Study the Mechanical and Physical Properties of Polyester Composite Reinforced by Multi Layers

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ABSTRACT

In this research, a laminate composite has been prepared, using unsaturated polyester resin (UP) as a matrix reinforced with Kevlar fibers in different number of layers, glass fibers were added to the optimum product, by replacing one of the layers of Kevlar Fibers with a layer of Glass Fibers. Hand Lay-up method was used to prepare the test samples. To evaluate the composite material properties, tensile, hardness, impact, optical microscope tests were done.

The results of composite made of polyester reinforced with Kevlar Fibers show that the mechanical properties (Tensile strength, Modulus of elasticity, Hardness, Impact strength) increase with increasing the number of reinforced layers.

The best experimental values of the mechanical properties (Tensile strength, Modulus of elasticity, Hardness, Impact strength) were (190 MPa, 1.72 GPa, 79.25, and 68.75KJ/m^2) respectively, for composite with three layers of Kevlar Fibers and then followed by composite with the sequence of layers (kevlar-glass-kevlar) and its mechanical properties (Tensile strength, Modulus of elasticity, Hardness, Impact strength) were (175.5 MPa, 1.69 GPa, 80, and 59.1 KJ/m^2) respectively, Optical microscope shows well distribution of reinforced layers in composite.

Keywords: Laminate composite, hybrid composite, unsaturated polyester (UP), Kevlar fiber (KF), Glass fibers (GF), tensile strength, Modulus of elasticity, hardness, impact strength, and optical microscope.

INTRODUCTION

Many of our modern technologies need materials with uncommon combinations of properties that cannot be met by the usual metal alloys such as ceramics, and polymeric materials. This is true for materials that are requires for aerospace, underwater, and transportation applications [1].

The constituents of a composite are generally arranged so that, one or more discontinuous phases are embedded in a continuous phase. The discontinuous phase is named the reinforcement and the continuous phase is the matrix. Both constituents are required, and each must accomplish specific tasks if the composite is to perform

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as intended. The physical and mechanical properties of composites are dependent on concentration of the constituents [2].
The composite structure consists of two phases, matrix and reinforcement [3].

Generally, a composite material is composed of (particle, fiber, flakes, and/or fillers) reinforcement embedded in a matrix of (polymer, metal, or ceramics) [4]. Polymer matrix composites (PMCs) are very popular due to their low cost and simple fabrication methods [5].

Thermosets are polymers that form networks and their curing involve chemical reactions. As a consequence of these chemical reactions they cross-link or set. This process is thermally activated and therefore the terminology thermosetting resin was coined. Using polymeric fibers result in lower densities which are desirable in structures [6].

Polyesters are important class of high performance and engineering polymers, which find use in many applications. Polyester was not produced until the 1930s, when W. H. Carothers systemically investigated reactions of diols with diacids. Carothers was not successful in producing a polyester fiber and switched the focus of his research. In 1942, John Whinfield and W. Dickson made the first high molecular weight Polyesters [7].The role of the polymer resin is to primarily bind the fibers together, give the composite a nice surface appearance in addition to environmental tolerance and provide overall durability.

Aramid fibers were developed during the 1960's and first introduced commercially by DuPont in 1970's under the trade name Kevlar [8]. Although there are several commercial grades of aramid fibers available, the three most common ones used in structural applications are Kevlar 29, Kevlar 49 and Kevlar 149 [3]. All grades have high strength and low density giving very high specific strength. The fibers also offer good resistance to abrasion, and chemical and thermal degradation. However, the fiber can degrade slowly when exposed to ultraviolet light [2].

Fiber-reinforced composite materials consist of fibers of high strength and modulus bonded to a matrix with distinct interfaces between them. In this form, both fibers and matrix maintain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the constituents acting alone [9].

