Study the hardness, Young's modulus and impact strength of Ep/ Fe_2O_3 and Ep/ AL_2O_3 nanocomposites

Hanan Obaid kathem[1], Mohammed Jebur Resen[2], Najwa J. Jubier[3]
[1,2,3] Wasit University / College of Science / Department of Physics

الخلاصة:

في هذا البحث استُخدمت طريقة القولبة اليدوية لأعداد مادة متراكبة نانوية مكونه من راتنج الايبوكسي كمادة الاساس , ومسحوق كل من اكسيد الحديد النانوي (Fe_2O_3) و اكسيد الالمنيوم النانوي (Al_2O_3) كمادة مدعّمة وبنسب وزنية مختلفة (15,10,6,0) % , ودرس تأثير اضافة الجسيمات النانوية على الخواص الميكانيكية لكلا النوعين, اجريت بعض الاختبارات الميكانيكية علي العينات المعدة (اختبار الشد ، الصلابة ، ومقاومة الصدمة) ، أظهرت النتائج ان قيم الصلابة ومعامل المرونة (E) تزداد بزيادة نسبه المادة المدعّمة النانوية بينما تقل قيم مقاومة الصدمة نتيجة تأثير الجسيمات النانوية على المادة الاساس .

Abstract:

In this research, the hand lay-up method was used for the preparation of a Nano composite material consisting of epoxy resin as a matrix material, Nano iron oxide powder (Fe_2O_3) and Nano aluminum oxide powder (Al_2O_3) as a reinforcement materials with a different weight ratio of (0, 6, 10, 15) %, the effect of addition of Nanoparticles on mechanical properties was studied for both types. Some mechanical test was performed on the prepared samples (Tensile test, Hardness, and Impact strength), Results showed that the value of the hardness and elastic modulus (E) increases with increasing the Nano added ratio while Impact Strength is reduced as a result of the effect of Nanomaterial properties on the matrix material.

Introduction:

Due to the rapid development in the field of technology and the need for High-spec materials, therefor the nano composite attracted the attention of many researchers and industrialists because it have high specifications of lightweight and high mechanical resistant as well as electrical and thermal insulating materials depending on additives, so the nano composite materials is a composite, in which one of the components has at least one dimension in nanometer range (10^{-9} nm) **[1, 2].** The Matrix material and the reinforcement material may be a polymer, metal or ceramic material, It is known that when the particle size reduce, the surface area exposed to the substance increases, When the size of the additives reduce, the proportion of additive in the composite material increases, This means increasing the pervasiveness ability of additives within the Matrix material, Which increases the rigidity of the material and increases its resistance to stress as a result of the increased cross-linking and interlink between the molecular bonds**[3].**

Polymer nano composites materials have attracted the interest of many researchers such as in 2015 Tao Sun others have studied enhance mechanical properties of nano Fe_2O_3-epoxy composite, A disproportionate

increase in mechanical properties of the obtained Epoxy nanocomposites was observed with the increased modified Fe_2O_3 nanoparticles loading ,also the tensile strength was increased by 50.2% [4].

In 2016, both V. R. Arun Prakash and A. RajaduraI have investigated on ultimate tensile strength, impact strength, flexural strength, hardness, and glass transition and degradation of E-glass fiber reinforced epoxy composites dispersed with fine iron (III) oxide particles. Composites of 15 Vol. % glass fibers dispersed with 0.5 and 1 Vol. % concentration of iron (III) oxide particle was fabricated by hand lay-up process. The test results show that there is a significant improvement in thermal and dielectric properties when the increment in particle loading with slight marginal decrements in mechanical properties [5].

In the same year S. I. Salih and other preparation two sets of polymer matrix Nanocomposite materials by hand layout technique, the first set consists of a Polymethyl Methacrylate (PMMA) resin as matrix material reinforced by nanoparticle of Aluminum Oxide (Al2O3) with average size (53.60) nm and the second group is composed of polymethyl Methacrylate resin reinforced by nanoparticle of Magnesium Oxide (MgO) with average size (52.54)nm . The influence of the selected volumetric fraction (0.5, 1, and 1.5%) of nanoparticles on the mechanical properties (flexural strength and Impact strength) at room temperature was studied. The result shows that the values of flexural strength, flexural modulus and fracture toughness increase with the increase of volume fraction of nanoparticle for both groups whereas decreased the values of impact strength. Moreover, the reinforcement with aluminum oxide nanoparticles possesses higher values of flexural strength, flexural modulus, and fracture toughness as compared with magnesium oxide nanoparticles [6]. In this research were studied three mechanical properties**.**

