Study the Mechanical Properties of Epoxy Resin Reinforced With silica (quartz) and Alumina Particles

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Abstract

In this work the mechanical properties of polymer composites reinforced with ceramic particulates are investigated. The epoxy resin used as a Matrix material is Ep-10 and the reinforcement particulate materials are silica with particle size (53-63)µm and alumina with particle size (106-150)µm ,and having weight fraction of 20%, 30% and 40% respectively. Specimens of the matrix material and the six types of composite materials were subjected to tensile, compression, bending, impact and hardness tests. Experimental tests results indicate that the composite materials have significantly higher modulus of elasticity than the matrix material. It was found that the enhancement in modulus of elasticity is directly proportional to the weight fraction of reinforcement material and that alumina composites have higher modulus of elasticity than silica composites with equivalent weight fraction .The highest modulus of elasticity is that of the composite with 40 % alumina, which is 182% higher than that of the matrix material. The tensile and bending strength of the matrix material were found to be significantly higher than those of the composite material while composites with 30% and 40% weight fraction reinforcement martial have marginally higher compressive strength than the matrix material. Test results also indicate that material toughness, fracture toughness and hardness of the composite materials are significantly higher than those of the matrix material. The enhancements in these properties are found to be directly proportional to the weight fraction of reinforcement materials. These properties of composites reinforced with alumina are significantly higher than that of composites reinforced with equitant silica(quartz) content. The highest material toughness, fracture toughness and hardness are that of the composite with 40 %alumina.

Keywords: Epoxy, mechanical properties, ceramic filler.

دراسة الخواص الميكانيكية للايبوكسي المدعم بدقائق سليكا(كوارتز) والالومينا

ملخص البحث

تمت دراسة الخواص الميكانيكية لمواد مركبة بوليمرية معززة بدقائق سيراميكية.الراتنج المستخدم كمادة أساس هوالايبوكسي نوعEp-10 والمواد المستخدمة للتدعيم هي السليكا بحجم حبيبي يتراوح مابين µm(53-63) والالومينا بحجم حبيبي يتراوح مابين µm(150-106) وبكسر وزني مقداره 40% -30% -20% . عينات من المادة الأساس والانواع الست من الماد المركبة تم إخضاعها لاختبارات الشد ،الانضغاط،الانحناء ،الصدمة والصلادة.نتائج الاختبارات العملية أظهرت ان المواد المتراكبة تتميز بارتفاع كبير في معامل مرونتها مقارنة بالمادة الأساس .وان التحسن في معامل المرونة يتناسب طرديا مع الكسر ألوزني للمواد المدعمة إضافة إلى أن المواد المركبة المدعمة بدقائق الالومينا كان معامل مرونتها أعلى من تلك المدعمة بدقائق السليكا وذات الكسر ألوزني المناظر وأن أعلى معامل مرونة هو في حالة التدعيم بنسبة40% الومينا حيث كان أعلى بنسبة% 182عما هو في المادة الأساس ومتانة الشد والانحناء للمادة الأساس كان

فيها أعلى قليلا من المادة الأساس .نتائج الاختبارات أظهرت أيضا أن متانة المادة ومقاومة الكسر والصلادة للمواد المتراكبة أعلى بكثير من المادة الأساس .وان التحسن في الخواص يتناسب طرديا مع الكسر ألوزني للمواد المدعمة اضافة إلى أن المواد المركبة المدعمة بدقائق الالومينا كانت متانة المادة ومقاومة الكسر والصلادة لها أعلى من تلك المدعمة بدقائق الكوارتز ذات الكسر ألوزني المناظر وقد أظهرت النتائج أن أفضل هذه الخواص هو في حالة التدعيم بنسبة % 40 الومينا.

1- Introduction

Polymer matrix composites (PMC_S) are the workhorse of the composites industries. They have excellent room –temperature properties at a comparatively low cost. The matrix consists of thermosetting resins and thermoplastics polymers. Most composites consist of a reinforcement component in the form of small – diameter fibers, whiskers, particles, and flakes (1-3). Particulate filled polymers are used in very large quantities in all kinds of applications and despite the overwhelming interest in advanced composite materials, considerable research and development is done on particulate filled polymers even today(4). Fillers increase stiffness, fracture toughness, and high temperature load-bearing capability, decrease shrinkage and improve the appearance of composites (5-7).The major parameters that influence the mechanical properties of the particulate composite are: Volume fraction or filler concentration, kind of the particles reinforcement, and particle size, shape of the particles and the interfacial adhesion between the matrix and the particles(8). Epoxy resins are used widely due to their good mechanical, thermal, and electrical properties). Many types of epoxy resins have been developed, including bisphenol- aliphatic cyclic, novolac types, etc. To further strengthen the properties of epoxy resins, the use of an additional phase has been a common practice(9). Epoxy resins modified with inorganic particles such as, titanium dioxide, silica, alumina, fly ash, clay and so on have shown improved performances.(10-13) .For .inorganic/organic composites, the size of particles and the interfacial adhesion have great effect on the properties of the resin matrix. The well dispersed inorganic fillers in polymer matrices and compatibility between inorganic and organic phases are important to achieve an overall good performance (14) .In order to obtain the favored material properties for a particular application, it is important to know how the material performance changes with the filler content under given loading conditions. In this study, epoxy resin are fabricated using conventional filler (aluminum oxide (Al2O3) and silicon oxide (Quarts) (SiO2). Involves studying the effects of weight fraction and the type of the reinforcement particulates on the mechanical properties of the composite materials which include tensile, compression, bending, impact, and hardness.

EXPERAMANTALWORK-2

2-1 Matrix Material

The material system used is a low viscosity epoxy resin type (conbextra EP-10),At room temperature curing and (Metaphenylene Diamine)hardener both supply by Fosrac Jordan company. The details of the specification of epoxy resin as shown in table (1).

2-2 Reinforcement particles

the x-ray diffraction and sieving analyses used to examination the particles reinforcement The filler that have been used are quartz(SiO2) and alumina phases, powders with particle size between(53-63) µm for quartzes. and (106 to 150) µm for alumina . The Properties of the Quartz as shown in table(2).

2-3 Specimens' preparation

All specimens in this study were manufactured by hand layup technique .The mould that was used in this work for casting process is made of galvanized steel with dimension of (20, 20, 5)cm. As shown in fig (1) . The mould must be clean and the sticker fablon is placed on the inside wall of the mould to prevent the adhesion between the mould and polymeric material. The polymeric material is prepared by mixing the epoxy resin with the hardener in (3:1) ratio at room temperature, the mixing was very slow, using glass rod for (15min.) until it becomes homogenous, then the mixture is poured in the mould from one side only to eliminate the entrapment of air, and then the mould cover is placed on top in order to obtain homogenous thickness, then the silica powder is added to the epoxy in different weight fractions of (20,30,40)%,and continuously mixing until it becomes homogenous , the mixing is completed after(2min),then the mixture is poured into the mould. The same steps using to prepare alumina particles enforcement epoxy. When the solidification process for all moulds is completed after 24 hours, the casts are released from the moulds .The curing is made in oven at 50°C temperature for three hours to decrease the induced stresses that occur during the solidification process).The mould is cut in to a standard specimen dimensions for each test and according to the stander dimensions as shown in table (3).