For fiber-reinforced composites, the matrix phase serves several functions. First, it binds the fibers together and acts as the medium by which an externally applied stress is transmitted and distributed to the fibers; only a very small proportion of an applied load is sustained by the matrix phase. The second function of the matrix is to protect the individual fibers from surface damage as a result of mechanical abrasion or chemical reactions with the environment and separate the fibers [1]. Polymers composites are used for applications such as car instrument panels, domestic shower units and crash helmets [10].

The objective of this study is to prepare a composite material made from unsaturated polyester as a matrix and reinforced by Kevlar fibers in different number of layers, and the optimum value will be reinforced with a glass fibers, by replacing one of the layers of Kevlar with a layer of GF, then study the uniformity and mechanical properties of the prepared composite. This composite can be used in applications like automotive, helmets, racing canoes, and construction industries.

Experimental procedure
Materials

The matrix used in this research was unsaturated polyester resin (UP), provided from Saudi Industrial Resins (SIR) Company in the form of transparent viscous liquid at room temperature. The initiator was Methyl Ethyl Keton Peroxide (MEKP), and accelerator was cobalt naphthanat. The resin will solidify after adding 2% of the initiator for each 100 gm of the resin and to speed up the curing process, 0.2%-0.3% of accelerator is added for the same amount of the resin.

The used reinforcement was woven Kevlar fibers type (49), provided from DuPont Company, the fibers were arranged with angle direction (0º/90º) and the woven glass fibers type (type E-glass) supplied from (the Tenax Company), the fibers were arranged with angle direction (0º/90º).

Preparation of the samples

Hand Lay-up procedure was used to prepare the samples because it's simple to use and a variety of shapes can be made. Glass mould was used in this study; the internal of the mould was covered with thermal paper made from poly vinyl alcohol (PVA) to extract the samples easily. The woven were cut based on the dimensions of the mould.

Mechanical properties

Tensile test was performed using universal tensile machine type (WDW-50), according to the ASTM (D638), at speed of (5mm/min) and applying the load until the samples break. Data were obtained from the machine, in order to get (tensile strength and modulus of elasticity). Hardness test was performed at room temperature; Shore D hardness tester was used. Impact test was performed according to (ISO 180). An optical microscope was used to examine the uniformity of layers in the composite material, with magnification (20X).

Results and Discussion

Figure (1) shows the tensile strength increases with increasing the number of reinforced layers. The maximum value of tensile strength achieved for three layers of Kevlar Fibers was (190 MPa), as compared to the matrix UP (58 MPa). Because its chains oriented parallel to the axis, this leads to improvement in the strength of the composite.

Figure (2) shows the tensile strength of composite and hybrid composite material, three layers of Kevlar Fibers and three layers of (Kevlar-Glass-Kevlar (KGK)) fibers, respectively. It can be seen that the tensile strength was (190 MPa) for composite reinforced with three layers of Kevlar Fibers, which is higher than that reinforced with the sequence layers (KGK) fibers (175.5 MPa). This is because Kevlar Fibers have higher tensile strength than (KGK) layering that contains Glass Fibers as the second layer, which it's a ceramic material, has brittle characteristics.

Figure (3) shows the modulus of elasticity increases with increasing the number of reinforced layers. The maximum value of the modulus of elasticity for three layers of Kevlar Fibers was (1.72 GPa) as compared to the matrix UP (1 GPa). Because of the high stiffness of the Kevlar fibers, this leads to improvement in the stiffness of the composite.

Figure (4) shows the modulus of elasticity for composite and hybrid composite material, three layers of Kevlar Fibers and three layers of (KGK) fibers, respectively. It can be seen that the modulus of elasticity was (1.72 GPa) for three layers of Kevlar Fibers, which is higher than (KGK) fibers (1.69 GPa). This is because Kevlar Fibers have higher stiffness than Glass fibers in (KGK) layering.

It can be noticed from figure (5), that the hardness increases with increasing the number of reinforced layers. The maximum value of hardness (shore D) obtained with three layers of Kevlar Fibers was (79.25) as compared to the matrix UP (75). Due to the higher hardness of Kevlar Fibers than the matrix UP alone, this leads to improvement in the hardness of the composite.