1. Impact Strength

Impact Strength expresses the ability of the material to resist breakage under the influence of a sudden load **[7].** There are several types of Impact force measurement, which are:

1. Izod impact test.
2. Charpy impact test.
3. Falling weight test.
4. Height speed stress- strain test.

The Charpy method was used in this search, Impact Strength was calculated through the following relationship (1) **[8]**:

$$\mathbf{Gc} = \frac{\mathbf{Uc}}{\mathbf{A}} \qquad \text{……..(1)}$$

Gc: The impact strength of the material (J/m2).

Uc : The energy needed to break the sample.

A: Sample cross section Area.

2. Hardness

Is a measure of resistance to penetration or is the resistance of the surface of the substance to scratch or damage or rupture or dent in any way as a result of strength or pressure **[9]**.

The hardness test is done easily and quickly without resulting in the destruction of the material to be tested and therefore the hardness test has been widely spread in the industrial field and there are several methods for conducting this test from **[10]:**

1. Brinell hardness.
2. Vicker's hardness.
3. Rockwell hardness.
4. Shorescleroscope hardness.

In the current study the hardness shore (D) was adopted because it used to measure the hardness of the polymer material.

3- Tensile testing

Also known as tension testing is a fundamental material science and engineering test in which a sample is subjected to a controlled tension until failure. The test process involves placing the test specimen in the testing machine and slowly extending it until it fractures. During this process, the elongation of the gauge section is recorded against the applied force. The elongation measurement is used to calculate the engineering strain($\boldsymbol{\epsilon}$) using the following equation (2) **[11]**:

$$\boldsymbol{\epsilon} = \frac{\Delta \boldsymbol{L}}{\boldsymbol{L_o}} \qquad \text{……..….(2)}$$

Where **ΔL**= (L -L_o)is the change in gauge length, L_o is the initial gauge length, and **L** is the final length. The force measurement is used to calculate the engineering stress **(σ)** using the following equation **[11]**:

$$\boldsymbol{\sigma} = \frac{\boldsymbol{F_n}}{\boldsymbol{A}} \qquad \text{…….(3)}$$

Where F_n is the tensile force and A is the nominal cross-section of the specimen **[11]**.

From the stress-strain curve that can calculate the coefficient of elasticity which represents the amount of resistance of the bonds that bind the atoms together to the external tensile strength on them. The coefficient of elasticity depends on the type and energy of the bonds that bind the molecules or atoms together and the coefficient of elasticity can be calculated by the Hook's law **[12]:**

$$\boldsymbol{E} = \frac{\Delta \boldsymbol{\sigma}}{\Delta \boldsymbol{\epsilon}} \qquad \text{……..(4)}$$

Materials and methods:

The materials used in this work for the preparation of Nanocomposite specimens and the studied of some mechanical properties in different concentrations are epoxy resin-type (euxit-50 KI) that were produced by (swiss Kim) as a matrix material and reinforcement material used Nano iron oxide powder (Fe_2O_3) and Nano aluminum oxide (Al_2O_3) powder because of the chemical stability in the form of Nanopowder with average diameter (64.24nm) for (Fe_2O_3) and (53.96 nm) for (Al_2O_3) that production by Sky Spring nanomaterial.

The hand lay-up method was used to prepare five samples of Nanocomposite material, the Nano iron

oxide powder (Fe_2O_3) with a weight ratio of (0, 6, 10, 15) % was added to the epoxy resin, the mixture is well mixed, then the hardener was added to the mixture until it becomes homogeneous, the same way using for preparing Nano aluminum oxide powder (Al_2O_3), after that The mixture is poured into templates with standard dimensions according to international standards for each type of mechanical tests to be studied. Using the atomic force microscope (AFM) to see the surface shape with 3D details and through it was known the grain size of Nano-powder as shown in Figure (1) and (2).