2-4 TEST PROCEDURE

2-4-1-Tensile test The tensile and compression test of material specimens was carried out on an Instron Universal Testing Machine Type 1195, and these test specimens was loaded to failure at a constant rate of 2mm/min. A direct plot of the loaded-deflection curve for each specimen tested have been obtained on the x-y recorder of the Instron.

The tensile strength (TS) has been by using

$$\sigma = \frac{P}{A} \quad \textbf{(1)}$$

where: σ = stress (Mpa), P = applied load in the test (N). A = original area of the test specimen $(mm)^2$.

The strain is given by eq (2):

$$\varepsilon = \frac{L - L_o}{L_o} \quad \textbf{(2)}$$

where : ε = strain , L = length at any point during the elongation mm.
L_o =original gage length (mm) .

The stress – strain relationship is defined by Hooke's -Law:

$$E = \sigma / \varepsilon \quad \textbf{(3)}$$

Where: E = Modulus of elasticity (Gpa) .

2-4-2-flexural test

The flexural test adopted in this work was the three-point test in accordance with ASTM D-790 standard. The load was applied at a rate of 2 mm/min until a rupture occurred .A direct plot of load-deflection curve for each specimen tested was obtained on the x-y recorder. In similar manner to that followed in tensile test.. Flexural strength can be calculated from below eq. (4).

$$F.S = \sigma_{\max} = \frac{3PS}{2B^2 D} \quad \textbf{(4)}$$

Where :p the applied load (N) S: span (m) B: width (m) D: thickness (m)

In addition, Young modulus can be calculated from following eq. (5).

$$E = \frac{PS^3}{4\delta BD^3} \quad \textbf{(5)}$$

Where: δ: deflection (mm).

2-4 3-Hardness test

Brinell hardness test set was used to determine the hardness of the specimens. The equipment used is type Ley Bold Harris No.36110**.**The Brinell test is conducted by impressing the indenter with diameter (5mm) under a load (1kN) into the surface of the specimen for a standard time,
usually 30sec.After measure the indention diameter (d) the hardness is calculated from the following eq.(6).

$$\text{BHN} = \frac{2P}{\pi D^*(D^* - \sqrt{D^{*2} - d^2})} \quad \textbf{(6)}$$

BHN: Brinell hardness (Kg force).P: The applied load (KN).D*: Indenter diameter (mm).
d: Indention diameter (mm).

2-4-4-Compression Test specimens

The compression test of material specimens was carried out using Testometric Co.Ltd M500-25KN.Each specimen have been loaded to at a constant rate of 2mm/min until failure. A direct plot of the loaded-deflection curve for each specimen tested was obtained on the x-y recorder of the Thermometric. Test begin by, placing the specimen between the surfaces of the compression tool, taking care to align the center line of the long axis with the center line of the plunger and ensuring that the ends of the specimen were parallel to the surface of the compression tool. The crosshead of the testing machine was adjusted until it just contacted the tip of the compression tool plunger and then applying load. The compression strength (σ), compression strain (ε), and Young modulus (E) are calculated by using the equations (1, 2, 3) respectively.

2-4-5- Impact Test

The impact test was performed by using Charpy impact test instrument [Testing Machine INC,AMITYVILLE,New York Company], and carried out in technology of University The procedure of the test is as follows, placing the notched specimen [the depth of the notch(1,1.5,2)mm]. The geometrical function (Ø) could be estimate by the following eq. (7).

$$Ø = 0.135\left(\frac{a}{B}\right)^{-0.77} \quad \textbf{(7)}$$

Where:
(a/B) the ratio of the notch depth to width of the specimen. This equation is used only when the span to width (S/B) is equal to (4) .Specimen with dimensions (10*10) mm and the span (40) mm have been used. The geometrical function in this work depends only on the notch depth (a)calculated by using the geometrical function index (BDØ) (mm^2) to plot the relationship between the fracture energy (Joule) and (BDØ) the slope

of this curve represents the toughness of the material (KJ/m^2). The fracture toughness ($Kc\ MN/m^{3/2}$) is calculated from the following eq. (8).

$$K_c = (EG)^{\frac{1}{2}} \qquad \textbf{(8)}$$

Where;
K_c:Fracture toughness ($MN/m^{3/2}$).
E: Young's Modulus taken from the tensile test.
G: Materail toughness (KJ/m^2).

Table(1). The Specification Of Epoxy Resin

Test Method	Typical Result	
Density(Kg/m^3)	**1100**	**At 20 ^oC**
Compression Strength(N/mm^2)	**77**	**At 20 ^oC**
Tensile Strength(N/mm^2)	**29**	**At 20 ^oC**
Flexural Strength(N/mm^2)	**91**	**At 20 ^oC**

Table (2) The Properties of the Quartz.

	High Form	Low Form
Density (gm/cm^3)	**2.63**	**2.65**
Hardness (knoop)	**820**	
Crystal Structure	**Hexagonal**	

