Mechanism of Hybrid Reinforcement and its Effect on some Properties of Binary Polymer Blend

Dr. Awham M. Hameed
Applied Sciences Department, University of Technology/ Baghdad
Email:awham_m@yahoo.com
Entihaa G. Daway
Technical Institute of Kut, Kut/Iraq.

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ABSTRACT

The aim of current study is carrying out some modifying in properties of resin material (Unsaturated polyester, UPE) by adding thermoplastic material (polystyrene, PS) with different weight ratios included (0%, 5%, 10%, 15% and 20%) of (PS) to prepare binary polymer blend.

The optimum ratio was selected in terms of the homogeneity case between the two polymers and studying the nature of the surfaces of the prepared materials using the optical microscope. Some mechanical tests were performed to determine the values of impact strength (I.S), ultimate tensile strength (UTS) for all prepared specimens. The ratio (80/20, weight/weight)% of (UPE/PS) blend was selected and reinforced with fibers volume fraction $\Phi_{f=}$ 10% using three types of fibers included

(glass fibers (G.F), Carbon fibers (C.F) and hybrid from the two types (5% G.F and 5% C.F). All the above tests were repeated after the reinforcement for comparing the results and studying the behavior of materials under work. The results exhibited that the values of (I.S) increase with increasing of the blending ratio of (PS) while the values of (UTS) decrease at blending ratios (10, 15) % of (PS) and return to increase at the ratio 20% . After the reinforcement, it was found that the composite reinforced with carbon fibers records the highest values of impact strength for un notch specimens while the hybrid composite has the highest value of the ultimate tensile strength comparing with E-glass and carbon fibers composites.

Keywords: Reinforcement, Polymer Blend**,** E-Glass Fibers, Carbon Fibers, Hybrid Fiber**.**

آلية التسليح الهجين وتأثيرها على بعض الخواص لخليط بوليمري ثنائي

الخلاصة

الهدف من الدراسة الحالية هو اجراء بعض التحوير في خواص مادة راتنجية (البولي استر غير المشبع , UPE) بأضافة مادة ثرموبلاستيكية (البولي ستايرين ,PS) وبنسب وزنية مختلفة شملت 0,5 (10, 15, 20)% من البولي ستايرين لتحضيرخليط بوليمري ثنائي.

وقد تم اختيار النسبة المثلى بدلالة حالة التجانس بين البوليمرين ودراسة طبيعة السطوح للموادالمحضرة بأ ستخدام المجهر الضوئي. أجريت بعض الاختبارات الميكانيكية لتحديد قيم مقاومة الصدمة (I.S) , مقاومة الشد القصوى (UTS) لجميع النماذج المحضرة.

تم اختيار النسبة الوزنية (80/20) % من خليط البولي استر غير المشبع/ البولي ستايرين وسلحت بالالياف وبكسرحجمي (10% = Φ_f) باستخدام ثلاثة انواع من الالياف شملت (الياف الزجاج (G.F), الياف الكاربون (C.F) وهجين من نوعي الالياف (G.F 5% و(C.F 5%). تم تكرار جميع الاختبارات اعلاه بعد التسليح لغرض مقارنة النتائج ودراسة سلوك المواد قيد البحث. أظهرت النتائج بأن قيم (I.S) تزداد مع زيادة نسبة الخلط للبولي ستايرين في حين قيم (UTS) تنخفض عند نسبتي الخلط (10, 15)% من البولي ستايرين وتعود لتزداد عند النسبة 20%. وبعد التسليح اظهرت النتائج بأن المتراكب المسلح بألياف الكاربون يسجل القيم الاعلى لمقاومة الصدمة لنماذج غير محزوزة في حين المتراكب الهجين يمتلك القيمة الاعلى لمقاومة الشد القصوى مقارنة مع متراكبات الياف الزجاج والكاربون.

INTRODUCTION

Blending of two or more different polymers has proved to be one of the most successful methods for developing new materials with desirable properties. Polymer blends are mixtures of two or more polymers that can either mix completely on a molecular scale or form two-phase structure. Polymer blends can exhibit new combinations of properties of component and strongly upon the morphology of the blended materials. This is synthetically somewhat easier than making copolymers because it allows the various polymer components to be produce by different polymerization methods [1, 2]. Blending of polymers may either result in compatible (miscible) system or incompatible (immiscible) system. A miscible polymer blend means single phase system; an immiscible polymer blend means multi phase system [3]. Although polymer blending looks to be a very attractive way to obtain new materials, most polymers blend are immiscible and/or incompabitible. Reason for incapability are high interfacial tension and, consequently, poor interface adhesion [3]. By blending polymers, new material can be developed that combine physical and mechanical properties of their components, depending on the composition and level of compability. Polymer blends are currently receiving great attention because they offer low-cost alternatives to the development of entirely new materials with improved properties.

The advantages offered by hybrid composites materials are often considered in terms of the improvement in a particular mechanical property resulting from the addition of a second reinforcement type. The existence of a positive or negative hybrid effect is determined by three factors [4]:

i) The relative volume fractions of the two fibers,
ii) The arrangement of the fibers in the hybrid, and
iii) The loading configuration.

In recent years, there has been a growing interest in the polymer blend composites due to their enhanced physical and mechanical properties.

Shenoy and Melo [5] investigated the effect of guar gum and its hydroxypropyl derivatives in unsaturated polyester composites were investigated with respect to their

mechanical and chemical properties. The effect of hydroxypropylation and the degree of hydroxypropylation on the properties of resultant composites. An increase in the degree of substitution resulted in increased polymer-filler interaction reflected by a positive effect on the mechanical properties of the composites. These results open an avenue for the use of polysaccharides and their derivatives as eco-friendly fillers as a replacement of mineral fillers.

Rosa *et al.*[6] studied the post-impact mechanical characterization of E-glass/basalt woven fabric interply hybrid laminates. In this study, the different configurations, including symmetrical and asymmetrical glass/basalt laminates, are fully characterized using interlaminar shear strength tests and flexural tests. Impact damage is characterized from the study of post-impact flexural properties assisted by acoustic emission and thermography, visualising damage using scanning electron microscope (SEM) fractographs. The results indicate that a symmetrical configuration including E-glass fiber laminate as a core for basalt fibre laminate skins presents the most favorable degradation pattern, whilst intercalation of layers may bring to further improvement of the laminate properties, but also to more extended and complex damage patterns.

