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Morphology and Mechanical Properties of (Epoxy/PVC) Blend

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Abstract

In this research, the morphology and mechanical properties of (Epoxy/PVC) blend were investigated. (EP/PVC) blend was prepared by manual mixing of epoxy resin with different weight ratios of (Poly vinyl chloride (PVC) after dissolving it in cyclohexanon). Five sheets of polymer blends in wt% included (0%, 5%, 10%, 15% and 20%) of PVC were prepared at room temperature. Tests were carried out to study some mechanical properties for these blends and compared with the properties of pure epoxy. The morphology of the prepared materials was examined to study the compatibility nature between the two polymers under work. It was found that the best ratio of addition is (20%) of PVC. This percentage gave the highest value of tensile strength compared with other percentages of mixing for (EP/PVC) blends.

Keywords: *Epoxy, PVC, Polymer Blend, Mechanical Properties, Morphology.*

1. Introduction

An epoxy resin is a polymer containing two or more epoxy group rings. Such groups can be terminal, internal or cyclic structures. They can bond with other molecules, forming a large three-dimensional network. The most used hardeners are aromatic and aliphatic amine as well as anhydride hardeners. All should be added into the epoxy resin with adequate weight ratio to provide cross-linking [1].

A lower crosslink density can improve toughness by permitting greater elongation before break. A higher crosslink density can give a higher glass transition temperature and improved resistance to chemical attack. Recently, rubber toughened epoxy resins have gained significantly in interest. Small rubber particles scattered in the epoxy resin are believed to improve the fracture toughness of the neat resin [2].

Polymer blends and alloys have received widespread attention for the last several decades. Polymer blends are defined as physical mixture of two or more polymers. They may be divided into different categories: miscible blends in which the components exist in a simple homogeneous phase and immiscible ones in which the components exist in two distinct separated phases. Generally, the former ones offer various advantages over the latter. The origin of miscibility between the polymer pairs has been understood based on theoretical background and experimental results [3].

Nowadays, polymer blending has been a most useful method for improving or modifying the physicochemical properties of polymer materials. An important property for the polymer blend is the miscibility of its ingredients, as it affects the mechanical properties, the morphology, the permeability, and the degradation [4].

Previous study used hand lay-up method to prepare sheets of unsaturated polyester/poly vinyl chloride (UPE/PVC) blends with different weight percentages of PVC (10%, 20% and 30%).

Results show increasing in the values of maximum stresses, yield stresses and modulus of elasticity for UPE/PVC blends with increasing the weight percentage of the polyvinyl chloride (PVC). UPE/PVC blends reinforced with one layer of glass fiber results showed good mechanical properties for the composite which contain 20% PVC. Also the results show that composites reinforced with two layers of glass fiber randomly increasing in values of maximum stresses with increasing PVC percentage [5].

Morphology studies and mechanical properties for Polystyrene / Styrene-Butadiene-Styrene (PS/SBS) blends were performed on the blends of Polystyrene (PS) and Styrene-Butadiene-Styrene (SBS) prepared in different ratios by melt blending technique using Haake Poly- Driver extruder. Tensile test, Differential Scanning Calorimetry (DSC) and Scanning Electron Microscopy (SEM) were used to study the mechanical and thermal properties and morphology [6].

The main objective of the present work is study the morphology and extent of modification of epoxy properties by blending it with (PVC). For this purpose, a series of blends with various weight ratios of (PVC) has been prepared. The effect of addition ratio of (PVC) on the morphology and mechanical properties of epoxy resin was investigated and the role of (PVC) as a plasticizer has been discussed.

2. Experimental

Binary polymer blend was prepared by mixing of epoxy resin (type Quickmast 105) with polyvinylchloride (PVC) after dissolving (5gm) of it with (100ml) of cyclohexanon solvent. Degree of polymerization of PVC ranges commercially from 625 to 2700.

