Experimental Measurements of the Mechanical Behavior of the Composite Materials and Hybrid Materials Subject to Tensile Test

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Abstract

Given the importance of hybrid materials and their uses in many field of life in all the world such as since of medicine used in the manufacture of orthoses and in the automobile industry, aircraft and ships and in the areas of sport in tennis rackets and bicycle tires and other...

so in this paper we have been making and testing five group of samples of the hybrid materials that have specific volume fraction of glass fibers and Kevlar fibers in malty layers and then a tensile mechanical testing them by means of a special machine of composite materials at the Institute Specialist For Engineering Industries according to the standard. It should be noted that each of number of layers and type of reinforced materials under investigation resulted a typical effect on FRP composite properties being produced. It showed that each of these parameters influences the properties of the resulted composites in different ways. The research was to investigate the influence of processing parameters on the mechanical properties (tensile) of the composites and determine an optimum processing route. A considerable positive hybrid effect was noticed for tensile strength and tensile modulus, particularly for the samples consisting of more than one layer and reinforced with two kinds of fibers.

Key words: *hybrid materials, volume fraction, Glass fibers, Kevlar fibers, tensile test.*

الخلاصة

نظرا لأهمية المواد الهجينة واستعمالاتها الكثيرة في كل مجالات الحياة ففي عالم الطب تستخدم في صنع جهاز لتقويم العظام و في قطاع صناعة السيارات والطائرات والسفن وفي مجالات الرياضة في مضارب التنس وإطارات الدراجات الهوائية وغيرها... فقد تم صنع واختبار خمسة مجاميع من عينات المواد الهجينة وبثلاث عينات لكل مجموعة وبكسر حجمي معين من ألياف الزجاج وألياف الكفلر بعدة طبقات وإجراء فحوصات الشد الميكانيكية عليها بواسطة جهاز خاص بفحص الشد للمواد المركبة في المعهد المتخصص للصناعات الهندسية وفق مواصفة قياسية.

تم استنتاج أن لكل من عدد الطبقات ونوع الألياف المقواة للمادة المركبة تأثير كبير على خصائص المركبات FRP التي يتم إنتاجها. وبينت أن لكل من هذه العوامل تأثير على خصائص المواد المركبة بطرق مختلفة. وتم في هذا البحث دراسة تأثير هذه العوامل على الخواص الميكانيكية (الشد) على المركبات وتحديد قيم أجهاد الشد. وقد لوحظ زيادة كبيرة لقوة الشد ومعامل الشد للماد الهجينة ، لا سيما بالنسبة للعينات التي تتكون من أكثر من طبقة واحدة وتعزيزها بنوعين من الألياف.

الكلمات المرشدة:
المواد الهجينة ، الكسر ألحجمي ، ألياف الزجاج ، ألياف الكفلر ، اختبار الشد.

Introduction and literature review

Most lightweight structures and substructures include compression members, or under a combination of flexural and compressive load. The usual design process for lightweight structures attempts to introduce loads as pure compression and pure tension. The flexural loading of framework or sandwich constructions, for example, is transformed into essentially pure compression and tension loading of struts or facings. Composite materials are especially adaptable for such designs owing to their high orthotropic. [١]

The essence of the concept of composites is this: the bulk phase accepts the load over a large surface area, and transfers it to the reinforcement, which being stiffer reinforcements are not necessarily in the form of long fibers. They can be particles, whiskers, discontinuous fibers, sheets etc. A great majority of materials is stronger and stiffer in the fibrous form than in any other form. This explains the emphasis on using fibers in composite materials design [٢].

The most common and inexpensive fiber used is glass fiber, usually for the reinforcement of polymer matrices. The E-glass is the most common reinforcement material used in. The glass fiber strength and modulus can degrade with increasing temperature. Although the glass material creeps under a sustained load, it can be designed to perform satisfactorily although the fiber itself is regarded as an isotropic material and has a lower thermal expansion coefficient than that of steel. [٣].