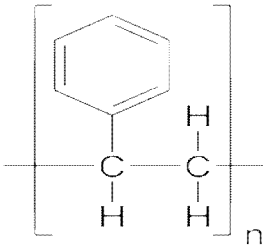
Esfahani *et al.*[7] investigated the effects of nanoclay particles on impact and flexural properties of glass fiber-reinforced unsaturated polyester (UP) composites. UP-reinforced nanocomposite containing 1.5 and 3 wt % nanoclay was used to manufacture laminated composite panels using glass fiber woven roving by hand lay-up method. X-ray diffraction and transmission electron microscopy analysis confirmed intercalation and exfoliation of the nanoclay in the UP resin. Flexural test results indicated better performance for the specimens containing 1.5 wt % nanoclay reinforcements. However, Izod impact test results showed a decrease with increase in nanoclay content.

The aim of this work is to study the effect of hybridization by two types of fibers on the impact and tensile characteristics of the polymer blend prepared from thermost resin (UPE) and thermoplastic polymer (PS).

THEORETICAL PART

Unsaturated polyesters are manufactured by condensation polymerisation of dicarboxylic acid (mallic acid) and dihydric alcohol (e.g., glycol) followed by curing with cross-linking agent (styrene). They have good resistance to heat and most chemicals except strong acids and alkalies. They are affected by sunlight unless stabilized [1, 8].

Polystyrene's chemical formula is $(C_8H_8)_n$; it contains the chemical elements carbon and hydrogen [1, 8] .



Polystyrene is very chemically inert, being resistant to acids and bases. It is not corrosion resistant like polyethylene and polypropylene; it is attacked by many solvents. It is low in cost and thus is widly used in throwaway items (plastic tableware, food container and toys) [1, 8]

Mixing of two or more different polymers together makes it possible to achieve various property combinations of the final material—usually in a more cost-effective way than in the case of synthesis of new polymers. Therefore, great attention has been paid to the investigation of these systems, as well as to the development of specific materials. Recently, the problem of polymer blends has also become important for recycling industrial and/or municipal plastics scrap [2].

Glass fiber is commonly used as an insulating material. It is also used as a reinforcing agent for many polymer products; to form a very strong and light fiber-reinforced polymer (FRP) composite material called glass-reinforced plastic (GRP), popularly known as "fiberglass" [9,10].

Carbon fibers are usually combined with other materials to form a composite. When combined with a plastic resin and wound or molded it forms carbon fiber reinforced plastic (often referred to also as carbon fiber) which is a very high strength-to-weight, extremely rigid, although somewhat brittle material [9,10].

EXPERIMENTAL PART

Procedure of samples preparation

(UPE/PS) polymer blends with weight ratios included [(95/5),(90/10), (85/15),(80/20)]% were prepared by mixing of Unsaturated Polyester resin (UPE) with polystyrene (PS).General purpose polystyrene (PS125) was supplied by Sabic company, Saudi Arabia ; while the (UPE) resin was supplied by Saudi Industrial Resins(SIR) Company, Saudi Arabia. The curing agent (hardener) was methylethyl ketone peroxide (MEKP) while the catalyst system was a solution of cobalt octoate in dibutyl phthalate as accelerator of reaction. After mixing the two liquid polymers (UPE with PS), the hardener was added to the mixture with 2% weight ratio; while the ratio of the accelerator was 0.5%. It is vital to mention that (UPE) is yellow liquid insoluble in cold water while (PS) is a clear, colorless polymer used extensively for low-cost applications. It is available commercially in both pellet and sheet form. White pellets of (PS) were used in this research. (PS) material was dissolved in toluene into glass sealed containers for (24 hour).

This binary polymer blend was poured in a mould prepared previously for this purpose from transparent plastic sheet with dimensions (14*12*5) cm^3 at room temperature; then after solidification, the resulted cast was interred into an oven with a set temperature of 50^oC for (1 hour); to ensure that full cure was achieved. Post-curing treatment reduces weight loss significantly while higher temperatures and relative humidity increases the weight loss rate [11].

The ratio (80/20)% of (UPE/PS) polymer blends was selected for the reinforcement. An addition more than 20% of PS reduces the stiffness of resin (UPE) and makes it behaves as ductile material, therefore the additional ratio of (20%) was selected. This polymer blend was reinforced with chopped (E-glass, carbon and hybrid fibers of the

two types) respectively. Table (1) lists the density and tensile strength values of E-glass and carbon fibers while Figure (1) represents photographic pictures of the three types of fibers used in this work.

By using the rule of mixture, all the three composites were reinforced with volume fraction (Φ_f =10%) of fibers to compare the results obtained from single and hybrid reinforcements. After preparing the moulds, the selected polymer blend was added as a primary layer and then E-glass fibers were put with arrangement by rolling tool and finally the remaining amount of polymer blend was added to saturate all the fibers with polymer blend. This process was repeated with carbon and hybrid fibers at the same volume fractions (Φ_f).

THE MECHANICAL TESTS

The impact and tensile test specimens were cut out from the casted sheets according to (ISO-179) and (ASTM-D 638) standards respectively.

In addition to the above; it is vital to mention that the surfaces of all specimens were polished by grinding machine before testing.

The impact test was carried out by using charpy impact instrument while tensile test was performed by using (Tinius Olsen instrument) produced from England. These tests were carried out at room temperature (25-30)^{o}C.

The impact strength values were calculated by applying the following equation [12]:

$$I.S = Uc / A \quad \ldots (1)$$

Where (Uc) is the energy required to break the sample.

(A) is the cross sectional area of the sample.

The optical microscope type (Nikon Eclipse) made in Japan was used for studying the morphology and fracture surfaces of the polymer blends and their composites under study.

RESULTS AND DISCUSSION

The impact test

In this work, the effect of blending ratios on the impact test was observed as shown in the Figure (2). It can be noticed that the values of (I.S) increase gradually and the ratio 20% of PS records the highest value of the impact strength. This may be related to the compatibility between the two polymers and as well as the nature of linear chains which has higher flexibility comparing with the three dimensional network of unsaturated polyester resin. This makes the material (after blending) has higher resistance to the impact load comparing with pure (UPE) which has stiffer structure [1, 2].

