 1, and 1.5%).

Results and Discussion

1. Impact Test results

Various mechanical properties were determined to give further insight in the behavior of epoxy / SWCNTs nanocomposites. Mechanical properties are important measures of product quality. Impact strength values of pure epoxy polymer (EP) and EP / SWCNTs nanocomposites were measured. Impact strength front different concentrations of SWCNTs in pure epoxy nanocomposites are illustrated in figure 1. From figure 1, it can be seen that the addition of different volume fractions % of SWCNTs to the epoxy resin leads to improvement the impact strength (absorbed energy) of epoxy resin. The great enhancement of impact strength reaches to (0.80 KJ / m^2 at 1 % SWCNTs) when compared with (0.25 KJ / m^2) for pure epoxy.

The impact strength of SWCNTs is larger than impact strength of pure epoxy which means that EP / SWCNTs nanocomposites show a better absorption performance. Based on mentioned values the impact strength of the neat epoxy increased with the increasing of SWCNTs content up to (1 volume fraction %). This was credited to the decent dispersals of the nanotubes in the medium and improved response between the epoxy and the SWCNTs [6]. Study of fracture superficial in nanocomposites bare that thinner crack-tips beneath the advancing blows were additional capably linked through the nanotubes in epoxy/SWCNTs [7]. The decrease in impact strength when the SWCNTs volume fraction % increases is due to: (i) deprived interaction between SWCNTs and the epoxy where little or no energy dissipation phenomena at the interface appears to occur. (ii) Agglomerate SWCNTs have high surface area results in high viscosity of EP / SWCNTs nanocomposites mixture which leads to formation of bubbles and agglomeration in the matrix [8]. Table 1 shows the values of impact strength of EP / SWCNTs nanocomposites with different volume fractions %.

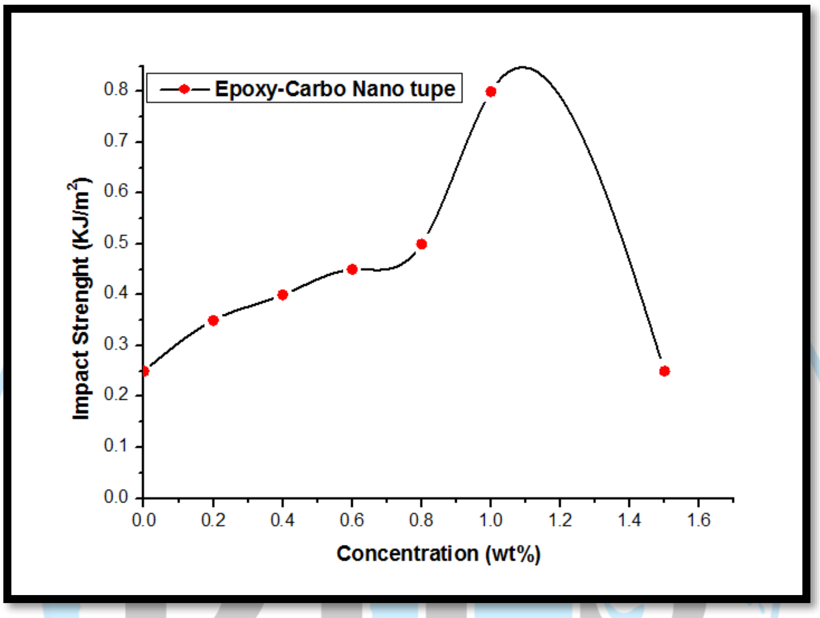

Figure 1: Impact strength vs. SWCNT volume fraction % of Epoxy/SWCNTs nanocomposite

Table 1: Values of Impact strength EP / SWCNTs nanocomposites with different volume fractions %

Concentration Wt %	Values of Impact strength (KJ / m^2)
0	0.25
0.2	0.35
0.4	0.4
0.6	0.45
0.8	0.5
1	0.8
1.5	0.23

2. Hardness test results

Hardness values of EP and EP / SWCNTs nanocomposites with different volume fractions % of SWCNTs are illustrated in figure 2. The results showed an increase in hardness values with increasing of SWCNTs volume fractions % in EP. The maximum value of hardness was 0.8 K J / m^2 at 1% of SWCNTs added to EP. After this value of volume fraction % of SWCNTs, the hardness values decreased. The increase in hardness with the addition of SWCNTs might be explained on the basis of the high stiffness of the SWCNTs (typically above 1000 GPa) which reinforced the nanocomposites structure. Additionally, this nanotube random orientation permits obtaining isotropic properties in the specimens regardless of the orientation on which they are built [9].

Hardness values by addition of SWCNTS were reached the maximum value 0.88 KJ/m^2 at 1% of SWCNTs compared to the hardness value of pure epoxy which was 25 KJ / m^2. This behavior is agreed with many studies [10]. Reason of the increased hardness values is due to the overlap and stacking, which reduced the movement of polymer molecules that leads to increase the resistance of material to scratch cut and becomes more resistance to plastic deformation. Hardness property of material depends on the kind of forces that quandary between particles, molecules and atoms in the material. Table 2 shows values of hardness for EP / SWCNTs nanocomposites with different volume fractions %.