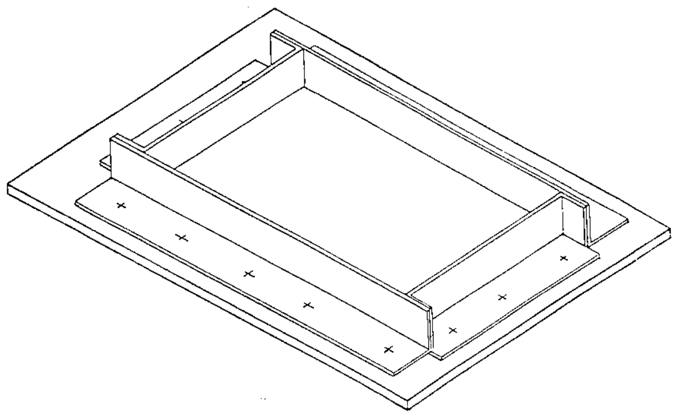
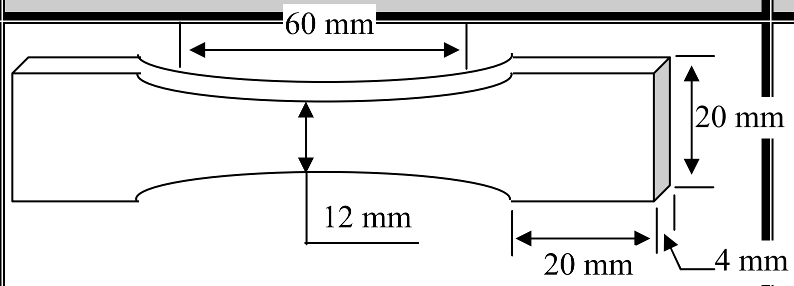
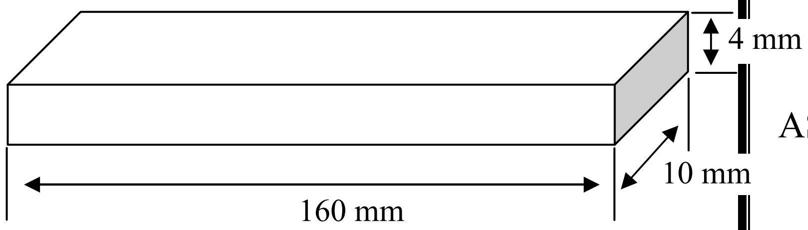
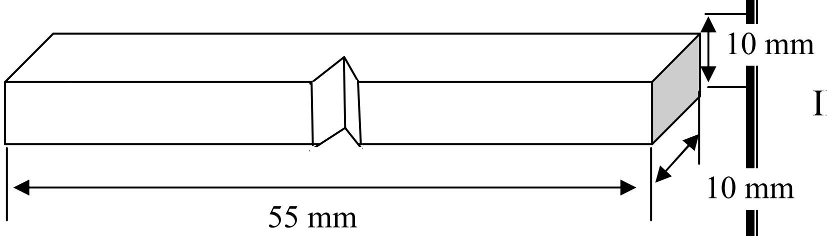
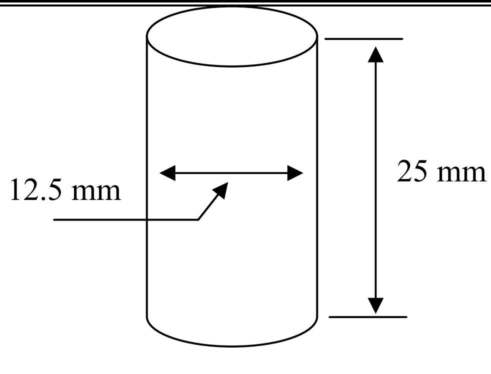


Figure (1) The Shape of the Mold.

Table (3) Standard Dimension Specimen

Test Type	Test Specimen Specification	Standardization Code
1. Tensile		ASTM - D638 (16)
2. Bending		ASTM - D790 (17)
3. Impact		IISO – 179 (18)
4. Compression		ASTM – D695 (19)

RESULT AND DISSCASION

1-Tensile stress result

Tensile stress-strain curves of the matrix material and the six types of composite materials are shown in Figures (2, 3 , 4).The ultimate tensile strength and tensile modulus of elasticity of these materials are given in Table 4.As shown in table(4).

Table 4: Tensile strength and Modulus of elasticity of Materials

Materials		Particle Weight Fraction %	Tensile Elastic Modulus Gpa (E)	Tensile Strength Mpa T.S
Matrix	Reinforcement Particle			
Epoxy	0	0	1.27	50.2
Epoxy	Silica	20	1.82	17.5
Epoxy	Silica	30	2.15	28.5
Epoxy	Silica	40	3.11	29.7
Epoxy	Alumina	20	2.48	40.7
Epoxy	Alumina	30	2.73	28.1
Epoxy	Alumina	40	3.58	25.9

In general, it is noted that the ultimate tensile strength of the matrix material is higher than those of the composite materials, while its tensile modulus of elasticity is lower. This indicates that adding silica or alumina particulate to the epoxy resin decreases the ultimate tensile strength and increases the modulus of the elasticity. In addition, it is noted that the failure strain of the epoxy resin is much higher than those of the composite materials, which indicates that the addition of silica or alumina particulate to the epoxy resin reduces its elasticity. This behavior can be explained as follows; the bonding in ceramic is more rigid and does not permit slip under stress. The inability to slip makes it much more difficult for ceramics to absorb stress, modulus of elasticity is evidence of interatomic bonding, and as a result, the ceramic has the higher modulus of elasticity. As shown in figure (2),the epoxy resin(unfilled)exhibited highest (50.2Mpa) tensile strength, lowest young modules(1.27Mpa),and the failure strain is 7%. Further due to addition different percentage fillers of quarts and alumina as shown in fig (3) and(4) respectively. In general increase in quarts and alumina content leads to an increase ultimate tensile strength but in comparison with material matrix reduces the tensile strength to (17.5Mpa ,28.5Mpa,29.5Mpa) for quartzes and (40,7Mpa.28.1Mpa 25.9Mpa) for alumina filler respectively .Ana the failure strain reduce from epoxy resin material matrix (7%) to (1.2%)of 40% quarts filler and ,1.%,1.6% for 30%,and

40% alumina respectively .This indicates that the composite property changes from ductile to tough and brittle due to addition the fillers particulates in epoxy resin composite.

Also the 30%specimen exhibits lowest tensile strength compared to other specimens may be due to agglomeration of filler in the resin at higher percentage of fillers.

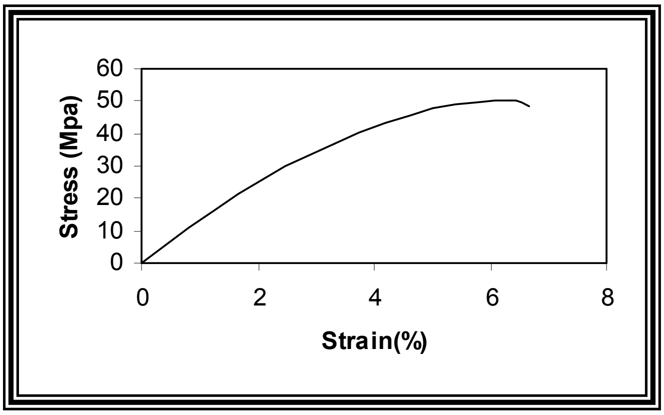


Fig (2) Tensile Stress-Strain Curve of Epoxy Resin.

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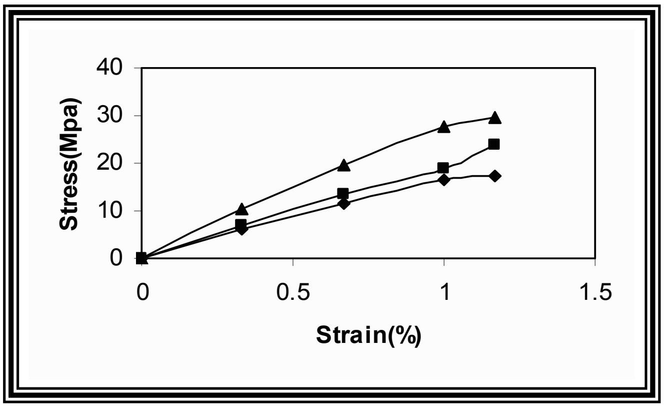

Fig (3) Tensile Stress-Strain Curve of Silica Reinforced Epoxy Resin.

