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## **Study the tensile strength for epoxy composite reinforced with fibers and particles**

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**Abstract:** This research include the study of tensile strength for the polymer and the composite materials, we using the epoxy resin as matrix for the reinforced materials that consist of artificial fibers (Kevlar, glass and PVC fibers) also aluminum powder for reinforcing. The slates made of composite materials and hybrid composite materials for both volume fractions 20% and 40% from the reinforced materials, Twenty one slates were made from the composite materials, all these slates were cut into samples with measurement (10x 80mm) in order to execute the tensile strength test for both volume fractions 20% and 40%. The results and laboratory examinations for these samples shows increase in the tensile strength for composite materials when the volume fraction increase from 20% to 40% for reinforced material, the samples from type (EK) have tensile strength is higher than all samples for both volume fraction.

**Keywords:** tensile strength , epoxy composite , reinforced ,fibers , particles

### **Introduction**

About 30% of all polymers produced each year are used in the civil engineering and building industries. Polymer offer many advantages over conventional materials including lightness resilience to corrosion and ease of processing. They can be combined with fibers or particals to form composite materials which have enhanced properties. Theoretically, any material that is not a pure substance and materials which have enhanced properties. Theoretically, any material that is not a pure substance and contains more than one component, may be classified among the composite materials, enabling them to be used as structural members and units polymer composites can be used in many different forms ranging form structural composites in the construction industry to the high technology composites of the aerospace and space satellite industries. Polymer composites were first developed during the 1940,s, for military and aerospace applications. Glass-reinforced plastics have been used in many other applications including pressure pipes, tank liners and roofs. In the last decade, polymer composites have found application in the construction sector in areas such as bridge repair, bridge design, mooring cables, structural strengthening, and stand-alone components [1-3]. In polymer composites, the matrix may be thermoplastic or thermoset materials. Epoxy resin is thermoset materials, the structure of epoxy resin is characterized by the epoxy group [-CH-O- CH<sub>2</sub>-

]. Also known as epoxide. Epoxy resins of several families are now available ranging from viscous liquids to high melting solid. Among them, the conventional epoxy resins manufactured from epichlorohydrin and bisphenol A remain the major type used. There are a varicly of hardeners or curing a gents generally used for epoxy resins. The amine type compounds are often used in structural application. The hardening effect is achieved through the formation of cross-links between the resin polymer chain and the hardener, or by direct linkage among the epoxy groups [4-6]. Reinforced plastics based on epoxy resins have better mechanical strength, chemical resistance, electrical insulating properties and environmental stability than those made with conventional unsaturated polyester [7, 8]. The matrix of composite materials, commonly made of epoxy binds and protects the fibers from damage, and transfers the stresses between fibers [9,10]. The fibers polymers are capable of being drawn into long filaments having at least a (100:1) length-to-diameter ratio [3]. Fibers are the principal structural component in a fiber- reinforced composite material. They support the majority of the load acting on a composite structure. However, the properties of a composite laminate such as compressive strength and modulus, tensile strength and modulus, specific gravity, fatigue strength, electrical and thermal conductivities and cost are influenced not only by the amount of fiber, but also by the orientation of the fibers. The most commonly used fibers in composites

are glass, polyvinylchloride (PVC) and aramid (Kevlar) fibers [11].

**Tensile force**

Whenever a force is applied to a solid material, that material will deform in response to applied force. If only small deformation are considered and the solid material will return to its original shape when the force is relieved, then the deformation is called elastic. In elastic deformations all of the mechanical energy that was put into the material by the applied force to cause the deformation was held within the material and was then used to cause the material to return to its original shape and position. A common example would be a spring that is deformed slightly, thus importing potential energy to the spring, which is then available within the spring to cause it to return to its original shape. Another way of saying this is that energy was returned or recovered. Energy is always recovered in elastic deformations.

