ISSN: 0067-2904

Effect of Water Absorption on impact strength of synthetic fibers with Epoxy-unsaturated polyester blends

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Abstract

In this study a composite materials were prepared containing matrix of polymer blend (Epoxy (EP) 90% + unsaturated polyester (UPS) 10%), (Epoxy (EP) 80% + unsaturated polyester (UPS) 20%), reinforced with Kevlar (K) or, and iron woven (Fe) with one value of volume fraction (30) %. This composite are from: (EP 90%, UPE 10% +K), (EP 90%, UPE 10% +K+Fe), (EP 80%, UPE 20% +K), (EP 80%, UPE 20% +K+Fe). All samples were prepared using hand layup method and then impact test was done in both normal condition and after immersion in tap water for the same period time (eight weeks) also diffusion test was done for period's time (three months). The results showed that had been effected differently after immersion, but specimen (EP80%+UPS20%+K+Fe) had superior values of impact strength in normal condition and after immersion in tap water also diffusion test that the binary blend, EP (80%) +UPE (20%) reinforced with Kevlar and iron woven gives a highest values of diffusivity in the tap water.

Keywords: Epoxy, unsaturated polyester, Kevlar woven, iron woven, impact strength.

تأثير امتصاص الماء على مقاومة الصدمة للألياف الصناعية مع خليط الايبوكسي–بولي استر غير المشبع

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الخلاصة:

تم في هذة الدراسة تحضير مواد متراكبة مكونة من مادة الاساس بوليمرية هي عبارة عن خلط بوليمري (EP 90%+ UPE 10%), (EP80%+UPE20%) والمسلحة بالكفلر و الحديد (المحاك) وبكسر حجمي واحد (30 %). المواد المتراكبة التي تم تحضيرها: عينات تتكون من (ايبوكسي 90 % + بولي استر غير مشبع 10 % والمدعمة بالياف الكفلر)، (ايبوكسي 90 % + بولي استر غير مشبع 10 % والمدعمة بالياف الكفلر والحديد)، (ايبوكسي 80 % + بولي استر غير مشبع 20 % والمدعمة بالياف الكفلر)، (ايبوكسي 80 % + بولي استر غير مشبع 20 % والمدعمة بالياف الكفلر والحديد)، حضرت جميع العينات بطريقة القولبة اليدوية والكبس، واجري اختبار الصدمة في الظروف الاعتيادية وبعد الغمر في ماء الحنفية لنفس الفترة الزمنية (ثمانية اسابيع). كذلك اجري فحص الانتشارية للعينات في فترة ثلاثة اشهر. اظهرت النتائج بأن العينات قد تأثرت بشكل مختلف بعد الغمر، لكن العينة (EP80%+UPS20%+K+Fe) امتلك القيم الاعلى لمقاومة الصدمة في الظروف الاعتيادية وبعد الغمر في ماء الحنفية. كذلك اظهر فحص الانتشارية ان المواد المتراكبة المصنعة من الخليط الثنائي(EP 80%+ UPE 20%) المسلح بالكفلر والحديد المشبك قد امتلكت القيم الاعلى لفحص الانتشارية في ماء الحنفية.

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1-Introduction:

A composite material generally possesses characteristic properties, such as stiffness, strength, corrosion resistance, hardness, and conductivity that are not possible with the individual components by themselves. Composite materials are used increasingly in many military, civil and spacecraft applications. When the fibers and the matrix are combined to form a composite, they retain their individual identities and structure influences the final composite properties. The resulting composite will usually be composed of layers of the filler and matrix stacked to achieve the desired properties in one or more directions [1]. Epoxy is a versatile and widely accepted matrix material for fabrication of advanced composites, hardware components, electrical circuit board materials and missile equipment, because of its excellent bonding, physicochemical, thermal, mechanical, dielectric and aging characteristics [2, 3]. The term polyester is analogous to the term steel in metals. Just as there are many types of steels with widely varying properties, so too there are a multitude of polyesters with a significant range of properties. Unsaturated polyesters are sold in a liquid form that requires catalyzation in order to cure [4]. Epoxy- polyester based polymers are enhanced the impact strength according to the percentage concentration of UPE, makes the blend a ductile, good mechanical properties and increase the energy absorption of the sample [5]. One kind of polymeric-fiber, aramid fiber (kevlar) is widely used in automobile industry, because it has good mechanical properties for example, light weight, high specific modulus and strength. The primary goal of this research was to develop a composite materials of desirable properties at low cost by investigate methods for improving the impact strength of composite materials by the addition of Kevlar and iron woven to the polymer blends to increase toughness of composites materials under work.