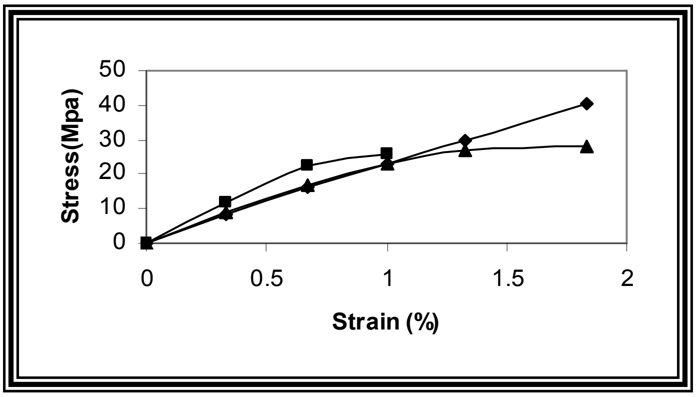

Fig (4) Tensile Stress-Strain Curve of Silica Reinforced Epoxy Resin.

The effect of quarts and alumina content on tensile strength and tensile modulus of elasticity are shown in figures (5), (6) respectively. As shown in figure (5).The tensile strength decreases at slow rate with the addition of alumina particulate until the weight of alumina

Content is 20%.Then a rapid reduction in tensile strength is observed with the increase of alumina content from 20% to 30%. Further increase in alumina content from 30% to 40% results in slight reduction in tensile strength. As shown in Figure (6), the addition of alumina to the epoxy resin significantly increases its tensile modulus of elasticity .The

modulus of elasticity increases at a constant rate up to 20% of alumina content .Then a slower rate of increase in the modulus of elasticity is observed with the increase of alumina

content to 30% .The highest rate of increase in the modulus of elasticity takes place with the increase of alumina content from 30-40%.

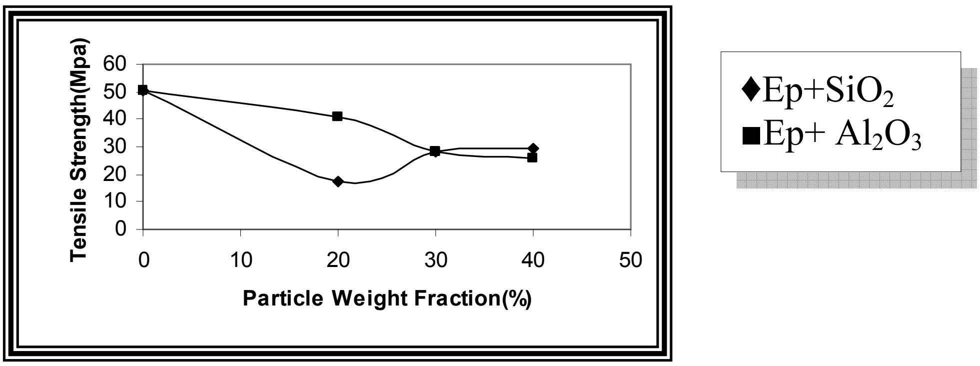

Fig (5) The Effect of the quarts and Alumina Particle Weight Fraction on the Tensile Strength.

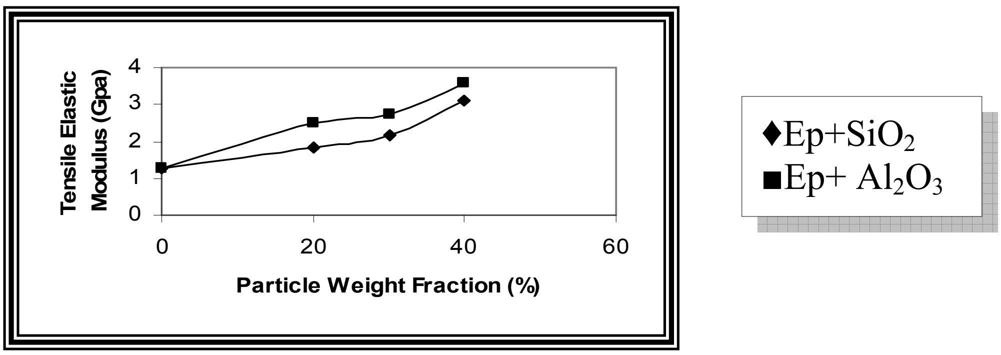

Fig (6) .The effect of the Silica and Alumina Particle Weight Fraction on the Tensile Elastic modulus.

2- Flexural Test

Flexural properties are strongly affected by the quality of the interface in composites, i.e. the static adhesion strength as well as the interfacial stiffness, which plays a major role in promoting the filler reinforcement (12). It has been proven that the flexural stress-strain could be used to study the changes induced by addition of filler. In this study, we have analyzed the changes in terms of flexural stress-strain curves with addition of quartzes (SiO_2) and α-alumina into the epoxy resin. The flexural properties of the epoxy matrix and the six types of composite materials are summarized in table (5).The flexural strength and modulus of composite material were clearly improved compared to the epoxy resin matrix.

Table (5). Flexural Strength and Stiffness of Materials.

Materials		Particle Weight Fraction %	Flexural Elastic Modulus Gpa(E)	Flexural Strength Mpa F.S
Matrix	Reinforcement Particle			
Epoxy	0	0	1.18	23.6
Epoxy	Silica	20	1.39	6.8
Epoxy	Silica	30	2.87	19.6
Epoxy	Silica	40	2.07	9.6
Epoxy	Alumina	20	1.36	15.8
Epoxy	Alumina	30	1.71	10.2
Epoxy	Alumina	40	2.73	8.3

Flexural stress-strain curves of the matrix material (epoxy) and composite materials reinforced with 20%, 30%and 40% quartz (SiO_2) and alumina (Al_2O_3) are shown in Figure (7,8,9).respectively. In fig(7), it is noted that the ultimate bending strength of epoxy matrix is (23.6Mpa) and higher than those of the composite materials while the bending modulus of elasticity is lower.

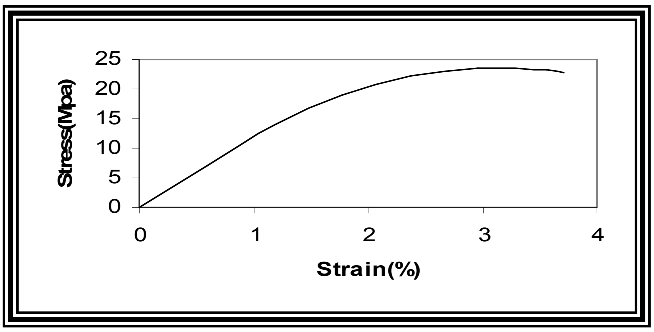

Fig (7) Bending Stress-Strain Curve of Epoxy Resin.