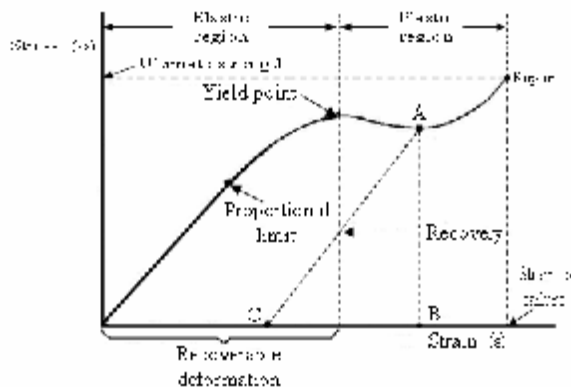


figure (1) Stress-strain behavior over the entire strain range for a typical polymeric material [12].

The elastic region in the stress-strain curve of figure (1) is the initial part of the curve, identified as the linear region where the stress and strain values are small. In this region the modulus is given by the Hooke's law relationship. The point where the stress-strain curve begins to deviate from linearity is called the proportional limit. Another key feature of the stress-strain curve is the onset of permanent deformation, which is marked as the yield point [12]. Beyond the yield point, the material is permanently deformed. That is, even when the stress is removed, the material will not recover to its original shape. The region beyond the yield point is called the plastic region [13].

The most common type of force is a pulling force "called tensile force". One of the most basic mechanical properties is tensile strength, which is the resistance to two forces pulling on a sample of the polymer in opposite directions. Entanglement and other intermolecular attractions have a strong effect on tensile strength. As the molecules are pulled in opposite directions (tension), the energy levels of the molecules increase. This increase in energy level creates more molecular movement (vibration,

rotation and translation), which has the effect of gradually disentangling the molecules. Ever more tensile force will create more disentanglement until the molecules are free to slide relative to each other. The force required to cause this sliding of molecules is called the tensile force. Hence, the more entangled the molecules, the more tensile force that is required to cause them to slide [14, 15].

**Experimental procedure**

Epoxy resin was used to fabricate the samples and the hardener material was added in order to solid it. This mixture are used to made the matrix, more over we used synthetic fibers and aluminum powder in order to reinforce the matrix to produce composite materials which are ready for tensile test. Hand lay-up was used to produce composite materials and hybrid composite materials. In this study, twenty one slated of composite materials were made.

We reinforced the resin by fibers and aluminum powder with different volume fractions like 20% (10% fibers and 10% aluminum powder) and also 40% (20% fibers and 20% aluminum powder) for different fibers.

**Cutting up of samples**

Two iron saws were used indented one smooth, the other in the rough cutting. Hacking was in accordance with the specifications used in the test, the samples were with the dimensions of (80 mm) for the length and (10 mm) for the width. The thickness depends on the number of layers in the sample fiber rating (number of layers of fibers), then was removed Pluses from the samples by using the iron rasp. Further refine and sleeking these samples by the private sleeking paper for this purpose. Table (1) shows the samples using in the tensile test.

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Number	Symbols	Description
	F	Epoxy samples
1	EA	Epoxy reinforced with aluminum powder
2	EA/PVC	Epoxy reinforced with PVC fibers
3	EA/PVC/F	Epoxy reinforced with PVC fibers and aluminum powder
4	EA	Epoxy reinforced with glass fibers
5	EA/G	Epoxy reinforced with glass fibers and aluminum powder
6	EA	Epoxy reinforced with Kevlar fibers
7	EA	Epoxy reinforced with Kevlar fibers and aluminum powder
8	EA/G	Epoxy reinforced with Kevlar, glass fibers and aluminum powder
9	EA/PVC	Epoxy reinforced with Kevlar, PVC fibers and aluminum powder
10	EA/PVC	Epoxy reinforced with glass, PVC fibers and aluminum powder

**The stress analysis system**

A universal testing machine was used to calculate the tensile tests for the samples. The machine is shown in figure (2), with capacity reaches to 200 KN force. The machine gives a computerized output data. This output was recorded as graphical and numerical data. This machine is found in the mechanical engineering department – college of engineering in Tikreet university.



Figure (2) Tensile instrument.