Hand lay-up method was used to prepare the molds of blend with different weight ratios (wt%) of PVC. It is important to remember that (PVC) powder was sieved by using sieve (type Retsch) produced by UK Company. The particle size of PVC ranged from 25 to 63 micron. PVC powder in all particle sizes were dissolved into cyclohexanon container. Five sheets of polymer blends with different wt% (0%, 5%, 10%, 15% and 20%) of PVC were prepared in this work. The molding process was carried out by using five polymer sheets (transparent paper) prepared with dimension (20×15×2) cm^3. These casted sheets were left inside the molds at room temperature for (24hours) and then removed from the molds after completing the solidification process; the casts were put into oven with (50^oC) for (1 hour) to complete the curing process. The homogeneity case of these blends was tested by using optical microscope. It is important to show that the mixing process with higher ratios of PVC were performed too, it is found that the cast become more ductile and difficult for handling with it to remove it from the mould.

The density of the prepared blends was determined from the equation [7]:

$$\rho_m = X_1\rho_1 + X_2\rho_2 \quad \text{... (1)}$$

Where ρ_m : the density of the matrix (polymer blends).

ρ_1, ρ_2 : the density of the polymers in the mixture

X_1, X_2: the percentage of the polymers in the mixture.

According to the standard specifications (ASTM-D638, ASTM-D695 and ASTM-D790), the samples of tensile, compression and flexural tests were cut respectively. The roughness test were carried out on small samples with dimensions (2×2×0.5) cm^3 for epoxy and its blends. All these tests were performed at room temperature and repeated three times for each sample and the average of values were determined.

Optical microscope type (Bel, made in Italy, model MTM-1A) was used to investigate the morphology of pure and blends specimens.

Tensile properties were measured by an Instron universal testing machine supplied by Chinese Company, model 1195. The crosshead load was at (5kN) and a speed of (5mm/min). The hydraulic press type (Leybold Harris, Germany, model 36110) was used for both compression and flexural tests.

The values of tensile and compressive strengths were determined directly from the corresponding instruments.

Flexural strength (F.S) and shear stress values were calculated from the flexural strength test by applying the following equations [8]:

$$F.S = {}^{3PS}/_{2bt^2} \quad \text{… (2)}$$

$$Shear\ stress = {}^{3P}/_{4bt} \quad \text{… (3)}$$

Where P: is the required load to break the specimen.

S: Span (is the distance between the two supported points of the sample) (mm).

b: is the width of specimen (mm).

t: is the thickness of specimen (mm).

3. Results and Discussion

Figure (1) illustrates the optical micrographs of the morphology for epoxy and its blends with different percentages of (PVC). It is clear that the best ratio which gives the better miscibility between the two polymers is (20 wt.%) while the nature of morphology for the surfaces of samples with lower wt.% exhibits unsmooth surfaces with less homogeneity.

Figure (2) shows the values of tensile strength as a function of weight ratios of (PVC). From this figure, it can be noticed that these values decrease with increasing (PVC %) at the first ratios of blending but return to increase at the 20% of (PVC). The reason behind this phenomenon may be related to the best homogeneity state between the two polymers at this ratio of mixing because of epoxy and PVC form as a single phase material as shown in Fig.(1e). In other words, the mixing ratio (15%) has the lowest value of tensile strength. There was probably no significant interaction between the modifier (PVC) and epoxy with below a modifier concentration of (20%). This result agrees with that of the study reported by Bhuniya and Adhikari [9]. It is necessary to mention that Chiang [10] reported that the properties of blend strongly depend on the morphology, that is, on miscibility, size and form of dispersed phase, character and size of the interphase domain.

Figure (3) shows the effect of weight percentages of (PVC) on the compressive strength values for (EP/PVC) polymer blend. It is also being noticed that compressive strength of epoxy decreases after blending it with (PVC). This fact may be attributed to that epoxy is thermoset material while PVC is thermoplastic, therefore when the two polymers were mixed together a semi-interpenetration network is formed which has less rigidity than full interpenetration network [11,12]. For this reason most mechanical properties decrease after blending epoxy with (PVC).

