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Effect of Silica Powder Addition on Mechanical Properties of Polymer Laminate Composite

Abstract- *In this study laminate composites were prepared, one was reinforced with three layers of kevlar fibers at (V_f = 17.89%) and the second was reinforced with hybrid laminate with sequence of layers (Kevlar-Glass-kevlar (KGK)) at (V_f = 15.3%), samples were tested before and after silica addition at volume fraction (3%). Tests were (tensile, flexural, impact, hardness, and optical microscope), hand lay-up technique used to prepare samples. Matrix was unsaturated polyester resin. Results showed that mechanical properties (tensile strength, flexural strength, and fracture toughness) decreased after silica addition from (190 MPa, 610 MPa, 35.6 MPa.$m^{1/2}$) to (100.5 MPa, 212MPa, 27.7 MPa.$m^{1/2}$) respectively for composite reinforced with three layers of Kevlar fibers at (V_f = 17.89%) and from (175.5 MPa, 387 MPa, 32.36 MPa.$m^{1/2}$) to (67.6 MPa, 210 MPa, 23 MPa.$m^{1/2}$) respectively for laminate composite with layers (Kevlar-Glass-Kevlar (KGK)) at (V_f = 15.3%). Hardness increased after addition of silica from (79.25 to 81.2) for composite with three layers of Kevlar fibers at (V_f = 17.89%) and from (80 to 82.3) for composite with layers (Kevlar-Glass-Kevlar (KGK)). Optical microscope showed that layers were distributed in matrix and addition of silica leads to delamination of composite after using flexural test.*

Keywords- *Laminate composite, Hybrid Composite, Unsaturated polyester resin, Kevlar fibers, Glass fibers, Silica.*

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1. Introduction

An essential factor that drives the increased applications of composite materials over the resent years is the development of new advanced forms of fiber reinforced polymer (FRP) materials, and this includes the development in high performance resin systems and new styles of reinforcement [1]. Despite the interest in polymer matrix composite (PMCs), considerable researches and developments are done on hybrid PMCs. Functional fillers improve stiffness, decrease voids, good appearance of composites, etc. The properties of particulate filled fiber reinforced PMCs are decided by component properties, composition, structure and filler/fiber matrix interaction [2]. The effect of silica powder addition in different weight fraction (0, 5, 10, and 15) % on the flexural properties of glass fibers reinforced epoxy composite were studied by Reddy C.V. et al., it showed that the composite with 10 % of SiO_2 had improved flexural strength and flexural modulus than the composite without filler, and further increase in SiO_2 leads to decrease in the flexural strength and flexural modulus [3]. The addition of silica powder in content (0, 5, 10, 15, 20) % weight fraction on the mechanical properties (tensile, bending, hardness, impact) of E-glass reinforced polyester resin was investigated by Attili and RamaKrishna, they concluded that the tensile strength and bending strength decreased with increasing silica content, the hardness at 5 wt% was maximum, impact strength increase with increasing silica content [4].

2. Experimental Part

I. Materials

The matrix used was unsaturated polyester resin (UP) provided from Saudi Industrial Resins (SIR) Company, the hardener was Methyl Ethyl Keton Peroxide (MEKP) added in amount 2% for each 100g of resin and the accelerator was cobalt naphthanat (it was added to the matrix by the company in amount (0.2%-0.3%) for every 100g of the resin). The reinforcement was Kevlar Fibers (49) provided from DuPont Company, the E-Glass Fibers supplied from Tenax Company, the fibers were in the form of plain weave woven at (0º/90º) angle direction and silica powder (SiO_2) supplied from Belgium with density (2.65 gm/cm³) and has mean particle size of 1.633µm.

II. Samples preparation

Hand Lay-up procedure was used to prepare the samples. The fibers were cut according to the dimensions of the mould, weighted and volume fraction of them was calculated using rule of mixture. In the case of powder addition, the powder was weighted based on the required volume fraction (3%). Four laminate composites were prepared. The first sample was reinforced with three layers of Kevlar fibers, the second

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sample was reinforced with layers (Kevlar-Glass-Kevlar) fibers, the third sample was reinforced with three layers of Kevlar fibers and silica powder and the forth sample was reinforced with layers (Kevlar-Glass-Kevlar) and silica powder.