2. Experimental Methodology

2.1. Materials used, properties and fabricating the specimens

The materials selected to evaluate the mechanical properties for the composites used, specially, the composite materials which are made from polymer blend materials, namely; (polyester and epoxy) used for fabrication of this composite materials.

Materials:

Unsaturated polyester (UPE)

Unsaturated polyester (UPE) which has two components composed of a base resin and curing agent (hardener), medium viscosity polyester system in the form of transparent liquid, which transforms into solid state after adding the hardener to it in a percentage of (2%). Which supplied by Saudi Industrial Resins (SIR) Company, Saudi Arabia, the curing agent (hardener) was methylethylketone peroxide (MEKP);

Epoxy Resin (EP)

Epoxy resin (Quickmast 105) was used in this research is a two component, low viscosity epoxy resin system in the form of transparent liquid (which transforms into solid state after adding the hardener to it in a percentage of 3:1) as supplied by Don Construction Products Ltd. UK and have a density (1.2 g/cm^3).

Kevlar (K) 49

Kevlar 49 is a registered trademark of E.I. du Pont de Nemours & Co., has been used in this work due to its high strength, modulus, and strength-to-weight ratio, and density of (1.44 g/cm^3).

Iron woven (Fe)

Iron woven has been used in this work due to excellent flexibility and softness, suitable for tying applications, and density of (7.8 g/cm^3).

The volume fraction of fiber Vf (fiber volume/total volume) in composites was selected in all sample with the exact weight such that it achieves a volume fraction of (30%).

Preparation methods for hybrids composites materials:

1. Epoxy resin mixed with hardener (3:1) ratio.
2. Polyester resin mixed with hardener to it in weight ratio of (98: 2).
3. The mixture in the step (1) mixed with the mixture in the step (2).
   (EP 90 % + UPE 10%) and (EP 80% +UPE 20%) in order to prepare the polymer blend.
4. The polymer blend in the step (3) reinforced by different types of fibers (K, Fe) with one value of volume fraction (30) %.
5. Four composites materials prepared:

- (EP 90%, UPE 10%) +K (30) %

- (EP 80%, UPE 20%) +K (25) % + Fe (5) %
- (EP 90%, UPE 10%) +K(30) %
- (EP 80%, UPE 20%) +K (25) % + Fe (5) %

6. For all cases, this was calculated by applying the relationship:

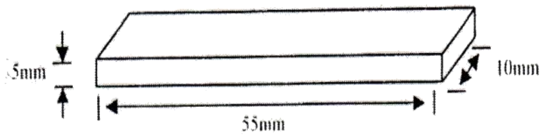
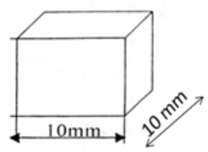
$$\Phi = \frac{1}{1+((1-\psi)/\psi)*(\rho_f/\rho_m)} \quad \textbf{(1)}$$

Where:
Φ, ψ are the volume and weight, fractions of the reinforcements respectively. ρf , ρm are the density of reinforcements and matrix respectively.
The density of the prepared hybrids was determined from the equation:
$\rho m = x1\rho1 + x2\rho2$ ……. (Rule of mixtures)
Where ρm : the density of the matrix (polymer blend). $\rho 1$, $\rho 2$: the density of the first polymer and the second respectively. x1, x2 : the percentages of the first polymer and the second respectively.