### Results and discussion

Tensile tests executed for the composite material samples with volume fraction 20% and 40% for the reinforced materials. The results and the laboratory examination show that the tensile strength for the samples increase when the volume fraction for the reinforced materials increase from 20% to 40% as shown in table (2).

Most of polymer materials, specially epoxy samples (E) without reinforced materials decreasing in the tensile strength and having long molecular chains which cross linked with each other when it become hard. The resistance of these materials depends on direction, regularity and cross linkage degree for molecular chains. The external forces play active role in the effect on cross linkage chains strength. Applied the external load on epoxy material will effect on nature and direction the cross linkage polymer chains and that causing broken the polymer chains when high loads applied. The applied load was few and the fraction region will be exhibit brittle behavior because there is not found reinforced materials prevent the cracks from propagate inside the samples and the samples will separate into two parts.

The reinforced epoxy samples with aluminum powder (EA), the laboratory tests and results show decreasing in the tensile strength for both volume fraction 20% and 40% when the load is applied.

We can not obtain the results for (EA) samples with volume fraction 20%, and the tensile strength for these samples with volume fraction 40% are few as shown in table (2). The applied load and the elastic for these samples are few; moreover, when the external loads increase, the inner stress increase too and that depends on longitudinal the chain clearly, ditto the applied load on the samples cause applied inner stress on the molecules chains for polymer materials. The increase in the applied loads cause increase the strain in the samples and that cause increase the effect range for tension force, that will accelerate formation of primary cracks in polymers because the high increasing in inner energy, so the collapse occur in the which have thermal inconstancies energy higher than chemical bonds energy, then the samples separate into parts, and the fracture will occur. Also the fraction region for these samples exhibit brittle behavior as shown in figure (3).



Figure (3) Shows the fracture region for (EA) sample.

The epoxy samples reinforced with (PVC) fibers and aluminum powder (EPVC and EAPVC) for both volume fraction 20% and 40%, we can not execute the tensile tests because of its little thickness (0.25 mm), the machine can not catch out these samples so the test failed. Also, we could not calculate the tensile strength for these samples because of the samples will fail at test start and the little coherence between (PVC) fibers, aluminum powder and the matrix. The samples (EG) and (EAG) with volume fraction 20% have tensile strength less than the same samples with volume fraction 40% as shown in table (2) and figure (4). Glass fibers are the most common of all reinforcing fibers for polymeric matrix composites. They have high tensile strength, chemical resistance and insulating properties and are inexpensive compared to most other fibers. But when addition of aluminum powder to matrix and reinforced with glass fiber, the tensile strength for these samples (EAG) will decrease for both volume fraction 20% and 40% when compared with samples from type (EG). This is because of nature, shape and size of aluminum powder molecules. The adhesive between aluminum powder, fibers and matrix will be weakly. The samples separate into two parts as shown in figure (5), this figure shows the pictures of the fracture

Table (2) Tensile strength test for the samples

Sample	Volume fraction 20%			Volume fraction 40%		
	Max load (N)	Area (mm <sup>2</sup> )	Strength (MPa)	Max load (N)	Area (mm <sup>2</sup> )	Strength (MPa)
E <sub>0</sub>	1000	100	10	1000	100	10
E <sub>20</sub>	1000	100	10	1000	100	10
E <sub>40</sub>	1000	100	10	1000	100	10
E <sub>20</sub> PVC	1000	100	10	1000	100	10
E <sub>40</sub> PVC	1000	100	10	1000	100	10
E <sub>20</sub> Al	1000	100	10	1000	100	10
E <sub>40</sub> Al	1000	100	10	1000	100	10

regions for samples (EG and EAG) for both volume fractions 20% and 40%. These regions will be uniform and we can see the fibers slinking in the fraction region because of increase applied load.