III. The applied tests

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. Flexural test was performed according to ASTM (D-790) at the same speed until the samples break. Impact test was performed according to (ISO 180), Shore D hardness test was used according to ASTM (D 2240). An optical microscope was used to examine the distribution of layers in the composite material with magnification (X20).

3. Results and discussion

The addition the SiO_2 powder leads to decrease in the tensile strength of the laminate composites, this can be due to the interference of the matrix by the SiO_2 powder and when the matrix contains the particles it makes it difficult for the matrix to penetrate between the fibers which reduces the wetting of the fibers and that lowers the efficiency in the load transfer and deceases the tensile strength of the composite, and that agree with the reference[5, 6], that can be seen in Figure 1 in which the tensile strength decreases from (190 MPa) without silica to about (100.5 MPa) with silica for composite reinforced with three layers of Kevlar fibers (KF) at (V_f = 17.89%) and from (175.5 MPa) without silica to (67.6 MPa) with silica for composite reinforced with (Kevlar-Glass-kevlar (KGK)) layering at (V_f = 15.3%).

The addition of SiO_2 powder leads to decrease in the flexural strength of the laminate composites, this can be attributed to the decrease in the bonding strength between the matrix and the fibers which result from low wetting of the fibers by the matrix, which is agree with the reference [3,7], it's shown in Figure 2 in which the flexural strength decreases from (610 MPa) without silica to about (212MPa) with silica for composite reinforced with three layers of Kevlar fibers at (V_f = 17.89%) and from (387 MPa) without silica to (210MPa) with silica for composite reinforced with (Kevlar-Glass-kevlar (KGK)) layering at (V_f = 15.3%).

The fracture toughness (that was calculated from the impact and flexural test) decreased after the addition of SiO_2 powder to the composites, this can be due to the decrease in the bonding between the matrix and the fibers, this leads to lower efficiency in the load transfer which is agree with reference [6], that's shown in Figure 3, the fracture toughness decreased from (35.6 $MPa.m^{1/2}$) without silica to (27.7$MPa.m^{1/2}$) with silica for composite reinforced with three layers of Kevlar fibers at (V_f = 17.89%), and from (32.36 $MPa.m^{1/2}$) without silica to (23$MPa.m^{1/2}$) with silica for composite reinforced with (Kevlar-Glass-Kevlar (KGK)) layering at (V_f = 15.3%).

The hardness (Shore D) property of the composites increased after the addition of SiO_2 powder to it, this is due to increase in the stiffness of the matrix which increases materials resistance to deformation under applied force due the presence of these ceramic particles and that increase the hardness of the composite , that's agree with reference [8,9], it can be seen in Figure 4 the hardness increased from (79.25) without silica to (81.2) with silica for composite reinforced with three layers of Kevlar fibers at (V_f = 17.89%) and from (80) without silica to (82.3) with silica for composite reinforced with (Kevlar-Glass-Kevlar (KGK)) layering at (V_f = 15.3%).

It can be seen by the optical microscope that the layers in the composites were distributed in a way that they were separated and covered by the matrix, that's shown in Figure 5, 6, 7, and 8, this can give improvement in the mechanical properties of the composites when the reinforcements are laminates only, but the improvement in the mechanical properties doesn't apply in the case of silica powder addition as it shown in previous discussions.

The fracture surface under the optical microscope shows the cross section of the samples after they have been tested under flexural test, when the silica added to the matrix, the mixture will be more dense, this can lowers the ability of the mixture to flow in to the laminate and lowers the wetting of the fibers by the matrix and this creates flaw in the composite, and under load it will increase in size and leads to failure of composite (delamination).It's shown in Figure 9 and 10.