7. The mold prepared in advance and made of vulcanized wood with dimensions (10 cm*10 cm).
8. The mixture poured into the mould and between woven roving Kevlar-49 and iron woven.
9. Thick sheet of wood placed on of the blend-kevlar layers before being pressed, with identical dimension of the mould face, was used to apply appropriate load on the casting sheet for releasing voids, bubbles, to have a specified thickness and smooth face.
10. Casting sheet was left inside the mould at room temperature about (24h).
11. After solidification, the casting sheets were released from the mould and placed in an oven with (50 ˚C setting temperature) for (3h) to post cure the considered sheets.
12. Finally, the sample was cut down into standard dimensions according to the standard qualities for fulfilling the specific tests in this work.

Table -1 shows the sample dimensions and standard specification, and Figure-1, 2, 3, 4 and 5 shows some images for samples:

Table 1- Sample dimension and standard specification for the testing specimens [6]:

Test	*Sample dimensions*	*Standard Specifications*
Impact		ISO-179
Diffusivity		ASTM-D570

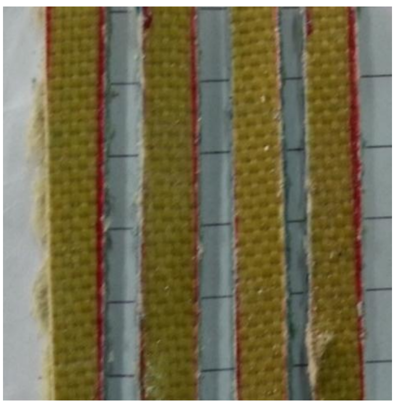


Figure 1-Samples of Impact strength for (EP(90%)+UPE(10%)+K)

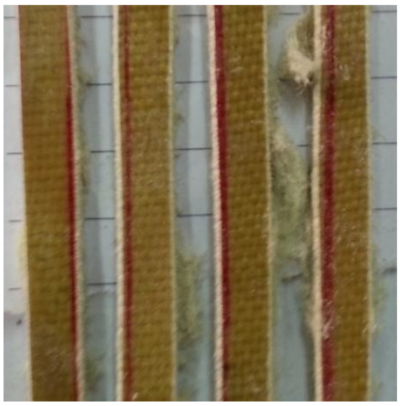


Figure 2- Samples of Impact Strength for (EP(90%)+UPE (10%)+K+Fe)

Figure 3- Samples of Impact Strength for (EP(80%)+UPE(20%)+K)

Figure 4- Samples of Impact Strength for (EP(80%)+UPE(20%)+K+Fe)

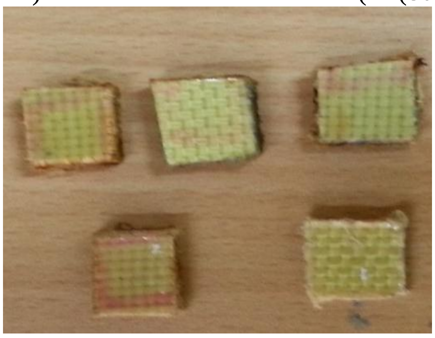


Figure 5- Samples of diffusion test

3 Instruments Description

3.1 Impact Test Instrument

Charpy impact test instrument, manufactured by the Testing Machines AMITYVILLE INC, New York, was used for the sake of performing impact test on the prepared samples. The technique of the instrument is done through lifting up the hammer to the highest point and fixing it well, and then the sample is placed in its position. First, put the energy gauge on the zero point energy then we release the pendulum by using the fixed lever on the gauge. The potential energy by a swinging movement will change to kinetic energy which will lose part of it in breaking the sample; therefore, the pointer gauge will read breaking energy value of the sample. This test was done in room temperature; impact strength is calculated from the relation [7-9]

$$I.S = U/A \quad (J/m^2) \qquad (2)$$

Where: I.S. = impact strength, U = Energy of fracture in (J), A = Cross section area in (m^2)

3.2 Liquid Absorption Test:

In order to study the effect and the diffusion of this solution on the samples immersed in tap water, first weight the samples before immersion using an electronic balance. After immersion, the samples were weighted frequently every week.