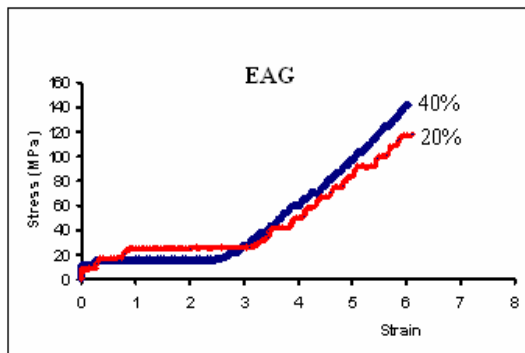


Figure (4) Stress- strain curve for (EAG) samples

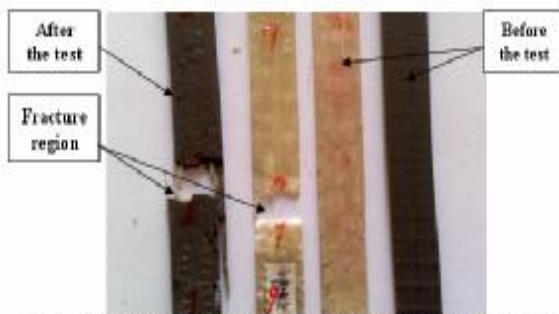


Figure (5) Shows the fracture regions for (EG and EAG) samples.

Therefore, the samples (EK and EAK) with volume fraction 20% have tensile strength less than the same samples with volume fraction 40% as shown in table (2) and figure (6). This figure shows the stress- strain curve for brittle polymer matrix composites, the figure shows the applied stress will increase at low strain (high Young modulus) and these samples have low elongation at fracture.

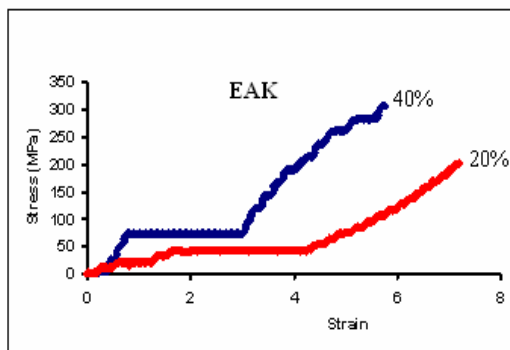


Figure (6) Stress- strain curve for (EAK) samples

This is because of Aramid fibers that are high-strength and high modulus, mechanically these fibers have longitudinal tensile strengths and tensile moduli

that are higher than other polymeric fibers materials; however they are relatively weak in compression. Also because of good adhesive between the Kevlar fibers and matrix, the Kevlar fibers can transport the stresses along the fibers and the resistance of it is bigger than the glass and PVC fibers. After the finished the tensile test, the samples separate into two parts at maximum stress (362) MPa for (EK) sample with volume fraction 40%. These samples have tensile strengths are higher than all samples for both volume fractions 20% and 40%, on the other hand all samples exhibit brittle behavior when subjected to large tensile stresses. Figure (7) shows the pictures of the fracture regions for samples (EK and EAK), these regions will be uniform and we can see the fibers slinking in the fraction region because of increase applied load.

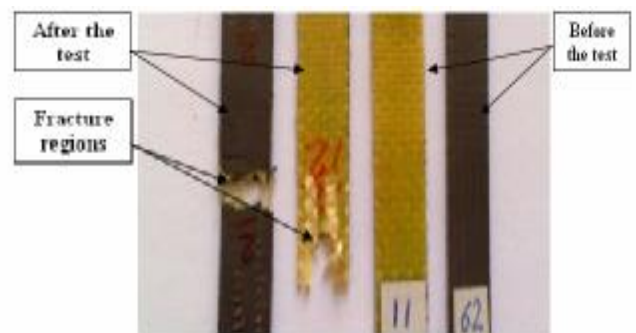


Figure (7) Shows the fracture regions for (EK and EAK) samples.