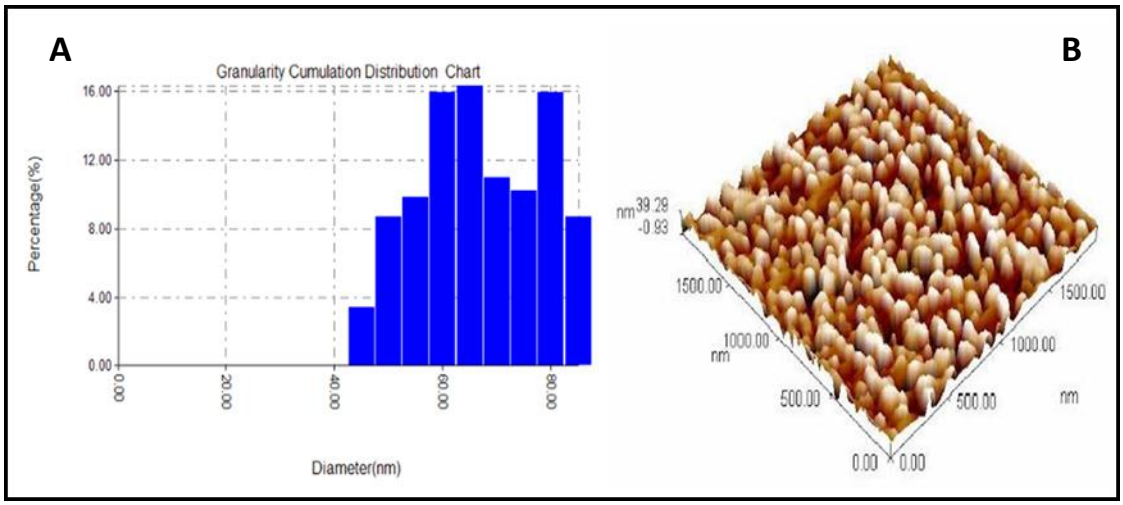

Figure (1):(A) Nano Particle distribution Scheme, (B) 3D image of material(Fe_2O_3).

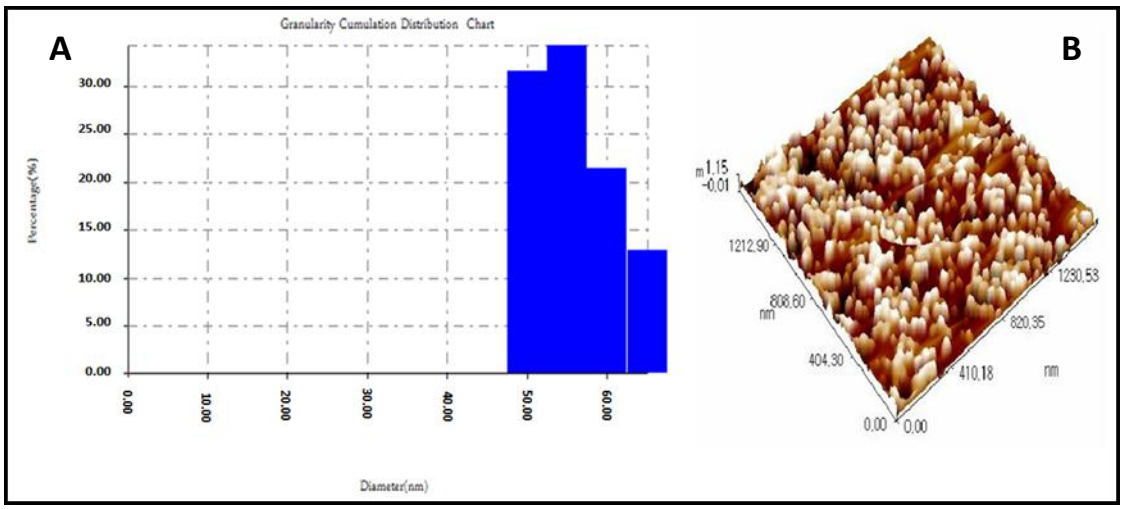

Figure (2):(A) Nano Particle distribution Scheme, (B) 3D image of material(Al_2O_3).

Results and Discussion:

The symbols were used to represent the used Nano composite material in this search for ease of reference as shown in Table (1).