To estimate the diffusion rate, we calculate the percentage of weight gain in mass (Wight Gain %) for the samples placed in the solutions by using eq. (3) :

$$\text{Weight Gain } \% = \frac{M_2 - M_1}{M_1} * 100\% \qquad (3)$$

Where: M_1: weight of sample before immersion (dry state) (g), M_2: weight of sample after immersion (g).

Then we plot a relation between (Weight Gain %) on Y-axis and time (week) on X-axis. The diffusion coefficient was calculated by using eq. (4) [10]:

$$D = \pi \left(\frac{k_t\, b}{4\, M_\infty} \right)^2 \qquad (4)$$

Where: D: Diffusion coefficient (m² / sec), b: sample thickness (mm), k_t: is the slope of the straight line of the curve between weight gain and √time, M_∞: optimum weight gain (maximum weight gain value).

4 Results and Discussion

4.1 Impact strength

Figure-6 shows the variations in the values of the impact strength were observed with continuous immersion time. Based on results obtained in laboratory conditions before immersion, the addition of polyester to enhance the impact strength according to the percentage concentration of UPE, due to the formation of entangled network structure developed in the unsaturated active sites of polyester - toughened epoxy system, makes the blend a ductile and increase the energy absorption of the sample [5]. The results and the laboratory examination show that the (EP(80%)+UPE(20%)+K+Fe) composite have highest value (285.2 kJ/m^2) of impact strength. Because the addition the polyester to epoxy lead to reduce stuffiness of matrix, this will reduce the Susceptibility of matrix to load concentration, more load will transform into reinforced material [11], the fiber will carry the maximum part of the impact energy which exposition on the composite material [12].

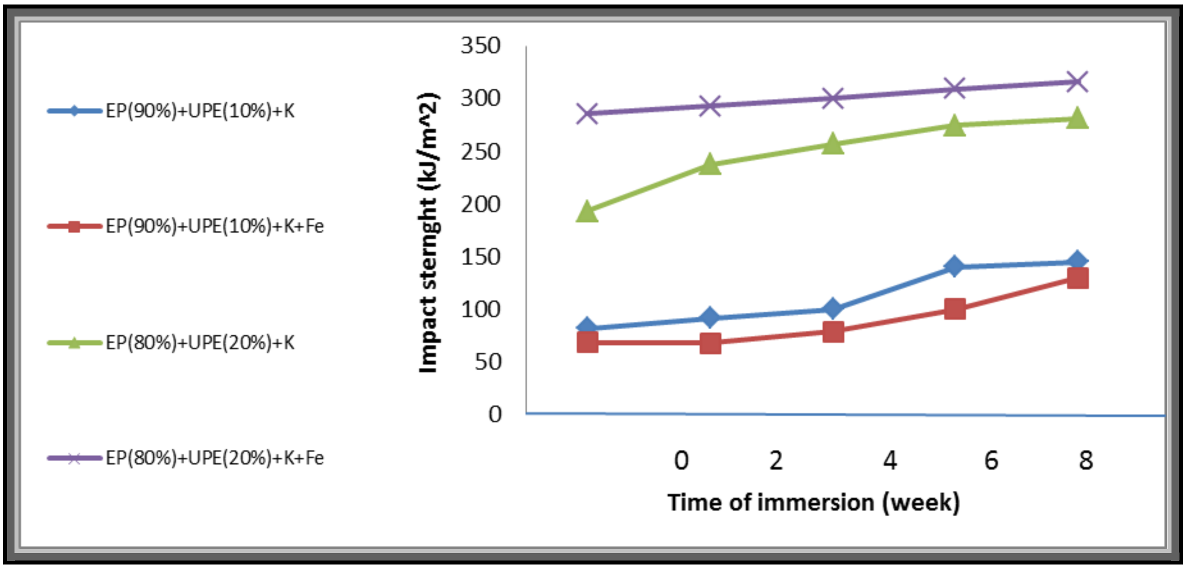


Figure 6- The variations in the values of the impact strength with time of immersion