Characteristics, although the one major disadvantage in glass is that it is prone to break when subjected to high tensile stress for a long time. However, it remains break-resistant at higher stress-levels in shorter time frames. This property mitigates the effective strength of glass especially when glass is expected to sustain loads for many months or years continuously. [٤]

So it may have been added to the glass fibers, Kevlar fibers in malty layers according to the volume fraction to strengthen and improve the mechanical properties of composite materials, so-called hybrid materials. Kevlar is the DuPont Company's brand name for a synthetic material constructed of para-aramid fibers that the company claims is five times stronger than the same weight of steel, while being lightweight, flexible and comfortable. Also very heat resistant and decomposes above without melting. Kevlar is a registered trademark of E.I. du Pont de Nemours and Company. [٥][٦]

Aramid fibers (Kevlar) have high tensile strength, high modulus and low weight. Impact-resistant structures can be produced from Aramid. The density of Aramid fibers is less than that of glass and graphite fibers. They are fire resistant apart from being high-temperature resistant and unaffected by organic solvents fuels. The fibers break into small fibers, which are like fibers within the fibers. This unique failure mechanism is responsible for high strength. They were initially used to reinforce automobile tires. Since then, they have also found other uses like bullet proof vests. As high strength applications, their use in power boats is not uncommon. [٧]

Hybrid composites are more advanced composites as compared to conventional FRP composites. Hybrids can have more than one reinforcing phase and a single matrix phase or single reinforcing phase with multiple matrix phases or multiple reinforcing and multiple matrix phases. They have better flexibility as compared to other fiber reinforced composites. By combining two or more types of fibers, it is possible to club the advantages of both the fibers while simultaneously mitigating their less desirable qualities. Normally, one of the fibers in a hybrid composite is a high-modulus and high- cost fiber such as carbon, boron and the other is usually a low-modulus fiber such as E- glass, Kevlar. The high-modulus fiber provides the stiffness and load bearing qualities, whereas the low-modulus fiber makes the composite more damage tolerant and keeps the material cost low. The mechanical properties of a hybrid composite can be varied by changing volume ratio and stacking sequence of different plies. [٨][٩]

Laminar Composites

Laminar composites are found in as many combinations as the number of materials .They can be described as materials comprising of layers of materials bonded together. These may be of several layers of two or more occurring alternately or fiber glass in a determined order more than once, and in as many numbers as required for a specific purpose. For instance, a strong sheet may use over ٩٢٪ in laminar structure, while it is difficult to make fibers of such compositions. Fiber laminates cannot over ٧٥٪ strong fibers glass. [١٠]

Tensile Properties

Tensile properties indicate how the material will react to forces being applied in tension. A tensile test is a fundamental mechanical test where a carefully prepared specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance. Tensile tests are used to determine the modulus of elasticity, elastic limit, elongation, proportional limit, and reduction in area, tensile strength, yield point, yield strength and other tensile properties.

The main product of a tensile test is a load versus elongation curve which is then converted into a stress versus strain curve. Since both the engineering stress and the engineering strain are obtained by dividing the load and elongation by constant values (specimen geometry information). [١١]

Experimental Work

Contemporary composites results from research and innovation from past Few decades have progressed from glass fiber for automobile bodies to particulate composites for aerospace and a range other applications.

Ironically, despite the growing familiarity with composite materials and ever- increasing range of applications, the term defines a clear definition. Loose terms like "materials composed of two or more distinctly identifiable constituents" are used to describe natural composites like timber, organic materials, like tissue surrounding the skeletal system, aggregates, minerals and rock. [١١]

Fabrication of Composite

The glass fibers and Kevlar fiber were cut to standard size rectangular sheets (١٠٠mm width ٢٠mm) the plies were then weighed and amount epoxy resin and hardener. (٢٥٪ of epoxy taken).

A plastic die with dimensions (١٠٠mm width ٢٠mm) is used, on to which mold release spray was sprayed, then a layer of epoxy was coated on the sheet, now alternately, layers of Kevlar fiber fabric and glass fiber fabric were laid upon other, with a layer of resin in between such fabric. The stacking sequence was maintained. At last a layer of resin mix was applied to it and this was put on to the last layer of composite. A flat board was then put on these sheets and dead loads were applied on to this prepared composite above this board, and the whole was then allowed to cure for around ٢٤ hours.