Charpy impact test was carried out for all prepared specimens with different notch depths included (0.25, 0.5, 0.75, 1, 1.25, 1.5)mm. Figures(3,4)show the relationship between the impact strength (I.S) and notch depth for the polymer blends and their composites respectively. From these two figures, it can be noticed that the values of

(I.S) decreases with increasing of notch depth of the specimens. This related to reduce the cross sectional area of the sample subjected to the impact load.

The tensile test

From this test, the ultimate tensile strengths (UTS) of all specimens were obtained. Figures (5, 6) illustrate the stress-strain curves of all polymer blends specimens and their composites respectively. From Figure (5), it is obviously that the mechanical behavior of (UPE) and its blend with (5%PS) is linear which means that the material is still brittle at this percentage, but after increasing of mixing ratio, the behavior transformed to the ductile manner which leads to increase of material toughness [1,2]. From Figure (6), it can be seen that the hybrid composite has the highest value of (UTS) comparing with the single composites. This result may be related to the compatible case between E-glass and carbon fibers within the polymer matrix where the tensile strength values for these fibers are close as shown in Table (1).

Figure (7) shows the effect of blending percentages on the (UTS) values. It can be concluded that the values deceases at the first stages of blending and then increases at the ratio 20% of (PS), this may be related to the homogeneity case of the blend is greater than the blends with ratios (10,15)% of (PS).

Optical microscope observations

There are many published studies on the mechanical and morphological properties of fibrous composites such as [13, 14], but this research interested with the nature of

Fracture surfaces of the prepared samples before and after the reinforcement.

Optical micrographs of various (UPE/PS) blend with different ratios of (PS) are shown in Figures (8, 9, 10, 11 and 12). It can be concluded that the fracture surface of pure (UPE) is brittle as in the Figure(8), it can be seen three regions at fracture surface. These may include a mirror zone, mist region and rib marks. After blending it with (5, 10) % of (PS), the nature of fracture surface seems glossy in many regions which means the fracture is still brittle while after the blending with (15, 20)% of (PS), it was observed that the brittle fracture was turned to ductile fracture and became dark, this result agrees with the study [14] . The fracture surfaces of the composites exhibits the debonding case of the fibers from the matrix as a single fiber or bundle of them as shown in Figures (13, 14 and 15).

CONCLUSIONS

In this study, the mechanical, morphological properties of (UPE/PS) blend reinforced with single and hybrid fibers were studied.

The following conclusions can be drawn:

1- It was observed that the impact behavior were optimized at (20wt.%PS)content. The impact strength of this blend showed increase about (194%) comparing with pure (UPE).

2- UPE was successfully be toughened by mixing it with (PS).

The impact strength of (UPE/PS) increased with increasing the content of the second phase.

3- The maximum stress before fracture of the pure specimen (UPE) is higher than its values after blending with polystyerene but the polymer blend (UPE/PS) behaves as ductile material at the ratio 20% of (PS).

4- It can be found that the ultimate tensile strength of the blend with 20% PS is higher than the other percentages (10,15)%.

5- It can be concluded that the hybrid composite has the highest value of the ultimate tensile strength comparing with E-glass and carbon fibers composites.

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Table(1) Density and tensile strength values of E-glass and carbon fibers.

Fiber type	Density (g/cm^3)	Tensile strength (GPa)
E-glass	**2.56**	**2.5**
carbon	**1.75**	**2.8**

(a)

(b)

(c)

Figure (1) Photographic pictures of chopped fibers (a) E-glass,(b) carbon and (c) hybrid .

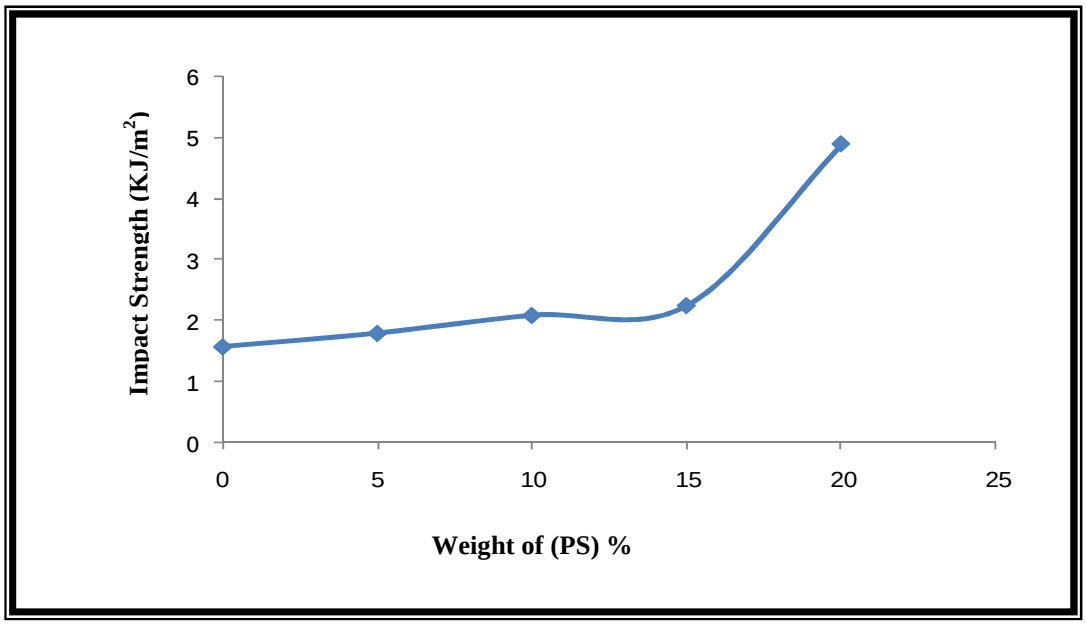

Figure (2) Effect of weight percentages of (PS) on the impact strength values of (UPE/PS) polymer blends.