By noticing Figure-6, it can be seen that at the first stage of immersion, the prime effects of tap water are increase the impact strength value which then increases gradually with increasing the immersion time. After (2) weeks of immersion, (EP(80%)+UPE(20)+K+Fe), composite gives the highest impact strength value, and the water acts as plasticization which increasing the impact strength. Other samples show increase in impact strength. Also (EP(80%)+UPE(20)+K), (EP(90%)+UPE(10)+K+Fe), (EP(90%)+UPE(10)+K) shows increasing in the impact strength. After (4) weeks of immersion, (EP(80%)+UPE(20%)+K+Fe), composite was still increasing in impact strength. Other sample shows increasing in impact strength. (6, 8) weeks of immersion, (EP(80%)+PSR(20%)+K+Fe), still increasing due to the water acts as plasticization which increasing the impact strength.

4.2 Absorption and Diffusion Test

The influence of water environment on the absorption characteristic of noticing Figure-7 shows the absorption test for composites material (EP 90 %, UPE 10% +K), (EP 90%, UPE 10% +K+Fe), (EP 80%, UPE 20% +K), (EP 80%, UPE 20% +K+Fe). The composite material (EP 80% + UPE 20% +K+Fe) shows the highest values of diffusivity in the tap water ($21*10^{-7} m^2$/sec). The lowest diffusivity value for this tap water was for the composite material (EP 80% + UPE 20% +K), ($5*10^{-7}$ m^2/sec).

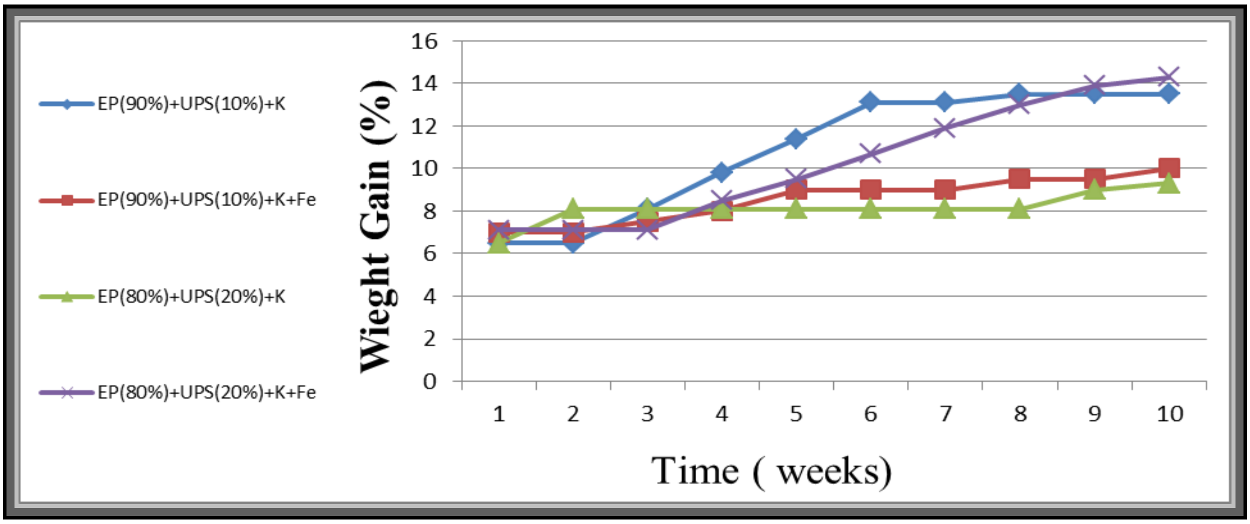


Figure 7- The percentage of weight gain with of immersion time

5. Conclusions

This work shows that successful fabrication of component hybrid composite (using epoxy-polyester as a matrix, Kevlar and iron woven as reinforcement). Incorporation of these fibers modifies the impact strength of the composites. The epoxy-polyester (80%-20%) blend reinforced with Kevlar and iron woven gives higher impact strength (315.7kJ/m^2) than other samples and diffusion test. The epoxy-polyester (80%-20%) blend reinforced with Kevlar and iron woven, gives a highest values of diffusivity in the tap water.

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