In this test five dies used to produce five molds with different fiber layers arrangement. Thus three groups of specimens molded in each group, there are fifteen specimens tested.

Specimens of Tensile Testing

The composite materials is formed using the procedure out lined above and is produced in a hard and dry state forming a rectangular plate with dimensions and different thickness .specimens for tensile testing are cut first in equal rectangular forms with ١٠٠mm length +/- ٠,٥mm using iron scissors (cutter) then the specimens are operated and ٢٠mm width in diameter ٢٠ mm and milling machine in the factory of specialized institute for engineering industries to make the particular flanks of the specimens according to the required ASTM D ٦٣٨ standard (١٥) as shown in Fig.(١).

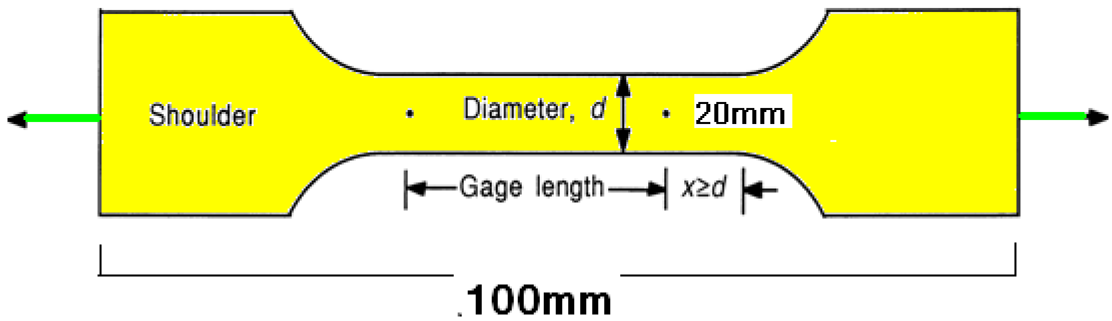

Fig.(١) Show the dimension of specimens.

To calculate the volume fraction of the specimens we must weight the glass fibers and Kevlar fibers before Molding with epoxy resin and total weight as shown in table (١).

Where: ٣ sp in table (١), refers to the number of specimens at every group, and the letter s refers to the Specimen and the letter p refers to the property.

Table (١) Shows the weight of the glass fibers, Kevlar fibers and Epoxy weight.

	Glass fiber weight (g)	Kevlar fiber weight (g)	Epoxy weight (g)	Total weight (g)
Group E ٣ sp ١ layers (Kevlar)	-	٢,٨٧٧	٤.٥٢٧٥	٧.٤٠٤٥
Group B ٣ sp ٢ layers (Kevlar + glass)	٥.١٣٣	٢.٨٦٩	٥.٤٧٨٨	١٣.٤٨٠٨
Group C ٣ sp ٣ layers (Kevlar + glass+ Kevlar)	٥.٥٤٤	٥.١٨٥٢	٦.٦٦٢٩	١٧.٣٩٢١
Group D ٣ sp ٣ layers (glass +Kevlar+ glass)	١٠,٧٦١٨	٢.٨٣١	٦.٥٦٨	٢٠.١٦٠٨
Group A ١ sp glass layers	٥. ٢٦١٨	-	٤,٣٦٨	٩.٦٢٩٨

We can determine the volume fraction of fibers by using the following equation:

$$V_f = \frac{W_k/\varrho_k + W_g/\varrho_g}{W_r/\varrho_r + W_k/\varrho_k + W_g/\varrho_g}$$

Where:

V_f : the volume fraction

W_* : the weight in grams

ϱ : density

For example to calculate the volume fraction of Kevlar fiber in a specimen from group E:

V = (٥,٧٠٦÷٢٥٠٠) ÷ [(٥,٧٠٦ ÷ ٢٨٠٠)+(٢,٨٧٧ ÷ ١٦٠٠)+(٧,٥٢٧٥ ÷ ١٣٠٠)]

V = ٠,٢٣٧

To calculate the volume fraction of Glass fibers, Kevlar fibers and Epoxy weight in all specimen from group A to group E, as shown in table (٢).

Table (٢) Shows the volume fraction of the glass fibers, Kevlar fibers and Epoxy weight in all specimens from group A to group E.