The results of mechanical tests shown in Table (2), it noticed that the hardness and elastic modulus (**E**) increases by increasing the added ratio as shown in the Figure (3) and (4) while Impact Strength is reduced as shown in Figure (5).

Table 1: Composition and symbols of prepared samples.

Composition	Symbol
pure Epoxy	P
Epoxy +6% Fe_2O_3	S1
Epoxy +10% Fe_2O_3	S2
Epoxy +15% Fe_2O_3	S3
Epoxy +6% Al_2O_3	A1
Epoxy +10% Al_2O_3	A2
Epoxy +15% Al_2O_3	A3

Table (2) shows the values of hardness Shore D, the impact Strength and Elastic Modulus of samples at the specified addition ratios.

Samples	Hardness Shore D				Impact Strength Gc (KJ/cm^2)				Elastic Modulus (E(MPa))			
	Wt.%				Wt.%				Wt.%			
	0%	6%	10%	15%	0%	6%	10%	15%	0%	6%	10%	15%
S	79.4	82.3	83.3	86.2	8.25	4.877	4.526	3.08	638.8	1388.8	1602.5	1882.5
A	79.4	81.2	82.8	83.5	8.25	4.667	3.587	4.294	638.8	1083.3	1111.1	1310.2

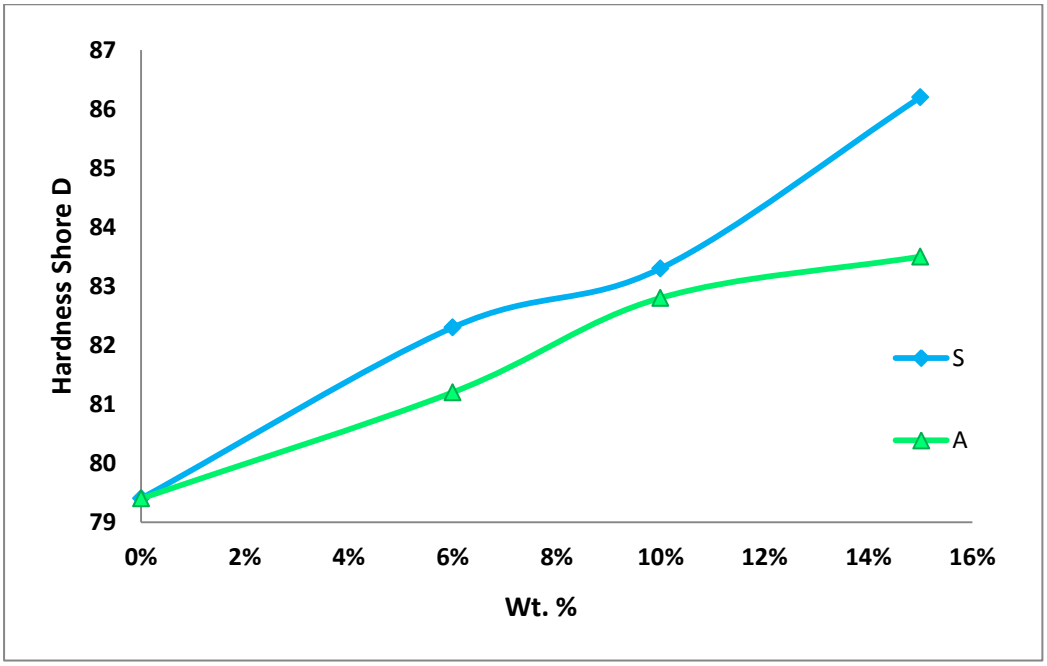

Figure (3) illustrates the relationship of hardness Shore D with the sample type and the addition ratio.