Figure (6) shows the hardness for composite and hybrid composite material, three layers of Kevlar Fibers and three layers of (KGK) fibers, respectively. It can be seen that the hardness was (79.25) for three layers of Kevlar Fibers, which is lower than (KGK) fibers (80). This is because (KGK) layering contains Glass Fibers which is made from ceramic materials that have higher hardness than Kevlar Fiber which is a polymeric material..

It can be realized from figure (7), that the impact strength increases with increasing the number of reinforced layers. The maximum value of impact strength obtained with three layers of Kevlar Fibers was (68.75 KJ/m^2) as compared to the matrix UP (3.25 KJ/m^2), this is due to the rigid chains of Kevlar fibers, this leads to improvement in the impact strength of the composite.

Figure (8) shows the impact strength for composite and hybrid composite material, three layers of Kevlar Fibers and three layers of (KGK) fibers, respectively. It can be seen that the impact strength was (68.75 KJ/m^2) for three layers of Kevlar Fibers, which is higher than (KGK) fibers (59.1 KJ/m^2). This is because Kevlar fibers have higher impact strength than glass fibers.

Figure (9, 10, 11, and 12) shows the cross section of the composite samples respectively. It can be seen that the layers were good distributed in the composite and that can give improvement to the mechanical properties of the composite.

CONCLUSIONS

From this study, it has been concluded the following:-

1- The mechanical properties, ultimate tensile strength, modulus of elasticity, hardness increased as the number of reinforced layers increase.

2- The maximum value of tensile strength obtained by three layers of Kevlar Fibers was (190 MPa), followed by hybrid composite (KGK) (175.5 MPa).

3- The maximum value of modulus of elasticity obtained by three layers of Kevlar Fibers was (1.72 GPa), followed by hybrid composite (KGK) (1.69 GPa).

4- The maximum value of hardness (shore D) obtained by (KGK) reinforcement was (80), followed by the composite three layers of Kevlar Fiber (79.25).

5- The maximum value of impact strength obtained by three layers of Kevlar fibers was (68.75 KJ/m^2), followed by hybrid composite (KGK) (59.1 KJ/m^2).

6- The good distribution of the layers in composite can give good mechanical properties of composite.