This indicates that adding quartz or alumina particulate to the epoxy resin fig (8, 9) decreases the ultimate bending strength. The composites materials with 20% ,30%,40% silica(quartz) has (6.8,19.6,9.6) Mpa ultimate bending strength respectively, while the failure strain is 1% which is significantly lower than that of the matrix material.

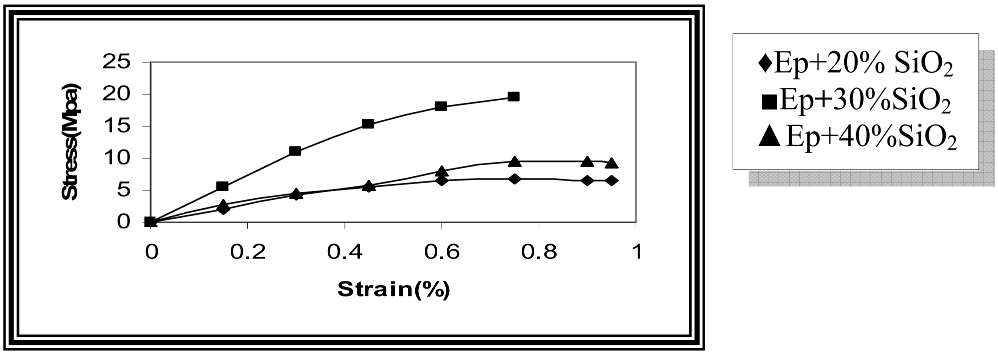

Fig (8) Bending Stress-Strain Curve of Silica reinforced Epoxy Resin.

As shown in fig (9), The bending stress-strain curves of composite materials reinforced with 20%, 30%and 40% alumina has an ultimate bending strength (15.8, 10.2,8.3) Mpa respectively.

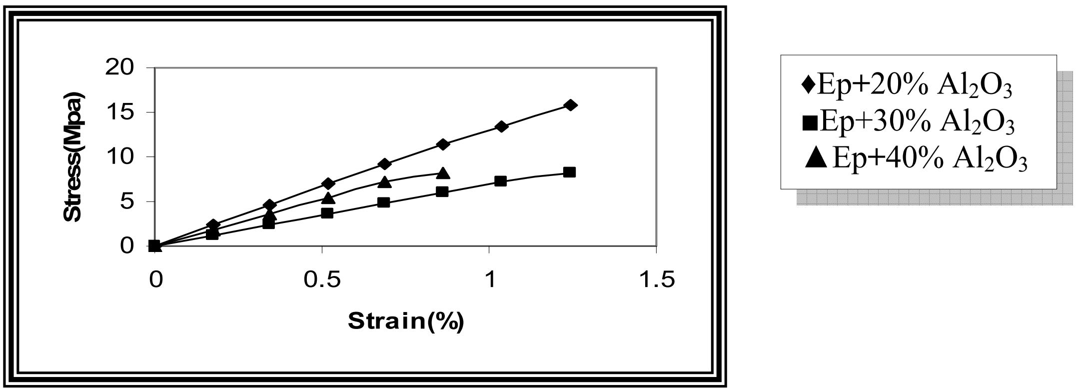

Figure (9) Bending Stress-Strain Curve of Alumina Reinforced Epoxy Resin.

In general, it is noted that these composites follow a brittle behavior to failure under bending load .They have higher modulus of elasticity in comparison with composites reinforced with equivalent silica content. The increase is expected since the α-alumina particle is inherently rigid and thus influences the rigidity of the composite as a whole (bulk). This finding indicates that the composite becoming increasingly brittle with lesser deflection is observed during flexural loading. However, it is also clear that the addition of 30 wt% to 40 wt% of α-alumina slightly reduces the level of stress at yield of the composites. From the same figures, it can also be seen that the degree of plastic deformation reduces with increasing α-alumina content. Ability of the material to plasticity deformed is largely determined by the mobility of the molecular chain (molecular motion) to take place under applied load. The presence of rigid particles such as α-alumina in this case has restricted the mobility of the molecular chain to pass each other and orientation which consequently resulted in instantaneous failure (brittle failure) area the yield stress is reached. However, the benefit that one material can gain in the presence of the rigid particle is the increase in rigidity (stiffness) that is indicated by an increase in the steepness of the stress-strain curve in the elastic region. The effects of silica and alumina content on tensile strength fig (10) as silica content is increased from 20 to 30% a rapid increase in bending strength takes place.

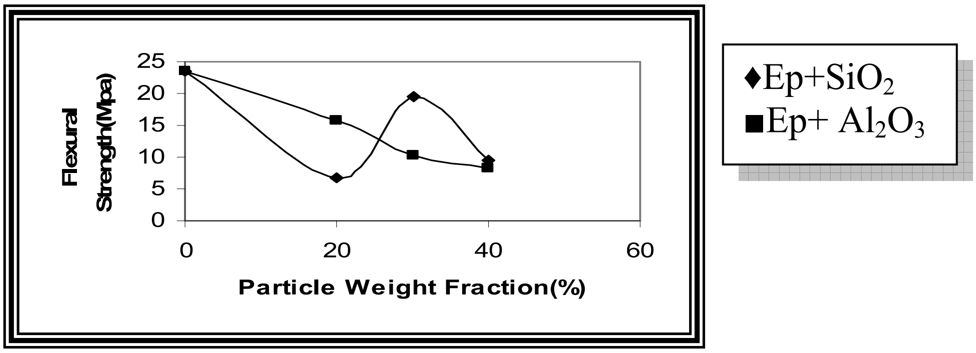

Fig (10) Effect of the Particle Weight Fraction on the Bending Strength.

As shown in Figure (10), the bending strength is inversely proportional to the alumina content. The bending strength decreases at almost a constant rate up to 30% alumina content, then as alumina content is increased from 30 to 40% the bending strength decreases at a lower rate. This because the formation of small and interconnected microvoids .Fibrlillar bridges form between these micriovoids wherein molecular chains become oriented. If the applied load is sufficient, these bridges elongate and break, causing the micro voids to grow and coalesce; as the microvoids coalesce, crack begin to form until the material failure [20] .

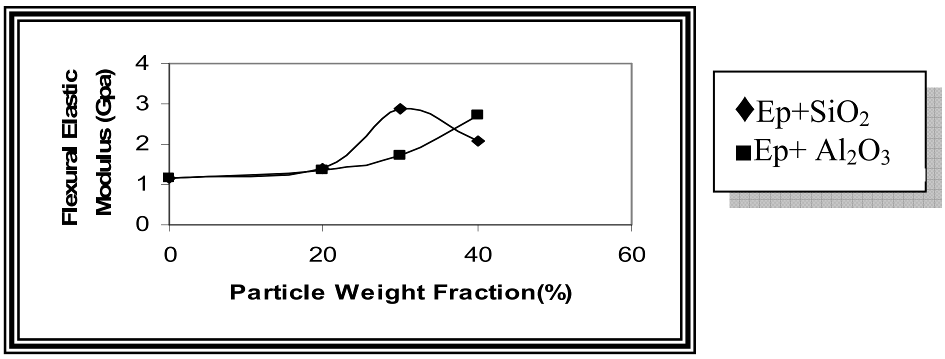

Figure 11: Effect of the Particle Weight Fraction on the Bending Modulus.