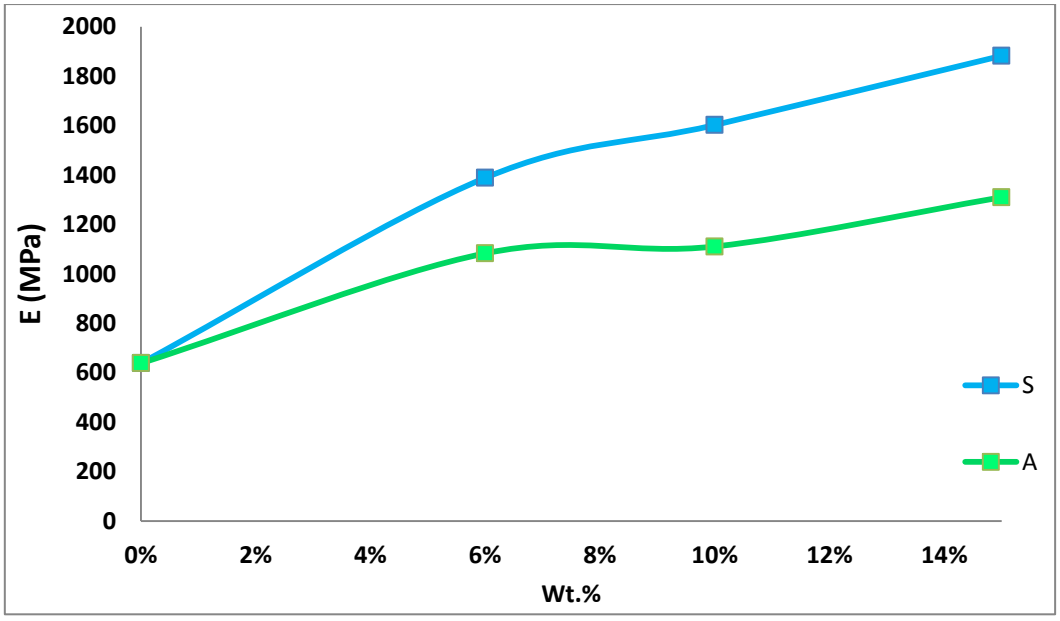

Figure (4) illustrates the relationship of modulus of elasticity (E) with the sample type and the addition ratio.

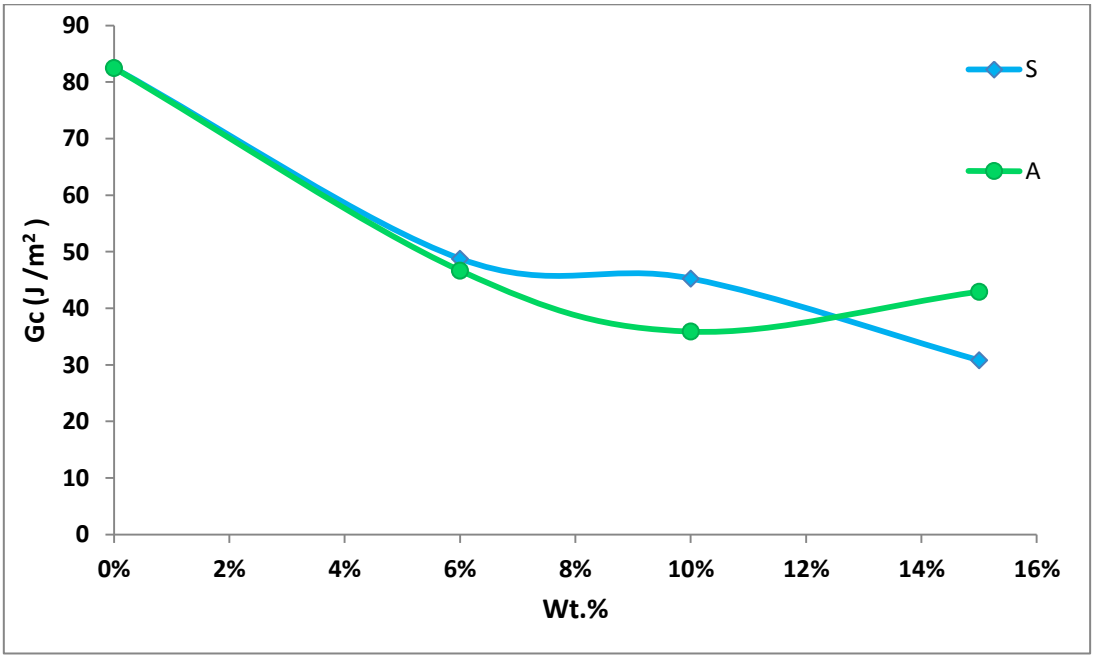

Figure (5) illustrates the relationship of Impact Strength with the sample type and the addition ratio.