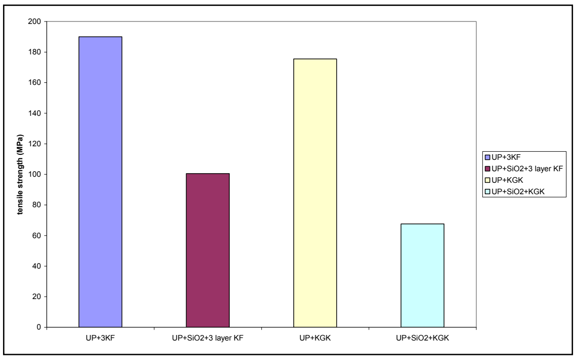

Figure 1: Tensile strength for composite and hybrid composite before and after SiO_2 addition

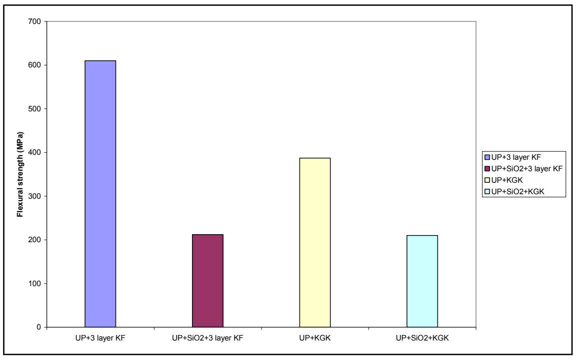

Figure 2: The flexural strength for composite and hybrid composite before and after SiO_2 addition

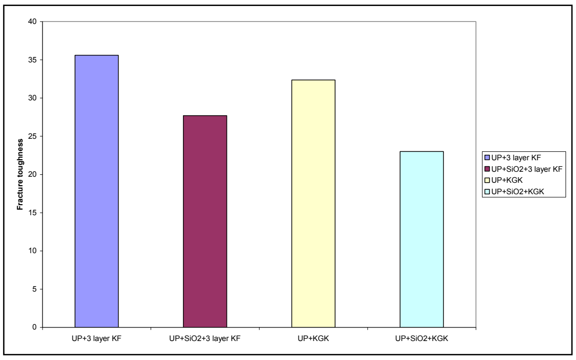

Figure 3: The fracture toughness for composite, and hybrid composite before and after SiO_2 addition

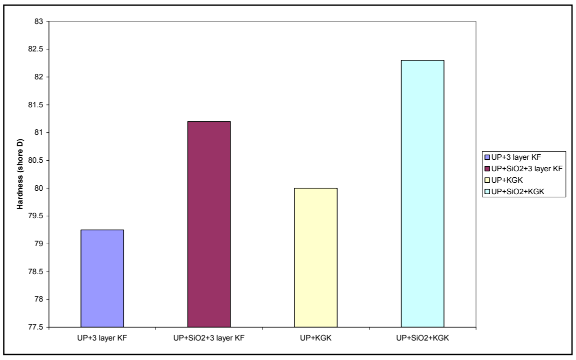

Figure 4: The hardness for composite and hybrid composite before and after SiO_2 addition

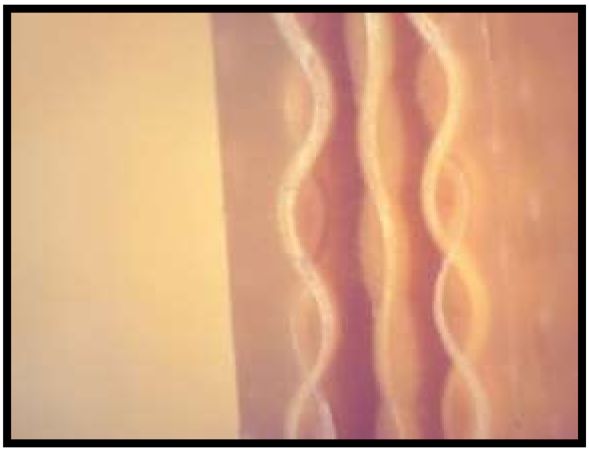

Figure 5: Optical micrograph of the cross section for composite reinforced with three layers of Kevlar fibers

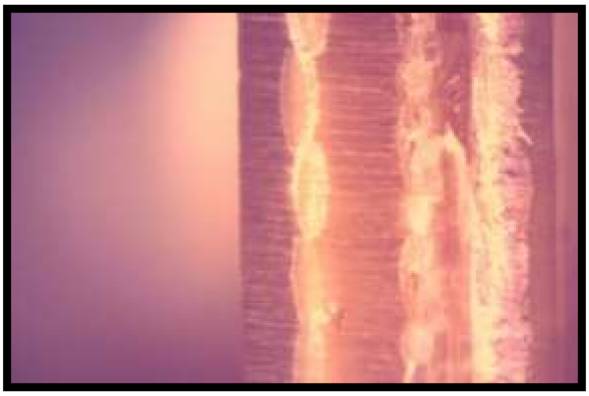

Figure 6: Optical micrograph of composite reinforced with the sequence of layers (Kevlar-Glass-Kevlar)