As shown in figure (10),the addition of alumina to the epoxy resin significantly increases the bending modulus of elasticity .It is observed that the increase in bending modulus of elasticity is gradual up to 30% alumina content ,then a rapid increase in the bending modulus of elasticity takes place with the increase of silica content from 30% to40%.

3- Compression Test Results

The ultimate compression strength and modulus of elasticity of the matrix material and the six types of composite materials are given in Table (6).

Table (6) Compression Strength and Stiffness of the Materials.

Materials		Particle Weight Fraction %	Compression Elastic Modulus Gpa (E)	Compression Strength Mpa C.S
Matrix	Reinforcement Particle			
Epoxy	0	0	1.29	84.5
Epoxy	Silica	20	1.71	82.7
Epoxy	Silica	30	1.74	87.7
Epoxy	Silica	40	1.90	91.4
Epoxy	Alumina	20	1.93	83.8
Epoxy	Alumina	30	1.97	87.6
Epoxy	Alumina	40	2.14	90.2

The compression stress-strain curves of epoxy resin matrix and composite material reinforced with 20%, 30% and 40% quarts and alumina are shown in Fig. (12, 13,14).respectively. All materials, including the matrix as well as the six types of composites had almost identical ductile behavior under compression. The matrix material as shown in Figure (12) has ultimate compression strength of 84.5Mpa and a compression modulus of elasticity of 1.29Gpa.

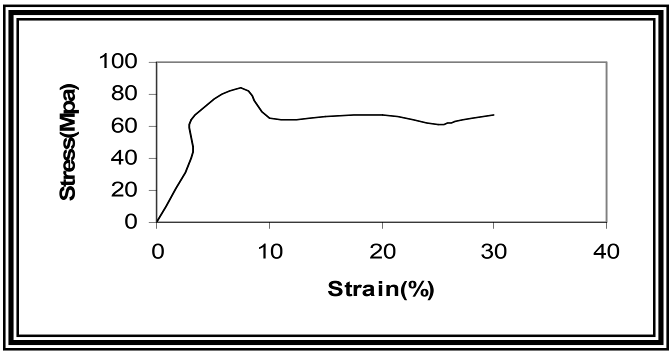

Fig (12) Compression Stress-Strain Curve of Epoxy Resin.

As shown in fig (12, 13).The ultimate compression strength of composites reinforced with 20% silica or alumina is lower than that of the matrix material, while other composites have higher compression strength than the matrix material,

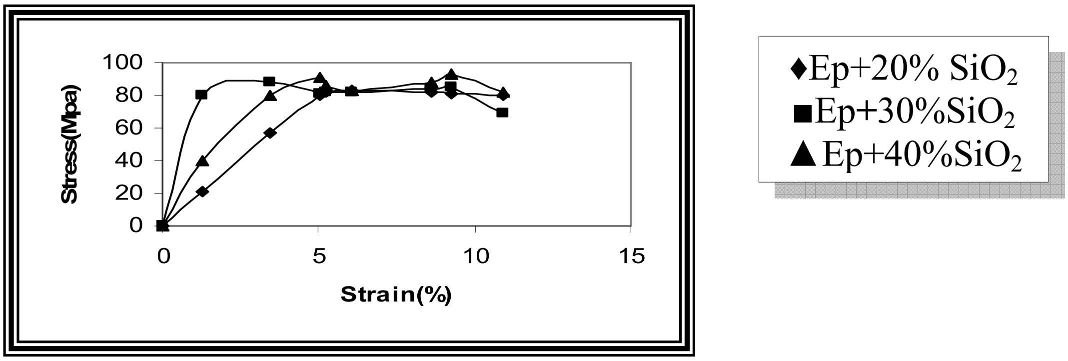

Fig (13) Compression Stress-Strain Curve of Silica Reinforced Epoxy Resin.

The increase of (quarts) and alumina content 30% to 40% further increase in ultimate compression strength. The composite material with 30% silica as shown in Figure (13) has an ultimate compression strength of 87.7Mpa and a compression this represents an increase in of 4% in ultimate compression strength. With the increase of silica content to 40% further increase in ultimate compression strength. The ultimate compression strength of this composite is 91.4Mpa which is 8% higher than that of the matrix material the compression stress-strain curve of the composite material with 40% alumina is shown in Figure (14).It has ultimate compression strength of 90.2Mpa which represent an increase of 7% in comparison to the matrix material.

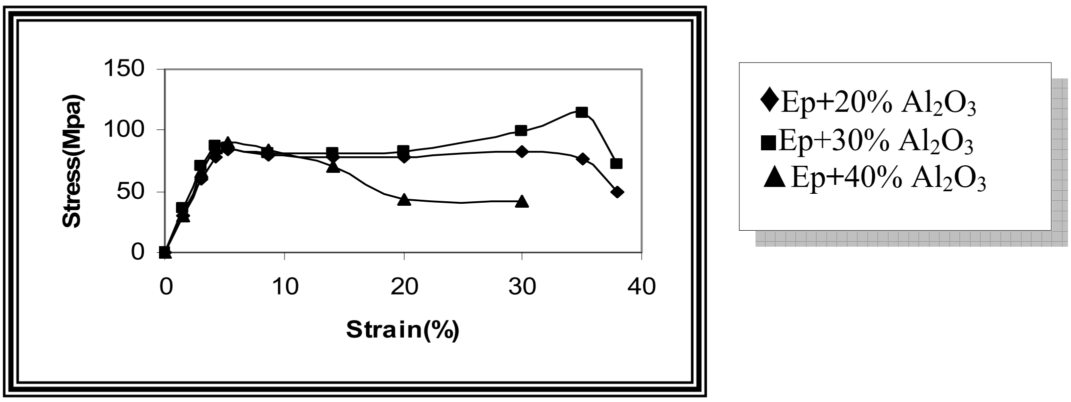

Fig (14) Compression Stress-Strain Curve of Alumina Reinforced Epoxy Resin.

The effect of silica content on compression strength and compression modulus of elasticity is shown in Figures (15) and (16) respectively. Both figures indicate that the ultimate compression strength ad modulus of elasticity is directly proportional to the silica content. As shown in Figure (15), a slight reduction in compression strength takes place with the addition of 20% silica content .This is followed by a gradual increase in compression strength as silica content is increased to 30% and 40%.