The increase in hardness is due to the easy penetration of Nano particles within the Matrix material and into the gaps and pores that are formed during the preparation process composite, which leads to an increasing the cross-linking between them, which restricts the mobility of both polymer molecules and dislocation and gives more positive values when testing the hardness.

Also increasing the values of modulus of elasticity (**E**) is due to the nature and strength of the bonding between the matrix material and the

Nano reinforcement material (Fe_2O_3, Al_2O_3 Nano powder), When the particle size is approaching the molecular size of the polymer chains, these particles overlap with the molecules of the polymer chains, resulting in increased cross-linking and bonding between the polymer chains by increasing the added ratio because of ease penetration of Nano particles within the matrix material leading to the creation Strong interface between matrix material and Nano reinforcement material.

Either explanation of the results of reduced Impact Strength is due to the fact that the resin material that is not reinforced when testing the Impact Strength broken the bonds or molecular forces by the growth of the initial cracks caused by the stress of Impact Strength ,When the polymer is reinforced with Nano particles, the energy required to break the polymer decreases because Nano particles lead to the formation of a strong interface zone, which increases the brittleness of the material because Nano particles act as concentrations of stress, which increases the probability spreading rapidly of cracks. Because of its presence within the main polymer bonds as well as the presence of agglomerates reduces Impact Strength because it acts as defects increase the probability of the spread of cracks more quickly than the rest of the samples.

Conclusions:

In this research, it is found that the value of the hardness and elastic modulus (**E**) increases by increasing the Nano additives ratio while Impact Strength is reduced as a result of the effect of Nano material properties of the matrix material, This is because it increases the cross-linking and bonding of polymer chains, increasing the values of modulus of elasticity and hardness and reduced Impact Strength because Nano particles act as concentration areas, which increases the probability of cracks spreading rapidly.

References:

[1] *Sh. Zhao,"Introduction to Nano Composite",Dept. of Mechanical & Materials Engineering University of Nebraska-Lincoln, (2013).*

[2] *Z. Han, A. Fina, "Thermal conductivity of carbon nano tube &their nano polymer" ,Progress in polymer Science ,vol(36),P.P(914-944) , (2011).*

[3] *J.Z.Liang, R.K.Y.Li &S.C.Tjong ,"Journal of Plastic Rubber and Composites Prpcessing and Applications", Vol.26, No.6, (1997).*

[4] *Tao Sun, Hongyu Fan , Zhi Wang , Xin Liu ,Zhanjun Wu ," Modified nano Fe2O3-epoxy composite with enhanced mechanical properties", Materials & Design, Volume 87, 15 December 2015, Pages 10-16.*

[5] *V. R. Arun prakash , A. Rajadural ," Mechanical, Thermal and Dielectric Characterization Of Iron Oxide Particles Dispersed Glass Fiber Epoxy Resin Hybrid Composite ", Digest Journal of Nanomaterials and Biostructures , Vol. 11, No. 2, April - June 2016, p. 373 – 380.)*

[6] *Sihama Issa Salih , Wleed Bdaiwi Salih , Salam Obaid Abdulghani ," Preparation and Characterization the Flexural Properties and Impact Strength of PMMA Nano Composite Used For Denture Base", International Journal &Magazine of Engineering, Technology, Management and Research ,Vol. 3,P.P (419-427) ,August(2016).*

[7] *B.A. Azhdar , " Impact Fracture Toughness of Fiber Reinforced Epoxy Resin " ,M.SC Thesis ,U.O.T ,Iraq,(1992).*

[8] *R.J. Timings ,"Engineering Materials . Vol. 1," Longman Scientific and Technical , Longman House , Burnt Mill , Harlow , Essex CM 20 2 JE, UK, 1989.379, (1989).*

[9] *J. Haidari, "Engineering material tests " Department of Materials and Minerals engineering, al-Balqa Applied University,. (2004).*

[10] *A. M. Al-Khatib and Kh. Ayoub, "Methods of manufacturing and operations (formation processes) " University of Mosul, (1988).*

[11] *Ives, Mead and M. M. Riley, "Handbook of Plastic Test Methods", Butter Worth Group, (1971).*

[12] *D . R . Askeland & P . P . Phule, " The Science & Engineering of Materials " , Fourth Edition , Thomson Brook / Cole ,(2003).*