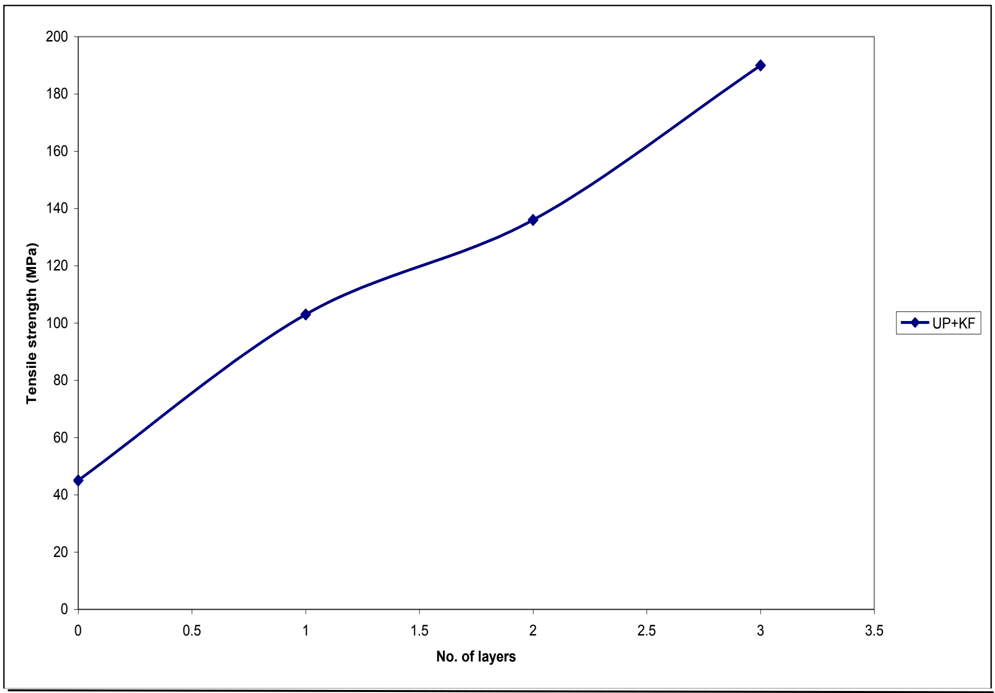

Figure (1) The tensile strength of composite reinforced with Kevlar Fiber (KF) in different number of layers.

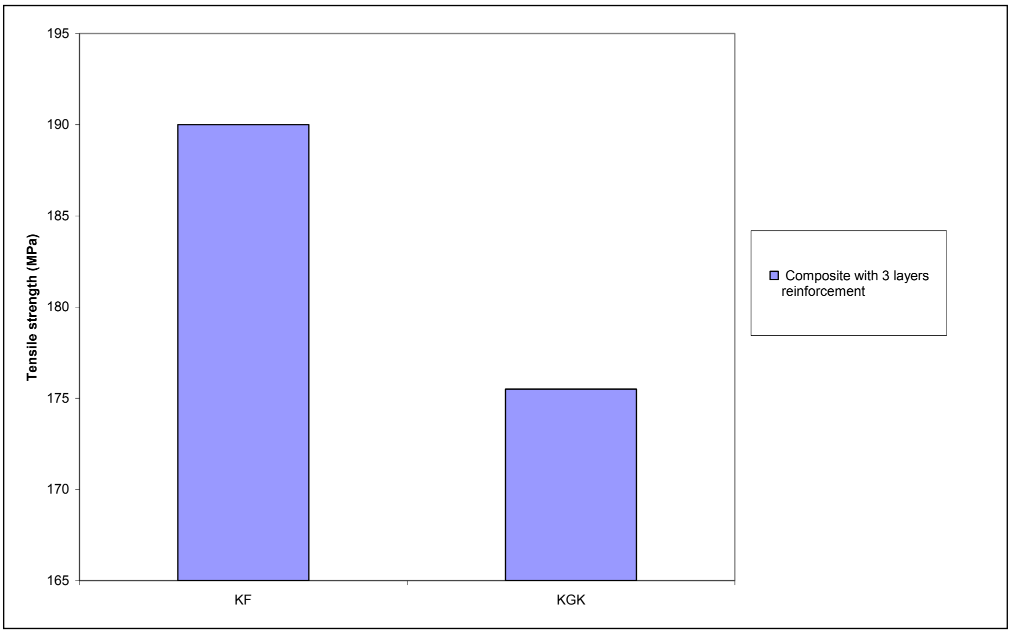

Figure (2) The tensile strength of composite and hybrid composite material, Kevlar Fiber (KF) and (KGK) layering, respectively.