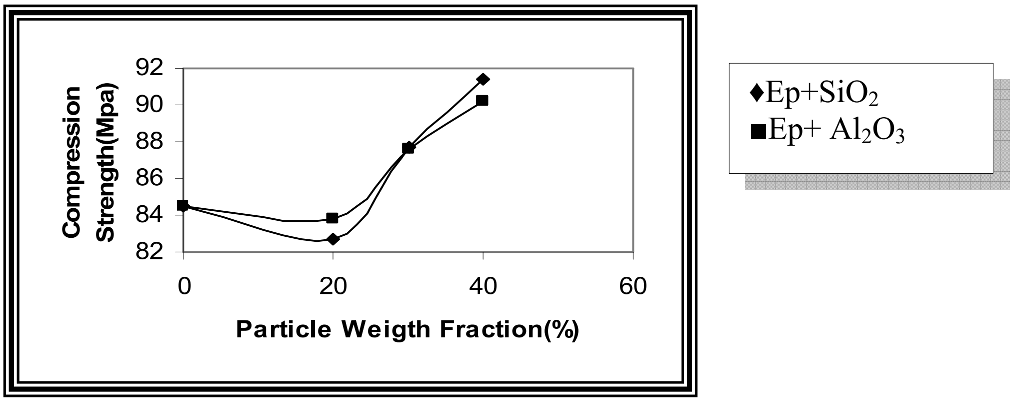

Fig (15) Effect of the Particle Weight Fraction on the Compression Strength.

The compression modulus of elasticity is directly proportional to silica content as shown in Figure (15) .A slight increase in compression modulus of elasticity takes place with the addition of 20% silica ,then a slight increase is observed as the silica content is increase from 20 – 30% and finally a higher rate of increase in compression modulus of elasticity is noted with the increase of silica content to 40%.As shown in Figure (15), a rapid increase in compression modulus of elasticity takes place with the addition of 20% alumina, and then a slight increase takes place as alumina content is increased to 30% and finally the compression modulus of elasticity increase at a higher rate with the increase of alumina content to 40%.

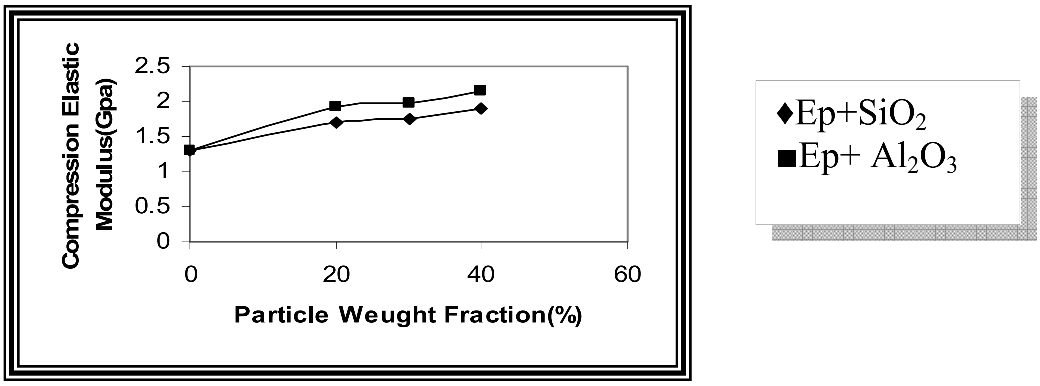

Figure (16) Effect of the Particle Weight Fraction on the Compression Modulus.

4- Impact Test Results

The resistance to impact is one of the key properties of materials. The ability of a material to withstand accidental knocks can decide its success or failure in a particular application. The material toughness and the fracture toughness are given in Table (7).

Table (7) The Material Toughness and the Fracture Toughness.

Materials		Particle Weight Fraction %	Material Toughness G_c (KJ/m^2)	Fracture Toughness K_c (MN/m$^{3/2}$)
Matrix	Reinforcement Particle			
Epoxy	0	0	1.7	1.9644
Epoxy	Silica	20	2.548	2.1534
Epoxy	Silica	30	3.217	2.6299
Epoxy	Silica	40	3.9	3.48267
Epoxy	Alumina	20	2.142	2.3048
Epoxy	Alumina	30	3.57	3.1287
Epoxy	Alumina	40	5.83	4.5685

In general it is noted that the material toughness and fracture toughness are directly proportional tom the weight content of the reinforcement material as shown in Figures (17 and 18). In fact, there is almost a constant rate of increase in material toughness and fracture toughness with the increase of reinforcement material content. It is also noted that the material toughness and fracture toughness of alumina composites are significantly higher than those of silica composites with equivalent reinforcement content. The matrix material has a material toughness and fracture toughness of 1.7(kJ/m^2) and 1.96(MN/m$^{3/2}$) respectively. With the addition of 20% silica the material toughness a fracture increase significantly to 2.55(kJ/m^2) and 2.15(MN/m$^{3/2}$) respectively which are higher than the matrix material by 55% and 9.62% respectively.

With the increase of Silica content to 30% the material toughness and fracture toughness to 3.22(kJ/m^2) and 2.63(MN/m$^{3/2}$) respectively which are higher than the matrix material by 89.2% and 33.87% respectively.

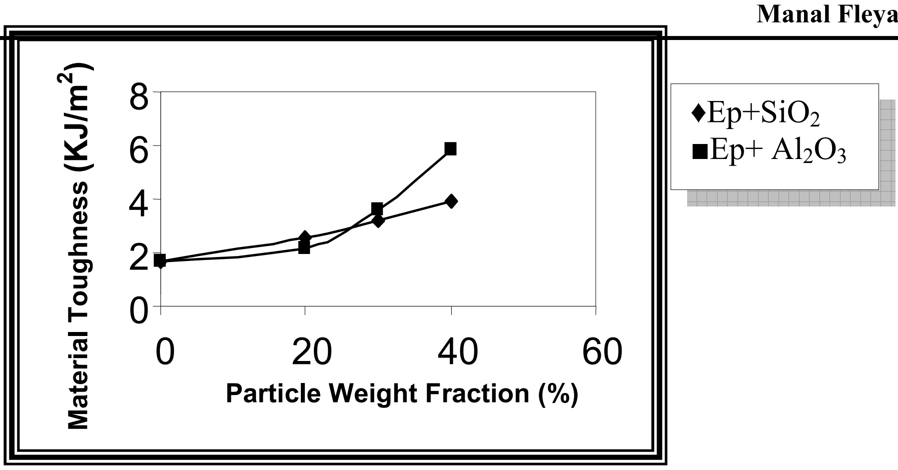

Fig (17) Effect of the Particle Weight Fraction on the Material Toughness.