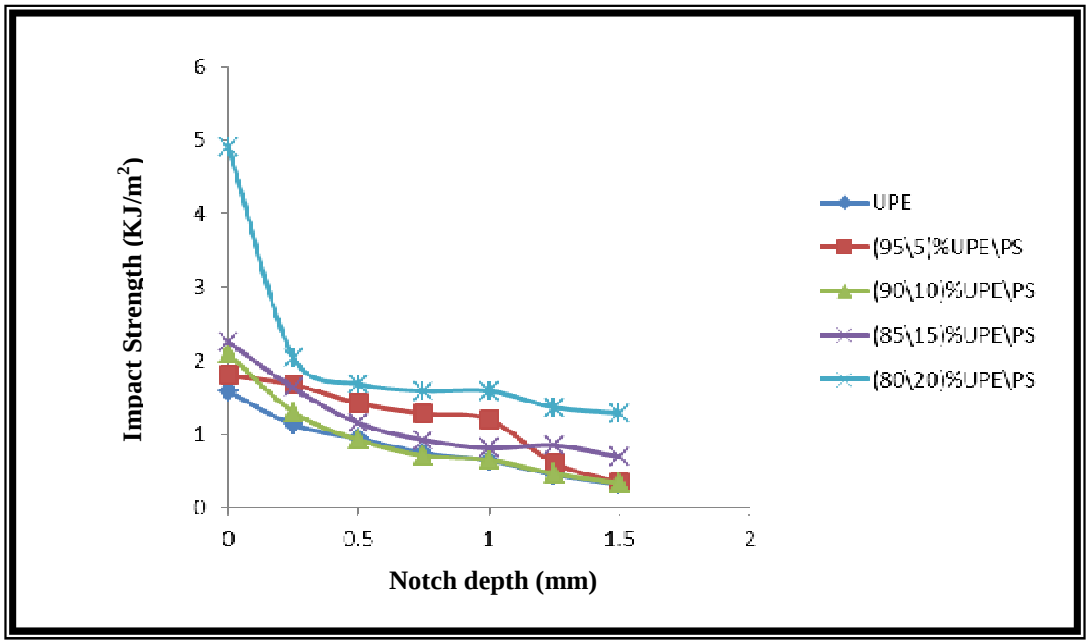

Figure (3) Effect of notch depth on the impact strength (UPE) and its blends.

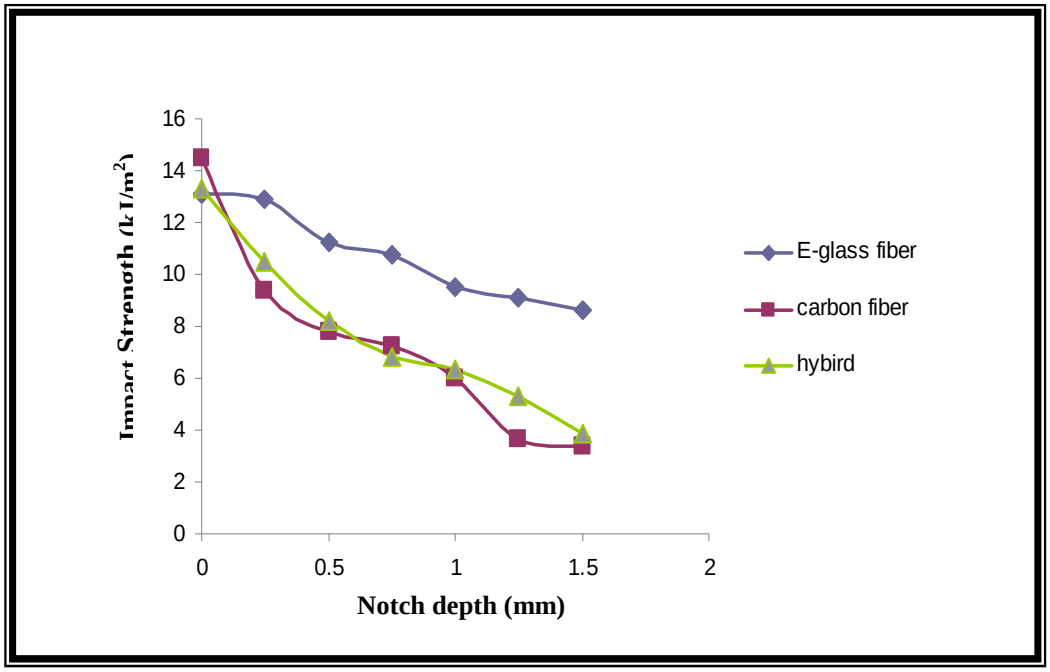

Figure (4) Effect of notch depth on the impact strength of composites materials.

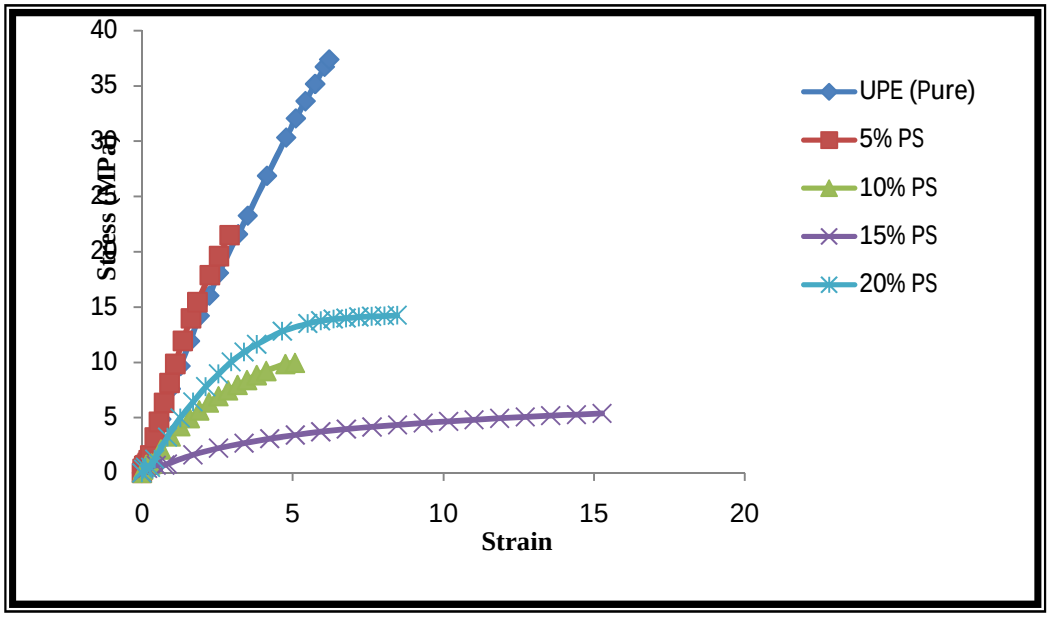

Figure (5) Stress-Strain curves for (UPE) and its polymer blend at different weight ratios.