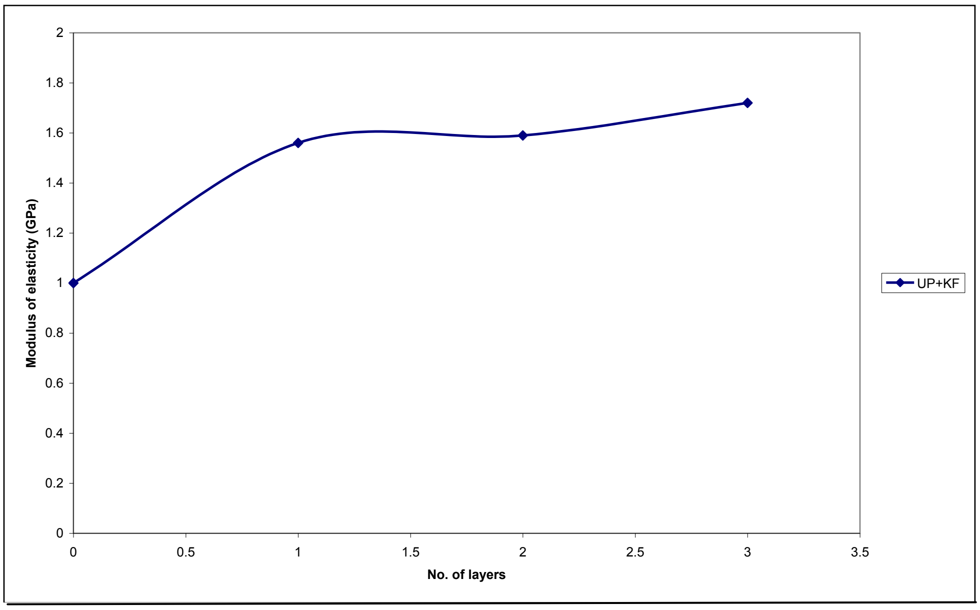

Figure (3) The modulus of elasticity for composite reinforced with Kevlar Fiber (KF) in different number of layers.

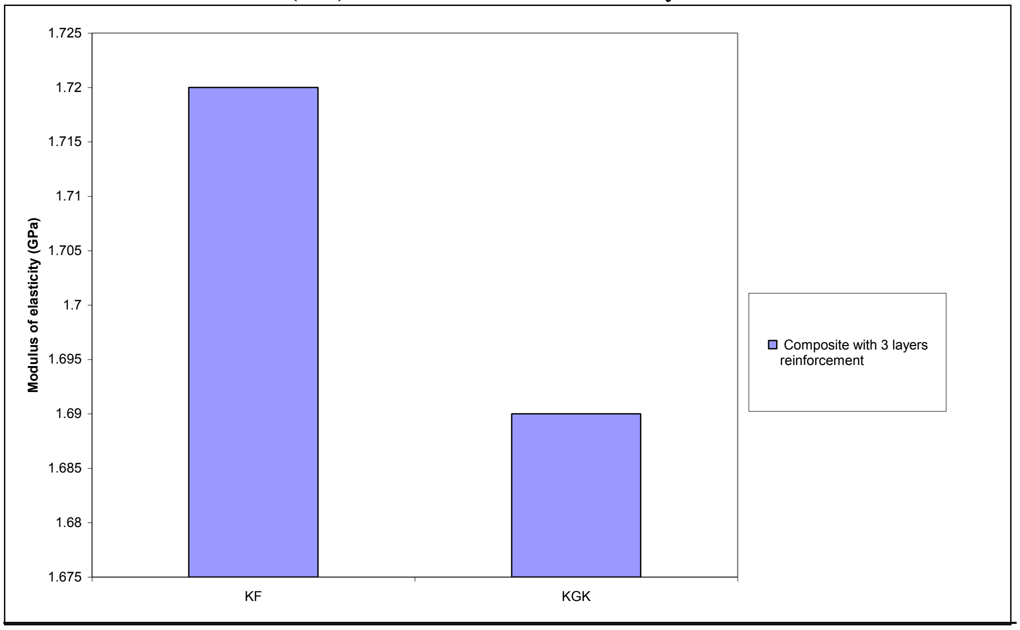

Figure (4) The modulus of elasticity of composite and hybrid composite material, Kevlar Fiber (KF) and (KGK) layering, respectively.