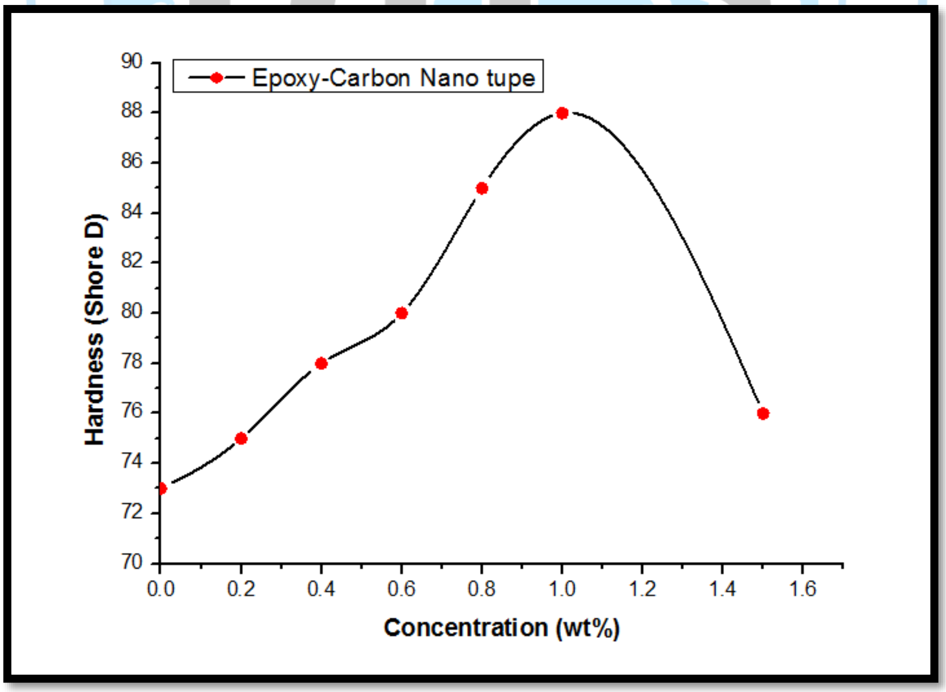

Figure 2: Hardness for EP / SWCNTs nanocomposites with different volume fractions % of SWCNTs

Table 2: Values of Hardness for EP/ SWCNTs nanocomposites with different volume fractions % of SWCNTs

Concentration wt. %	Values of Hardness Shore (D)
0	73
0.2	75
0.4	78
0.6	80
0.8	84
1	88
1.5	76

3. Creep Test

When the base material is reinforced with carbon nanotube, we noticed that the creep rate decreases gradually when the concentration of the reinforcement material (SWCNTs) increases. When reinforced by SWCNT the result was a gradual decrease in the creep rate until it reached the lowest creep rate at the largest reinforced ratio of SWCNTs, and the lowest creep value was 0.1% concentration of the SWCNTs. The improvement in mechanical properties is due to the strong bonding between the support material and the base material an important factor that increases the durability of the material is the way the superposed material is prepared. The result showed that the creep rates gradually decreases when the SWCNTs volume fraction increase [11].

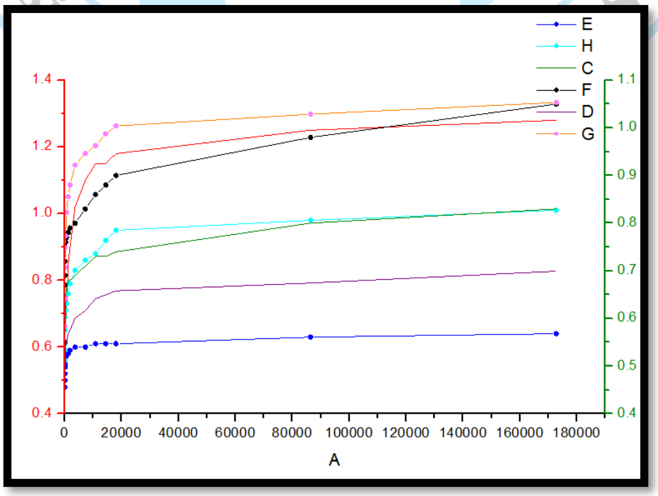

Figure3: Strain volume fraction % of Epoxy / SWCNTs nanocomposites

Conclusion

Addition of Single wall carbon nanotubes to pure epoxy increases the impact strength of it. The hardness of SWCNTs / EP overlays with increasing concentration of SWCNTs due to size of SWCNTs and their high solidity within polymeric material. The improvement in mechanical properties is due to the strong bonding between the support material and the base material an important factor that increases the durability of the material is the way the superposed material is prepared. The result showed that the creep rate gradually decreases when the SWCNTs volume fraction increases. In general, and from the results of this study we can conclude that this kind of nanomaterials can be used in scratch resistant applications when exposed to scratching in high concentration and inside buildings where the temperature is low. Also, from the results, method of ultrasound technique which was used for preparation samples is not the most effective method to make very good dispersion SWCNTs in EP.

Acknowledgment

The authors gratefully acknowledge the technical support provided by College of Science, University of Diyala, Diyala, Iraq, also we would like to thank the center of Nanotechnology and Advanced Materials Research, University of Technology, Baghdad, Iraq.

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