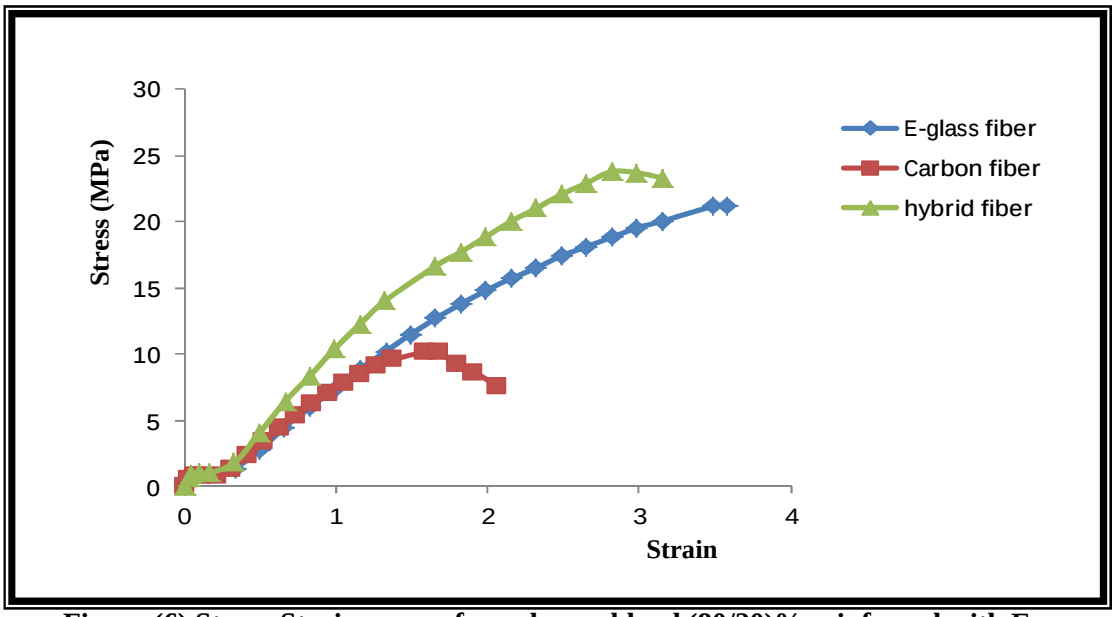

Figure (6) Stress-Strain curves for polymer blend (80/20)% reinforced with E-glass and carbon and hybrid fibers of the two types.

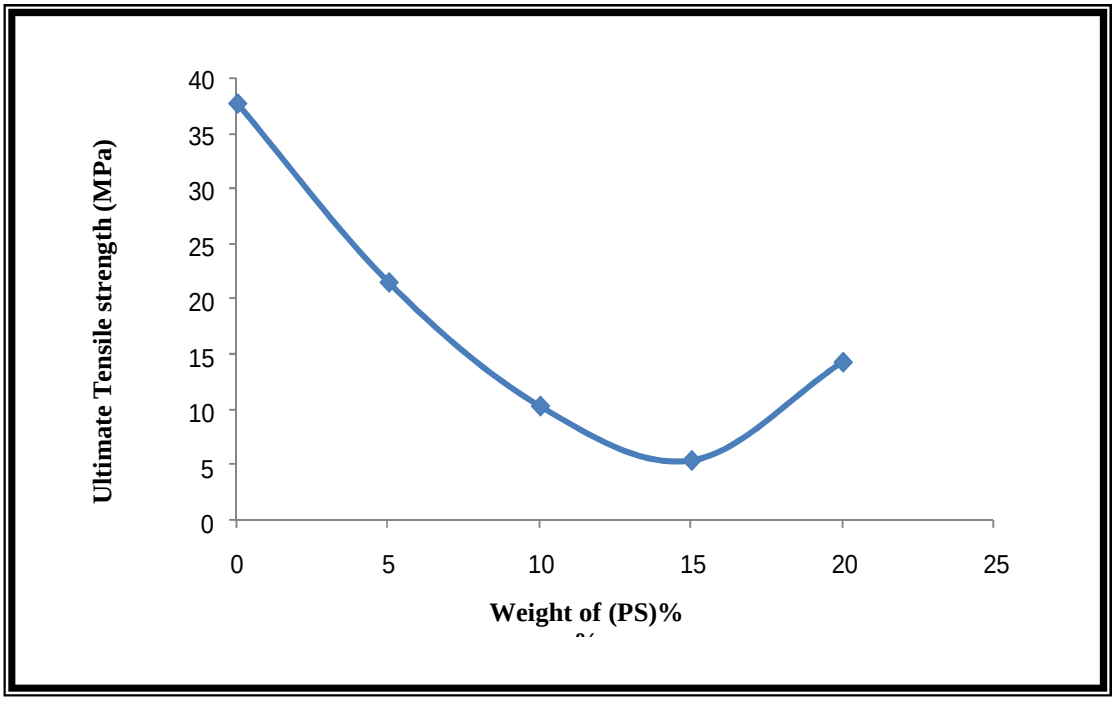

Figure (7) Effect of weight percentages of (PS) on the ultimate tensile strength values of (UPE/PS) polymer blends.