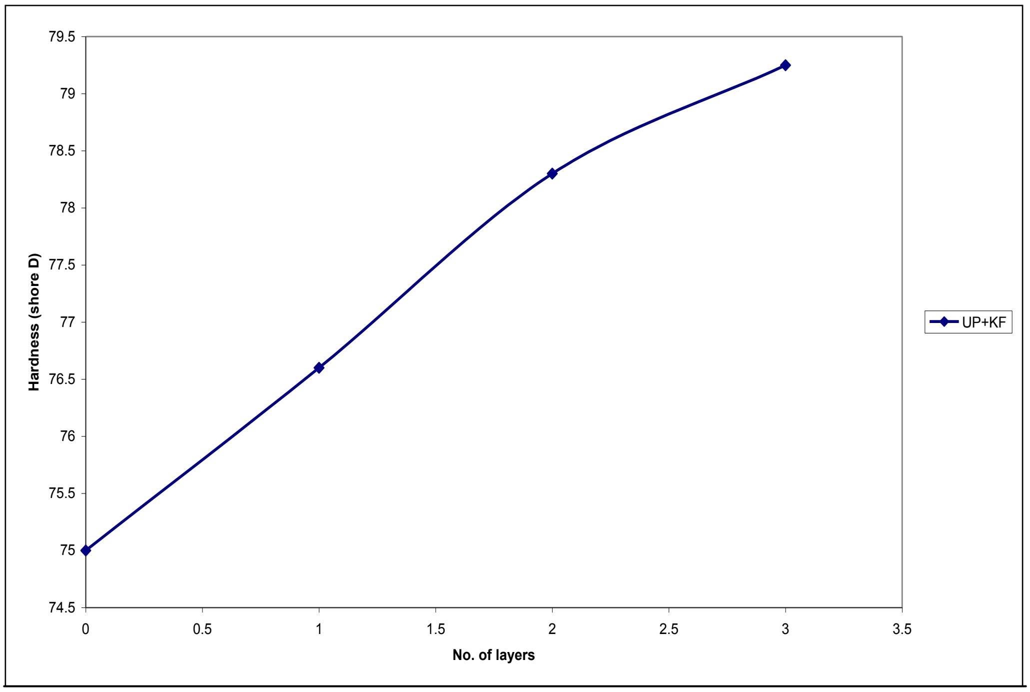

Figure (5) The hardness for composite reinforced with Kevlar Fiber (KF) in different number of layers.

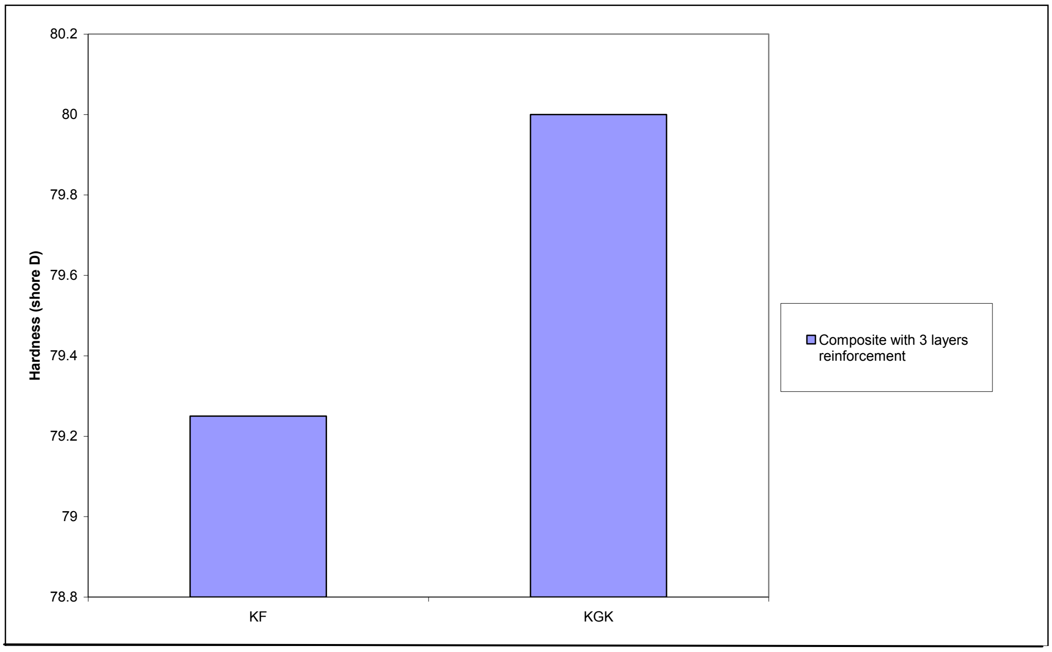

Figure (6) The hardness of composite and hybrid composite material, Kevlar Fiber (KF) and (KGK) layering, respectively.