	Glass volume fraction	Kevlar volume fraction	Epoxy volume fraction
Group E ٣ sp ١ layers(Kevlar)	-	٠,٢٤	٠.٥٦
Group B ٣ sp ٢ layers (Kevlar + glass)	٠,٣	٠,١٥	٠,٥٥
Group C ٣ sp ٣ layers (Kevlar + glass+ Kevlar)	٠,٢٥	٠,٠٥	٠,٧٠
Group D ٣ sp ٣ layers (glass +Kevlar+ glass)	٠. ٥	٠,١٢	٠,٦٣
Group A ٣ sp ١ layers glass	٠,٣	-	٠. ٦

For example:

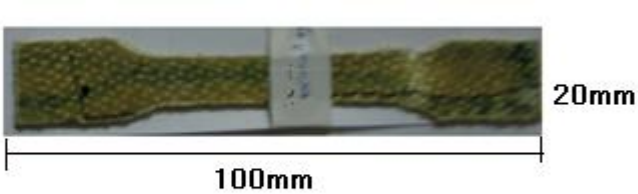

Fig.(٢) Show the Specimen of group E.

It's a double action machine used for tensile and compression tests, This machine is used for testing plastic and ceramic bodies with a maximum load of (١٠٠٠٠ tons), and often at speed of (٢٥ mm/min).

Fig.(٣) Show the machine of tensile tests.

And the all specimens are as shown in Fig. below:

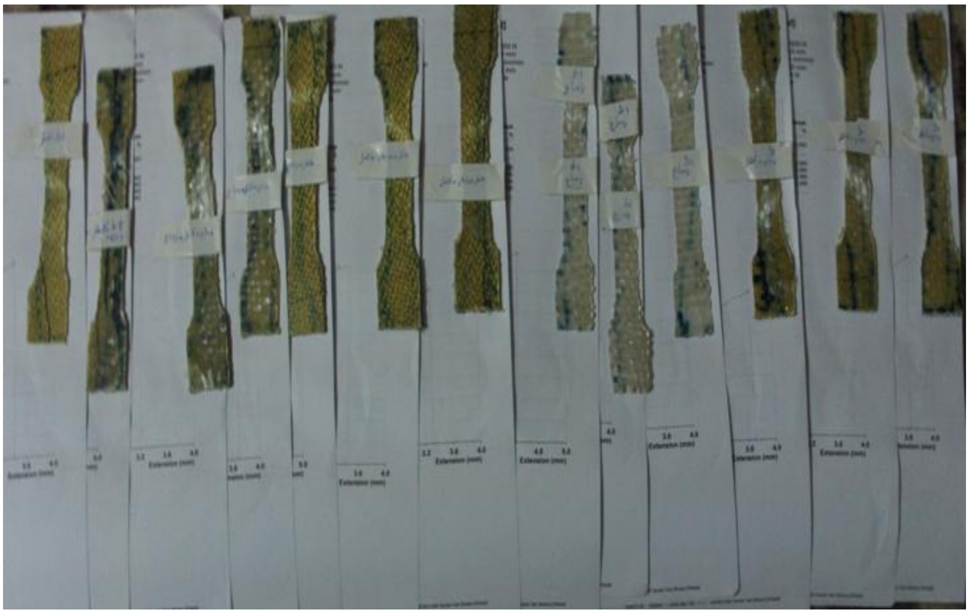

Fig. (٤) Show all groups of specimens.

The Results

The tensile test results outline in this paragraph are for hybrid composite material of reinforced epoxy resin with different volume fraction for each group of specimens. And the tensile test specimens with dimension of standard ASTM and All tests are performed at laboratory temperature .

The figures obtained from the tensile test machine are in the shape of a relationship between stress (N/mm) and the extension (%).The results of group specimens are shown in table with figures to The group with kevlar, glass layers shows the highest results of forces and stresses with different values of modulus of the volume fraction to the composite materials.

The results of tensile test specimens are shown in table (٣) refer to the all groups with kevlar and glass layers, frome one layer to three layer . This group of specimens were reinforsed by one type of fibers (composite mateirals) and with two type of fibers (hibrid mateirals) . As shown in table (٣).