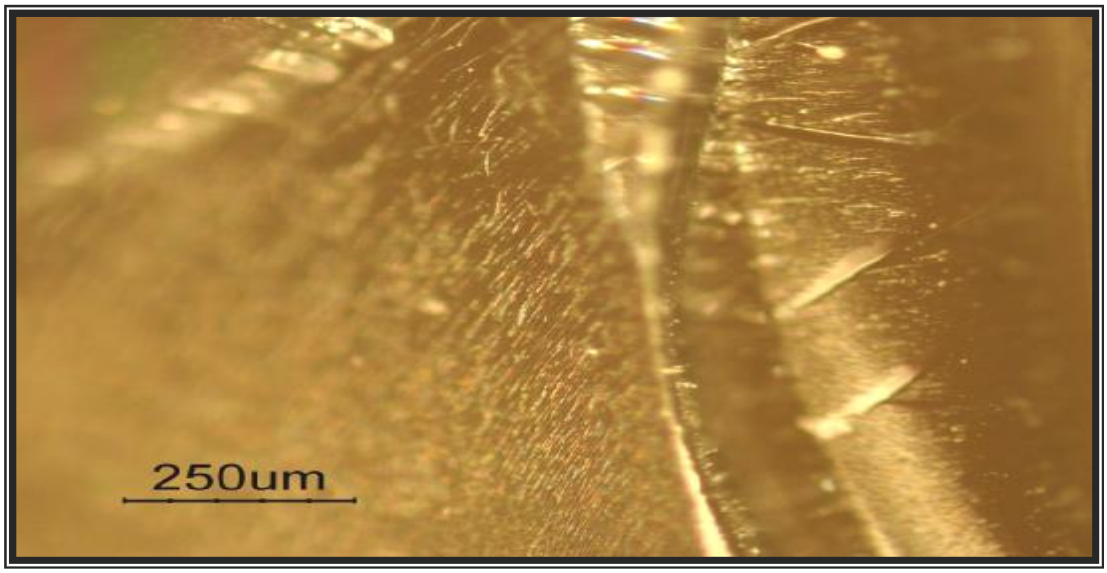

Figure (8) Optical micrograph of fracture surface for pure (UPE) after impact loading.

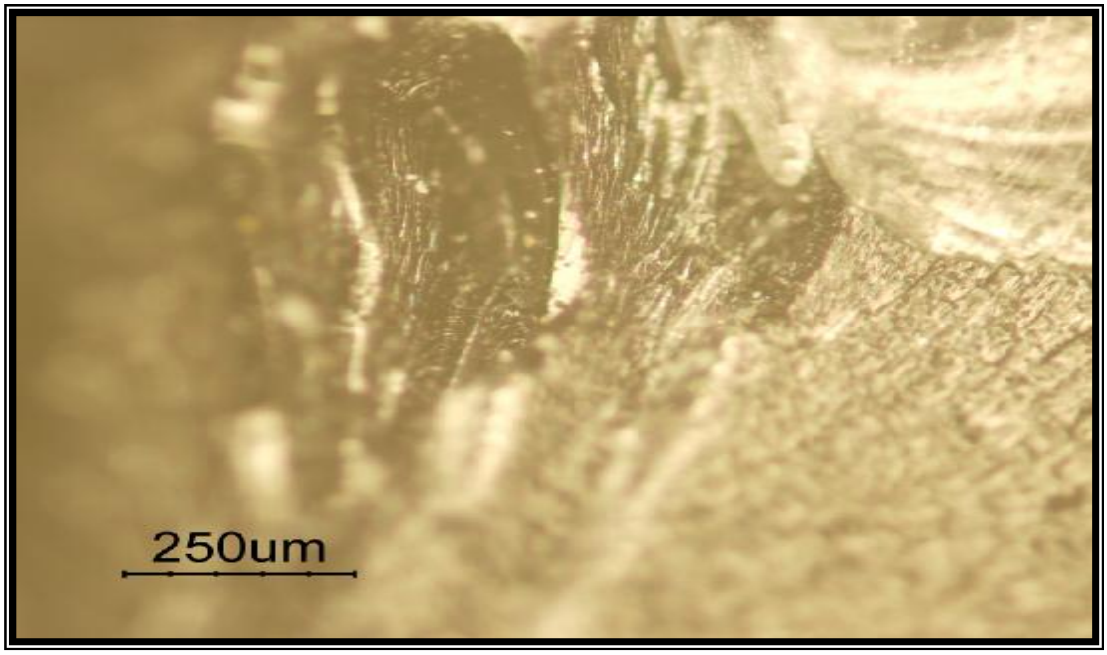

Figure (9) Optical micrograph of fracture surface for (UPE/PS, 95/5%) after impact loading (100X).

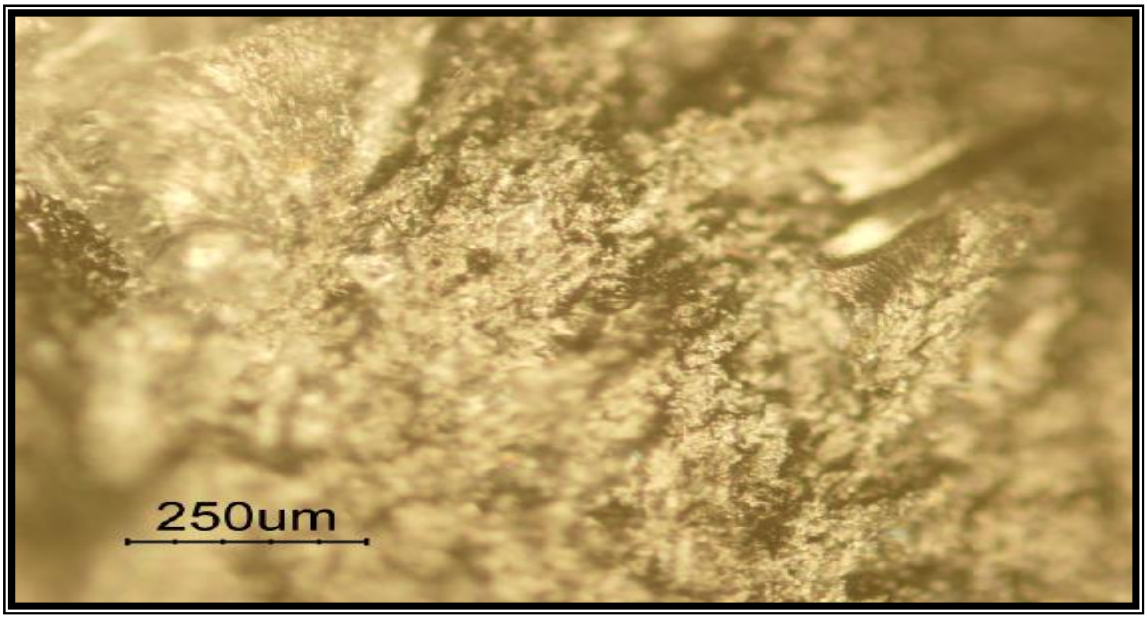

Figure (10) Optical micrograph of fracture surface for (UPE/PS, 90/10%) after impact loading.