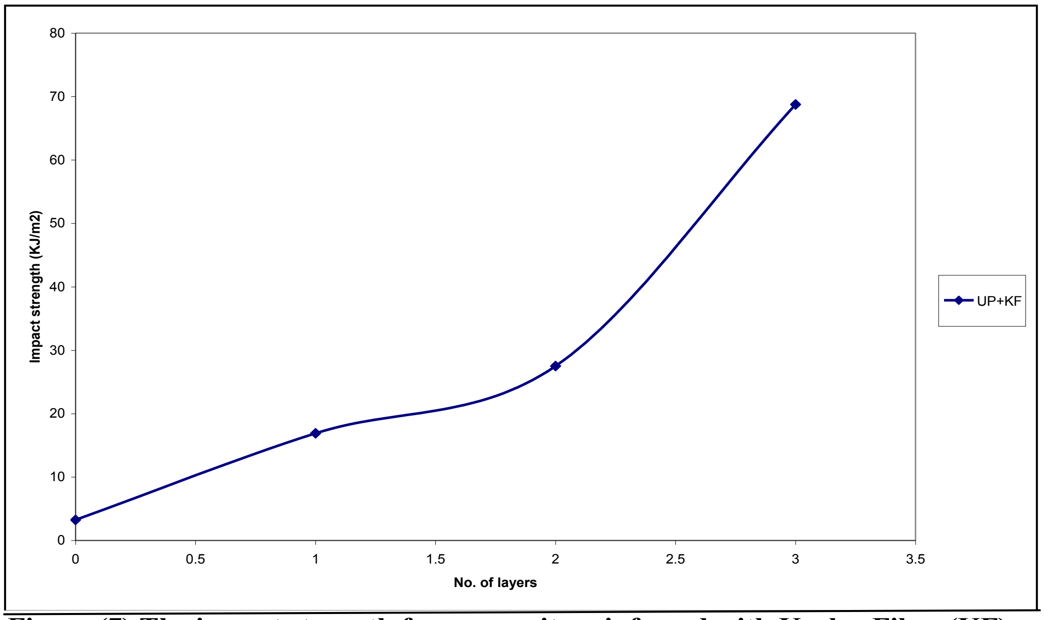

Figure (7) The impact strength for composite reinforced with Kevlar Fiber (KF) in different number of layers.