The increase in silica content to 40% results in obtaining higher material toughness ad fracture toughness which have values of 3.9(kJ/m^2) and 3.48(MN/$m^{3/2}$) respectively ad are higher than the matrix material by 129.4% and 77.28%. With the addition of 20% alumina the material toughness a fracture increase significantly to 2.142(kJ/m^2) and 2.3(MN/$m^{3/2}$) respectively which are higher than the matrix material by 26% and 17.32% respectively. With the increase of alumina content to 30% the material toughness and fracture toughness to 3.57(kJ/m^2) and 3.12(MN/$m^{3/2}$) respectively which are higher than the matrix material by 110% and 59.27% respectively. The increase in alumina content to 40% results in obtaining higher material toughness and fracture toughness which have values of 5.83(kJ/m^2) and 4.56(MN/$m^{3/2}$) respectively ad are higher than the matrix material by 243% and 133%. These increase the material toughness and the fracture toughness because the particles restrain the crack growth through the composite material and it is dislocation, the crack will change its shape and direction, thus the cracks will transfer to microcracks. This change in the cracks behavior and loss the crack energy lead to increase in the toughness.

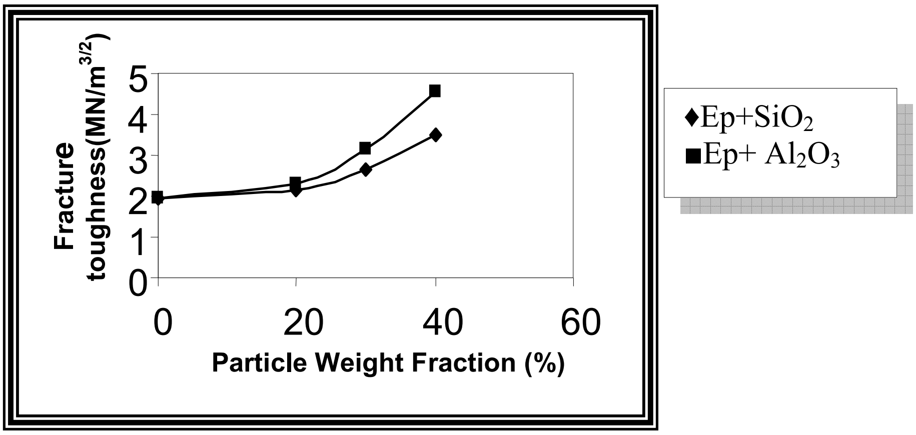

Fig (18) Effect of the Particle Weight Fraction on the Fracture Toughness.

5-Hardness Test Result

Hardness test results are given in Table (8) It is noted that all composite materials have significantly hardness than the matrix material; these increase the hardness because the silica and alumina particles have very high hardness and the strengthening occurs due to the load-carrying of the particles.

Table (8) The Hardness of the Six Types of Materials.

Materials		Particle Weight Fraction %	Hardness BHN (Kg/mm^2)
Matrix	Reinforcement Particle		
Epoxy	0	0	17.8269
Epoxy	Silica	20	23.1954
Epoxy	Silica	30	28.1129
Epoxy	Silica	40	34.6573
Epoxy	Alumina	20	25.4873
Epoxy	Alumina	30	31.1405
Epoxy	Alumina	40	38.778

In addition to that it is clearly evident that the increase hardness is a function of reinforcement material content and that the hardness is directly proportional to the reinforcement content. The effect of silica content and alumina content on the hardness is shown in Figure. This figure indicates that the hardness increases at almost constant rate with the increase in reinforcement material content.

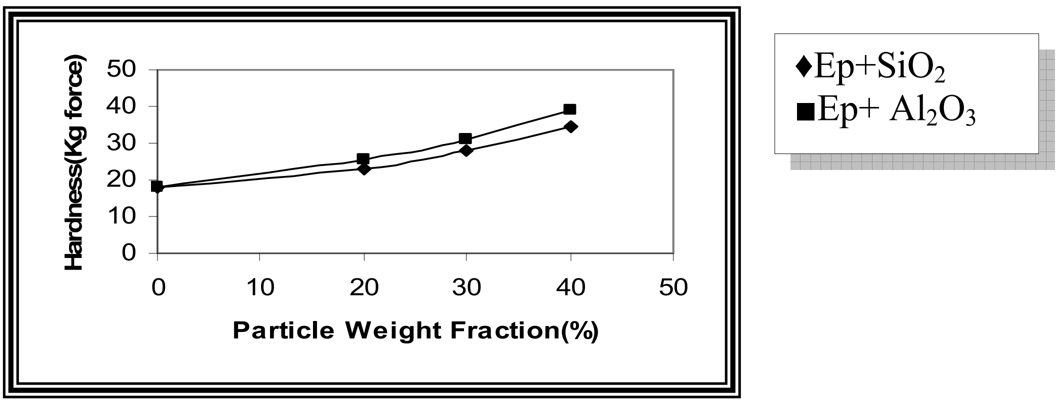

fig (19) Effect of the Particle Weight Fraction on the Hardness.

It is also noted that composite materials reinforced with alumina content have significantly higher hardness than the composite materials reinforced with equitant silica content. The matrix material has a hardness of 17.82(Kg/mm^2). The composite material with 20% silica has a hardness of 23.19(Kg/mm^2), which is 30% higher than that the matrix material.

With the increase of silica content to 30% the hardness increase to 28.11(Kg/mm^2), which is 58%higher than that of the matrix material. As increase in silica content to 40%, its hardness is 34.6573Kg/mm^2, which is 94%higher than that of the matrix material. At 20% alumina content the hardness is 25.4873 Kg/mm^2 that is 43%higher than that of the matrix material. Then, further increase in the hardness takes place with the increase in alumina content to 30%, its hardness 31.1405Kg/mm^2, which is 75%higher than that of the matrix material. With the increase of alumina content to 40%; further increase in hardness to 38.778(Kg/mm^2), which is 178%higher than that of the matrix material.

CONCLUSIONS

1. The modulus of elasticity of composite materials is significantly higher than that of the matrix material and it is directly proportional to the weight fraction of reinforcement material. Alumina composites have higher modulus of elasticity than silica composites with equivalent weight fraction of reinforcement material. The highest modulus of elasticity is that of the composite with 40 % alumina, which is 182% higher than that of the matrix material.
2. The tensile and bending strength of composite materials are significantly lower than that of the matrix material .The reduction in tensile strength is found to be 19-65% in comparison with the matrix material while that of the bending strength is found to be 17-65%.
3. Compression strength of composites reinforced with 20%silica or alumina is1-2% lower than that of the matrix material ,while comparison with 30% and 40% reinforcement materials have 4-8% higher compression strength than the matrix material.
4. The material toughness and fracture toughness of composite materials are significantly higher than those of the matrix material and are directly proportional to the weight fraction of reinforcement material. The enhancement in material toughness of composites in comparison with the matrix material is 26-129% while the enhancement in fracture toughness is 10-133%.The material

toughness and fracture toughness of composite materials reinforced with alumina is significantly higher than composites reinforced with equitant silica content.

5. The hardness of composite materials is also significantly higher than that of the matrix material and is proportional to weight fraction of reinforcement material. The enhancement in hardness of composite material in comparison with the matrix material is found to be 30-118%. The hardness of composites reinforced with alumina is significantly higher than that of composites reinforced with equitant silica content.

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