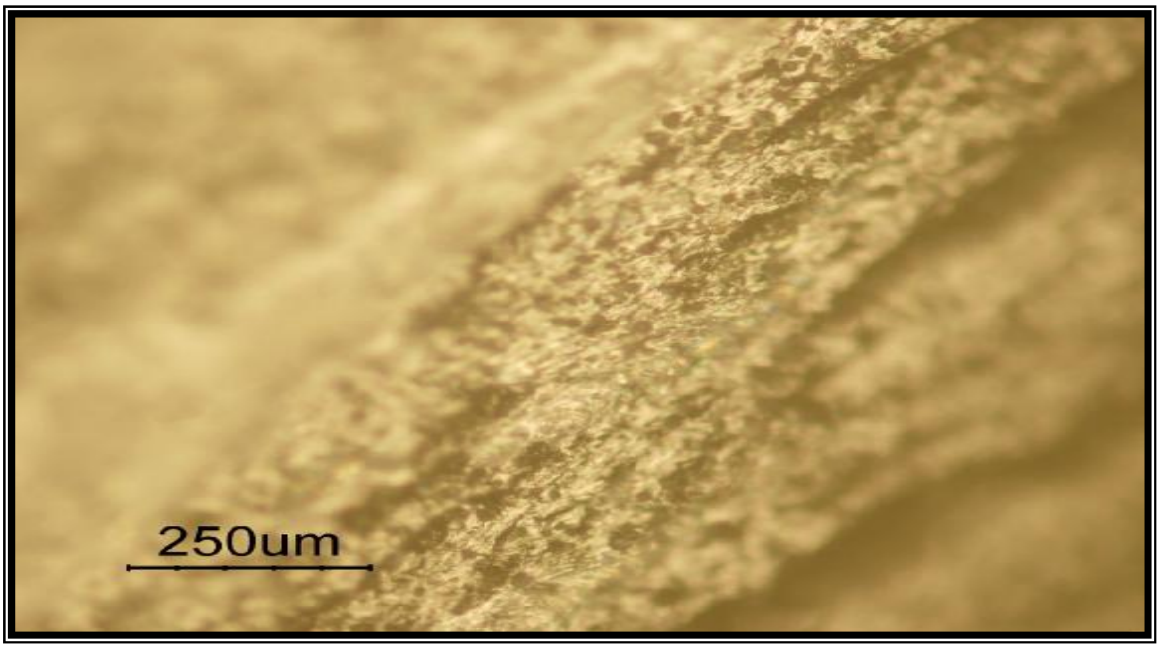

Figure (11) Optical micrograph of fracture surface for (UPE/PS, 85/15%) after impact loading.

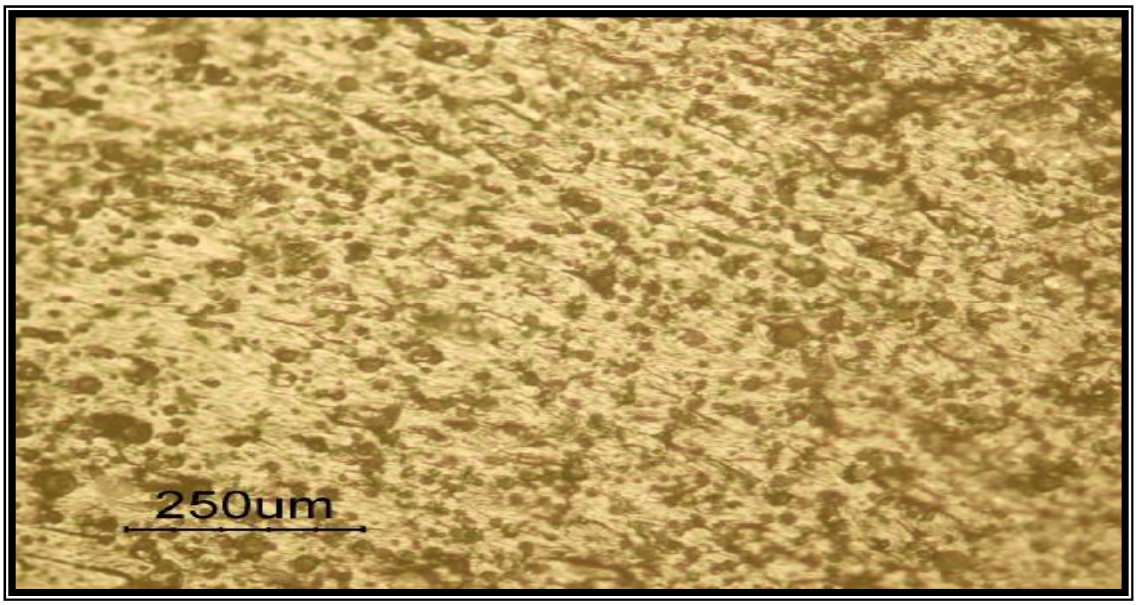

Figure (12) Optical micrograph of fracture surface for (UPE/PS , 80/20%) after the impact loading (100X).