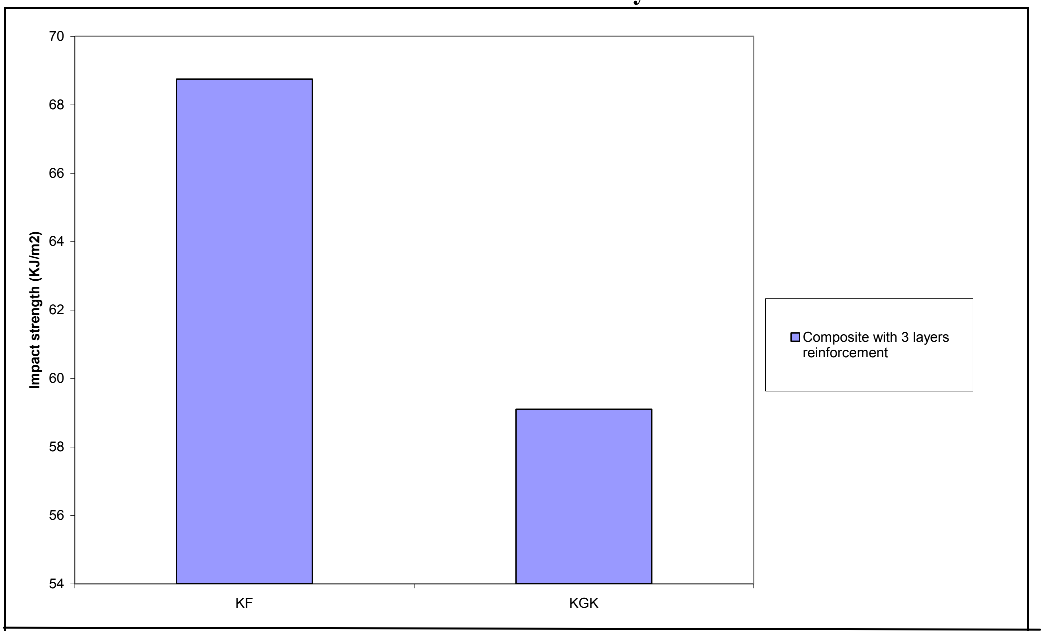

Figure (8) The impact strength of composite and hybrid composite material, Kevlar Fiber (KF) and (KGK) layering, respectively.

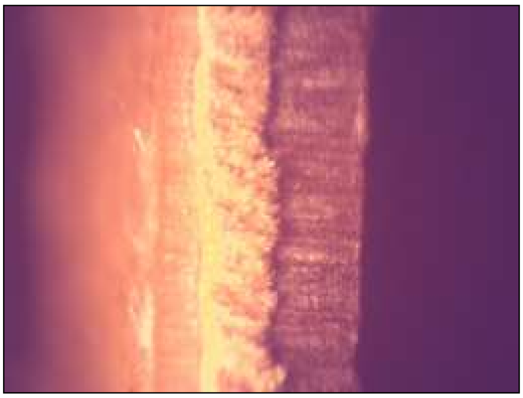

Figure (9) Optical micrographs of the prepared composite with one layer of the reinforcing material.

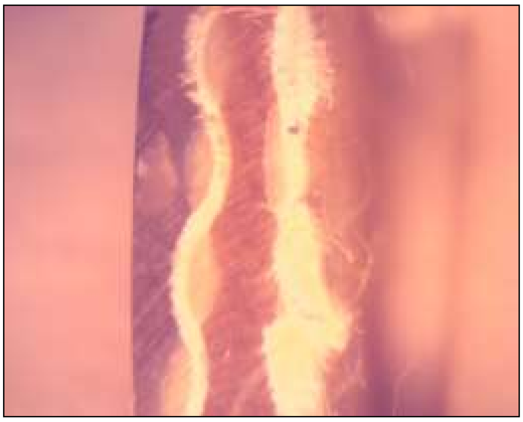

Figure (10) Optical micrographs of the prepared composite with two layers of the reinforcing material.

Figure (11) Optical micrographs of the prepared composite with three layers of the reinforcing material.

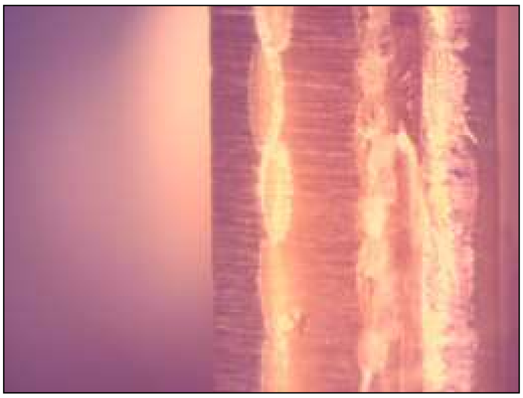

Figure (12) Optical micrographs of the prepared hybrid composite reinforced with (Kevlar fibers mainly on the top and bottom surfaces, glass fibers in between) (KGK).

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