The laboratory tests and the results for the samples from type (EAKG, EAKPVC and EAGPVC) shows the tensile strength for these samples with volume fraction 40% are higher than the same samples with volume fraction 20% as shown in table (2) and figures (8, 9). We note the tensile strength for the (EAKG) sample is higher than all these samples for both volume fraction. This is because of the good adhesive by the interface between the matrix and all reinforced material. The applied load is effectively transferred from the matrix to the fibers via the interface clearly, the interface generally has an important bearing in this regard. Specifically, in the case of a fiber reinforced composite material, the interface or more precisely the interfacial zone consists of near surface layers of fiber and matrix and any layer of material existing between these surface. The structure and properties of the fiber- matrix interface play major role in the mechanical and physical properties of composite materials, thus, the excellent mechanical properties of fiber composites can only be realized if stress can be effectively transferred from fibers to matrix. Figure (10) shows the picture for these samples and we can note the rapture of these samples because of the applied stress on them, the fibers slinking in the fraction region.

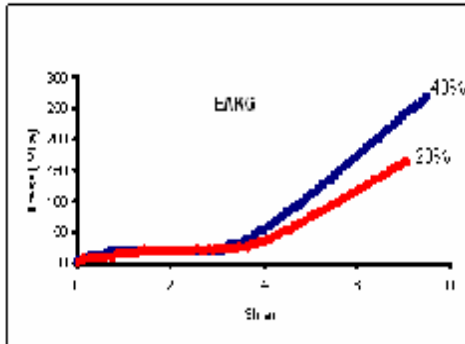


Figure (8) Stress- strain curve for (EAKG) samples

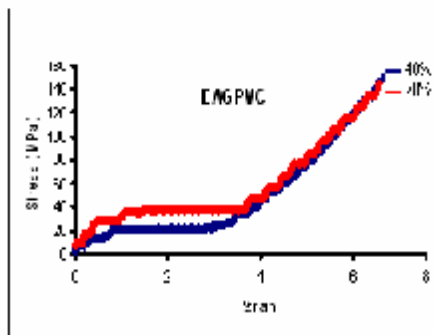


Figure (9) Stress- strain curve for (EAGPVC) samples.



Figure (10) Shows the fracture regions for (EAKG, EAKPVC and EAGPVC) samples

## Conclusion

- 1- The tensile strength is increase when the volume fraction for reinforced material for the composite materials increase from 20% to 40%.
- 2- The samples from type (EK) have tensile strength is higher than all samples for both volume fraction.
- 3- All samples separate into two parts and exhibit brittle behavior when subjected to large tensile strength.
- 4- The Kevlar fibers can transport the stress as easily as along the fiber, therefore the resistance of the Kevlar fibers bigger than the glass and PVC fibers.
- 5- Slinking the reinforced fibers from the matrix in fraction region when the load (stress) is applied.

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## دراسة مقاومة الشد لمتراكبات الأيبوكسي المسلح بالألياف والجسيمات

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### الخلاصة

تضمن هذا البحث دراسة مقاومة الشد للمواد البوليمرية والمتراكبة المسلحة بالألياف والجسيمات. حيث استخدم راتنج الأيبوكسي كمادة رابطة لمواد التسليح والمتكونة من الألياف الصناعية مثل ألياف (الكفلر والزجاج والبولي فينيل كلورايد) بالإضافة إلى مسحوق الألمنيوم. صنعت ألواح من المواد المتراكبة والمواد المتراكبة الهجينة وبكسرين حجميين 20% و 40% من مواد التسليح. حيث تم تصنيع (21) لوحاً من المواد المتراكبة وكل هذه الألواح تم تقطيعها إلى عينات بالقياسات (80x10 ملم) لكي يتم بعد ذلك إجراء اختبار متانة الشد ولكلا الكسرين الحجميين 20% و 40%. أظهرت النتائج والاختبارات المخبرية لهذه العينات إن هناك زيادة في مقاومة الشد عند زيادة الكسر الحجمي لمواد التسليح من 20% إلى 40% وإن أفضل قيمة لمقاومة الشد تمتلكها عينات الأيبوكسي المسلح بألياف الكفلر عند مقارنتها بالعينات الأخرى ولكلا الكسرين الحجميين من مواد التسليح.