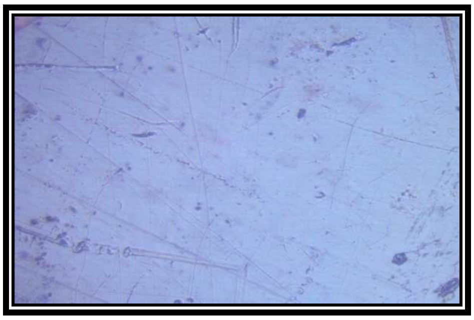
It is well known that the stress-strain of polymers divided into two behaviors, the first is named the elastic and the second is named plastic deformation. From this simple definition, it can be noticed that epoxy behaves the elastic behavior with little deformation before fracture as shown in Fig.(4) which represents the (stress-strain) relations for epoxy and its blends with different weight ratios of (PVC) under compression loading. It is clear that the behavior of epoxy changes after blending process with PVC where transformed from brittle to ductile or semi-ductile at the ratio (15%). This change can be obvious from the increasing of plastic strain which increased after the blending clearly. The reason for this change comes from the increasing of mobility polymer molecular chains. It also can be noticed that the mixing percentage (20%) has modulus of elasticity higher than that of the ratio (15%) as shown in Fig. (5). This behavior may be attributed to the homogeneous physical nature between the two polymers under study at the mixing ratio (20%). This result corresponds with previous study in this field [13].

The reason for increasing of flexural strength and shear stress at (20% content of (PVC) is the same reason as for the increasing in tensile and compressive strengths as shown in the Fig.s(6,7).

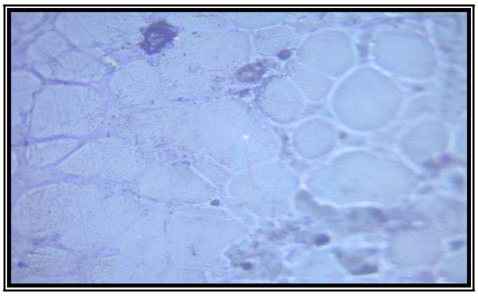
It is clear that the roughness value of epoxy decreases after addition (PVC) that is shown in Fig.(8)which illustrates the effect of weight percentages of (PVC) on the roughness values for (EP/PVC) polymer blend. It is important to mention that the roughness of surface depends on the hardness amount of material. So after blending thermo set polymer (epoxy) with thermoplastic polymer (PVC), the hardness will be dropped due to the plasticizing of material. This behavior will be reflected on the values of roughness which decreased after the blending process.

After this study, we can obtain on epoxy modified with thermoplastic material by addition PVC. It is well known that epoxy is brittle material deforms under effect of stresses with little elastic strain, but it can transform to material deforms with larger plastic deformation after blending with PVC.

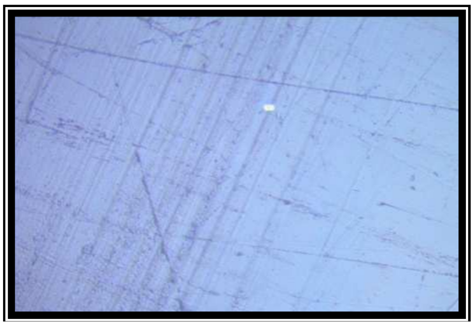
It is vital to indicate that there is previous studies about the modification of epoxy with thermoplastic material for increasing the toughness [14, 15], but the current work is interested in study the morphology and mechanical properties of (EP/PVC) blend.



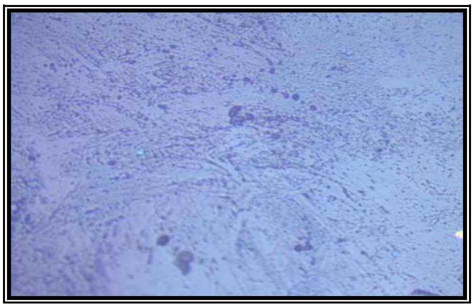
(a) 0% PVC



(b) 5% PVC



(c) 10% PVC



(d) 15% PVC

(e) 20% PVC

Fig. 1. Optical micrographs of the morphology for epoxy and its blends (150x).