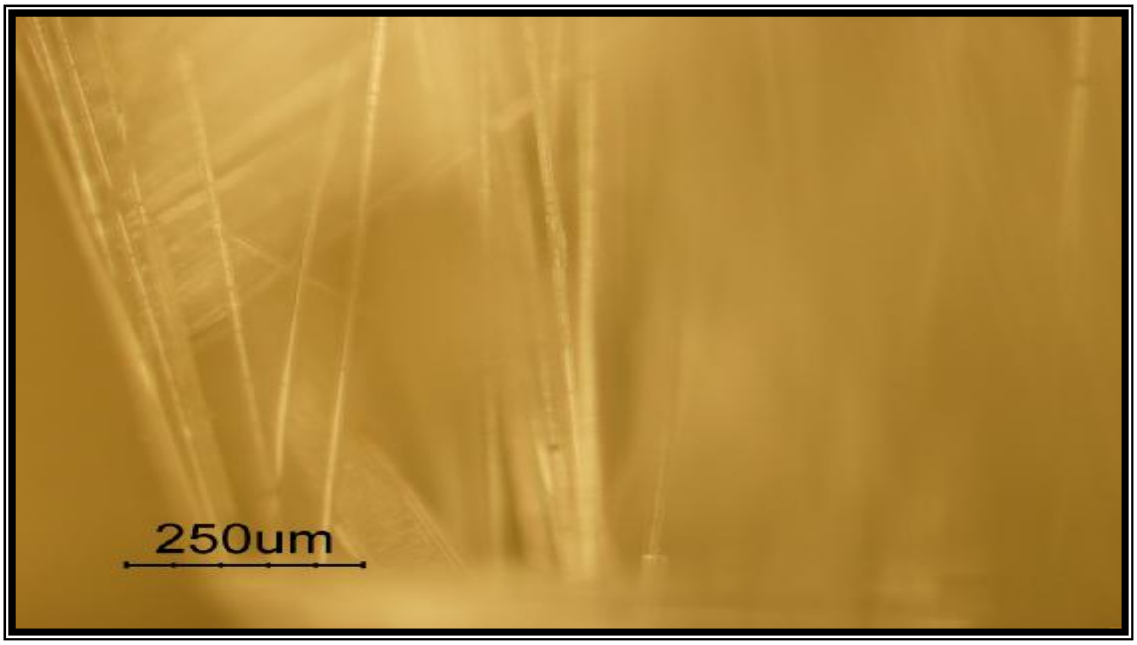

Figure (13) Optical micrograph of fracture surface for (UPE/UP, 80/20%) polymer blend reinforced with E-glass (100X) fibers.

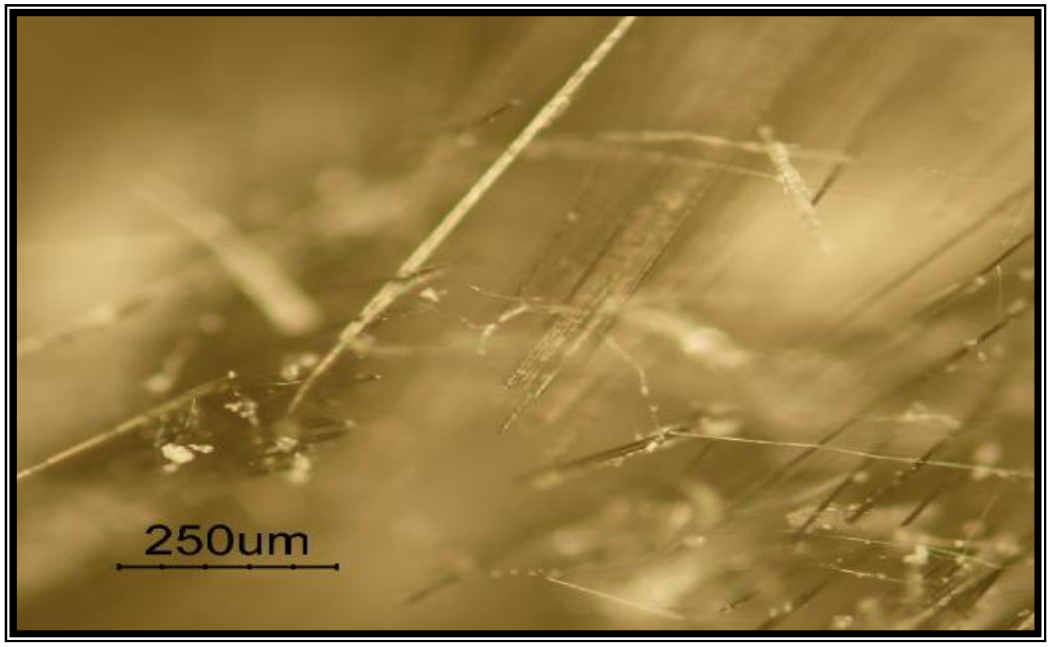

Figure (14) Optical micrograph of fracture surface for (UPE/UP, 80/20%) Polymer blend reinforced with carbon fibers (100X).

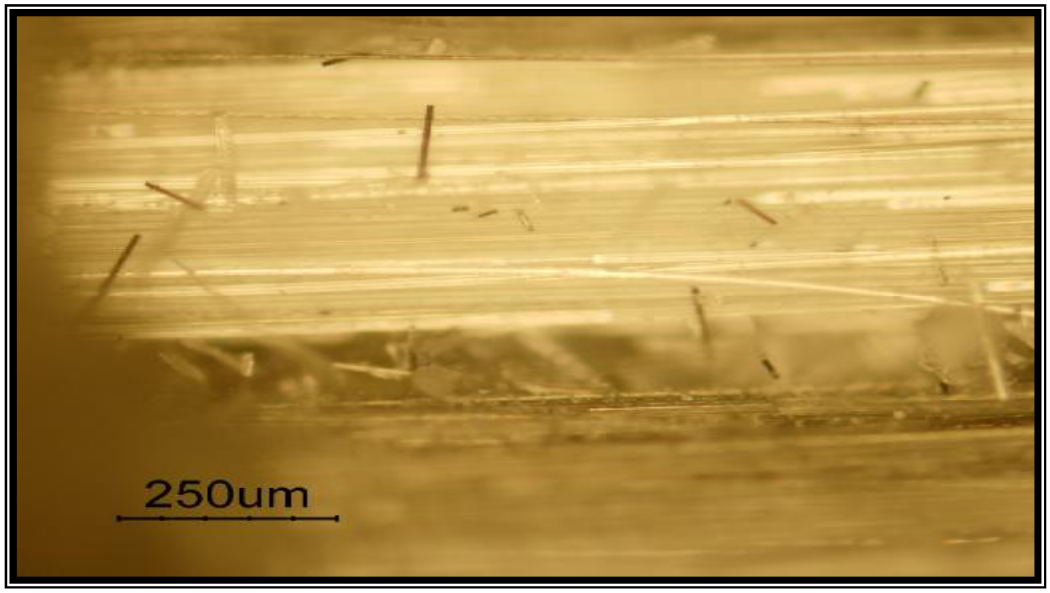

Figure (15) Optical micrograph of fracture surface for (UPE/UP, 80/20%) polymer blend reinforced with hybrid fibers (100X).