Discussion and Conclusions

The results of test specimens are shown with figures this group of specimens has closer values of stresses in its results. The tensile test results also showed to the rate of average max. tensile stress of three samples of a single layer of(Group E) Kevlar is ١٣٦,٣٣ Mpa, higher than the average max. tensile stress of test results of the three samples of a single layer of glass (Group A) is ٨٣,٢٣ Mpa. This is expected to happen in addition to light weight samples of (Group E) allowing use in areas that need high tensile strength in addition to light weight.

Table (٣) show all the tensile test results.

Specimens \ property		Yield %	F (N) Max. force	σ (Mpa) Max. stress
Group E	No.١	٣,٠٣٢	٤٧٠٠	١٦٠,٢
	No.٢	٢,٧٢٠	٢٩٥٠	١٠١,٧
	No.٣	٣,٦٦٠	٤٤٠٠	١٤٧,١
Group B	No.١	٣,٣١٢	٥٣٠٠	١٩٢,٣
	No.٢	٣,٢٧٢	٤٧٠٠	١٨٤,٠
	No.٣	٤,٥٢٠	٤٥٠٠	١٧٥,١
Group C	No.١	٣,٣٠٠	١٩٥٠	١٨١,١
	No.٢	٣,٤١٦	١٤٠٠	١٤٥,٣
	No.٣	٢,٨٠٠	١٦٥٠	١٧٢,٧
Group D	No.١	٣,٦٩٦	٢٨٠٠	١٢٧,٦
	No.٢	٢,٩٠٨	٢٧٩٠	١٤٦,٨
	No.٣	٣,٦٤٤	٤١٠٠	٢١٢,٣
Group A	No.١	٢,٥٦٠	١٦٩٠	٩٦,٢
	No.٢	٤,١٠٠	١١٢٠	٨٠,٧
	No.٣	٢,٠٣٢	١١٠٠	٧٢,٨

As for the group B consisting of ٣ samples each have ٢ layers (glass + Kevlar) have the rate of average max. tensile stress is١٨٣,٨ Mpa. Improve and increase the tensile stress of the glass after the addition of a single layer of Kevlar fiber to glass fiber to become improve the tensile properties of the composite material consisting of a single layer of glass fibers or Kevlar fibers each end and this characteristics and features of hybrid materials .

In addition, for the group B hybrid systems under investigation, the most significant change in tensile properties was noticed following substitution of the first layer at the surface.

It was also noted that tensile properties increased with the increase in number of layers, this change appeared more obvious in comparison with that the other two hybrid systems with this change being accompanied by a significant increase in tensile strength.

Although the use of three layers of reinforcing fibers in each group (C, D), but group C (Kevlar + glass+ Kevlar) have the average max. tensile stress is ١٦٦,٣٦٧ Mpa greater than the average max. tensile stress of group D (glass +Kevlar +glass) that is ١٦٢,٢٣ Mpa. And because of a group C that has been put Kevlar fiber as two layers at the surface, While in the group D put glass fiber out of the sample and was put Kevlar fiber as an intermediate layer between them. Thus as turned out to be also expected that the tensile strength of the material specifications of composite reinforced by Kevlar mat better than the composite material reinforced by glass mat only for the purpose of comparison with the tensile properties when mixed mats of articles to be a hybrid material.

Observed when using two layers of Kevlar mats and one layer of glass mats in group C did not improve the tensile properties of the hybrid material largely with compared with using two layers of glass mats and one layer of Kevlar mats in group D .Fracture strength of the reinforced material with Kevlar must much higher than in the hybrid material. It is meaning for the same application can be replaced sites layered with article hybrid which reduces the cost and improves the tensile properties of the hybrid material.

The main general conclusions that could be drawn from this investigation were that, although the tensile strength appeared to obey the rule of number of layers and type of hybrid fiber-reinforced polymer matrix composites. An increase in tensile strength together with the presence of a hybrid effect would most probably be observed when the fiber substituted at the surface side possessed a significantly lower tensile strength combined with significantly higher tensile strength as demonstrated by the hybrid Kevlar - E-glass FRP composite.

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