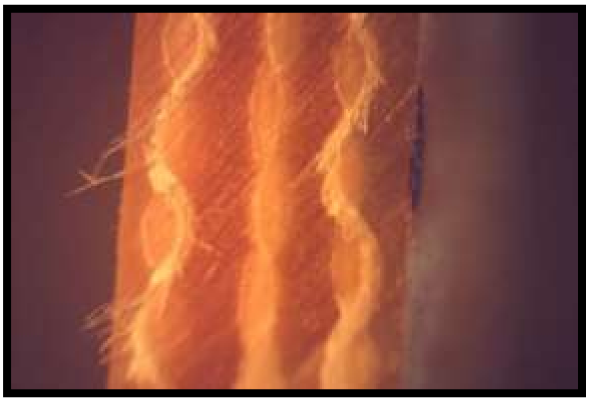

Figure 7: Optical micrograph of the cross section for composite reinforced with three layers of Kevlar fibers and SiO_2 powder

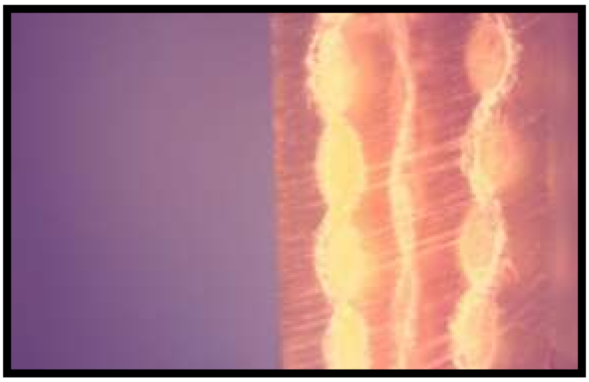

Figure 8: Optical micrograph of the cross section

for composite reinforced with the sequence of layers (Kevlar-Glass-Kevlar) and SiO_2 powder

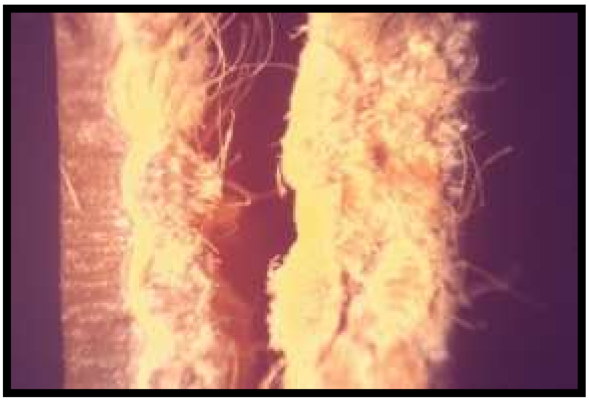

Figure 9: Optical micrograph of the cross sectional fracture surface after flexural test for composite reinforced with three layers of Kevlar fibers and silica powder

Figure 10: Optical micrograph of the cross sectional fracture surface after flexural test for composite reinforced with the sequence of layers (Kevlar-Glass-Kevlar) and silica powder

5. Conclusion

From this study, it has been concluded the following:

- The mechanical properties (tensile strength, flexural strength, and fracture toughness) are decreased after the addition of silica powder while the hardness is increased.
- The composite reinforced with three layers of Kevlar fibers at (V_f = 17.89%) had higher values in the flexural strength, tensile strength, and fracture toughness than the hybrid laminate with the sequence (Kevlar-glass-kevlar) layers except for the hardness.
- Optical microscope showed that even when the layers are distributed in the matrix the mechanical properties of the composites decreased after of silica powder addition, the addition of silica powder to the composites lead to composites failure (delamination).

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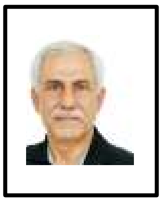

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