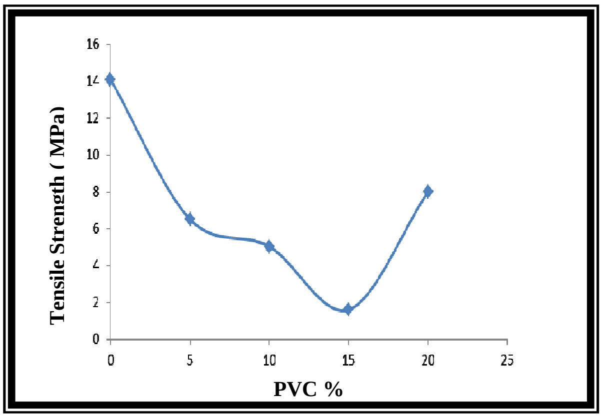


Fig. 2. Effect of weight percentages of (PVC) on the tensile strength values for (EP/PVC) polymer blend.

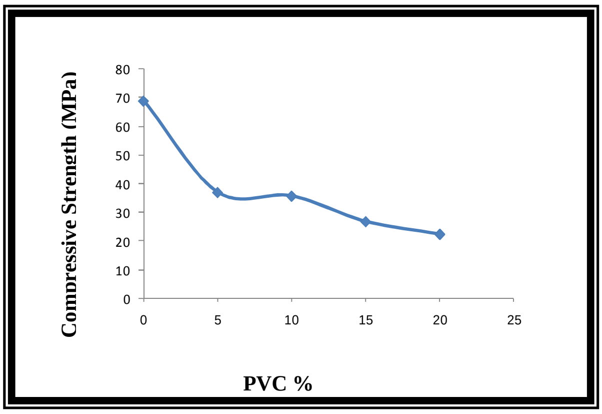


Fig. 3. Effect of weight percentages of (PVC) on the compressive strength values for (EP/PVC) polymer blend.

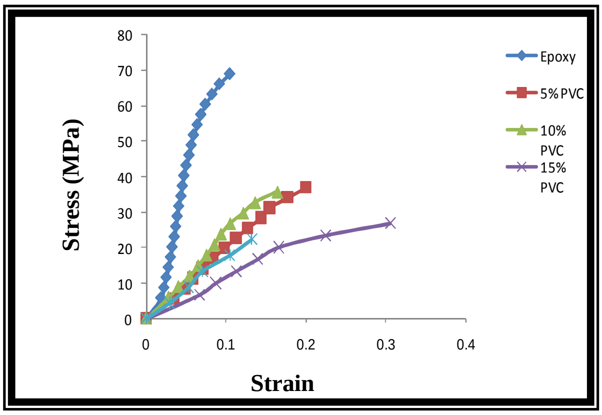


Fig. 4.Stress-strain curves for epoxy and its polymer blends under compression loading.

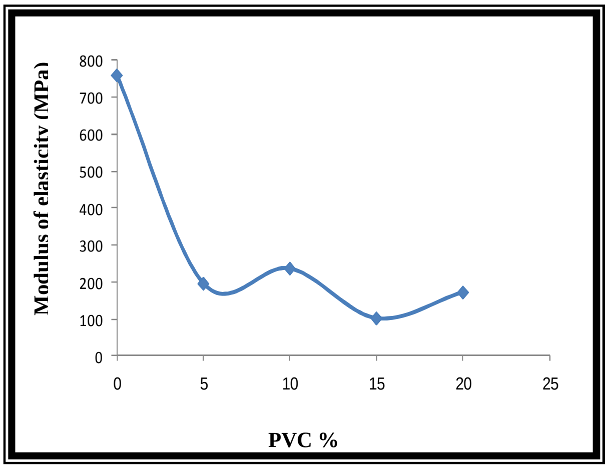


Fig. 5. Effect of weight percentages of (PVC) on the modulus of elasticity values for (EP/PVC) polymer blend.

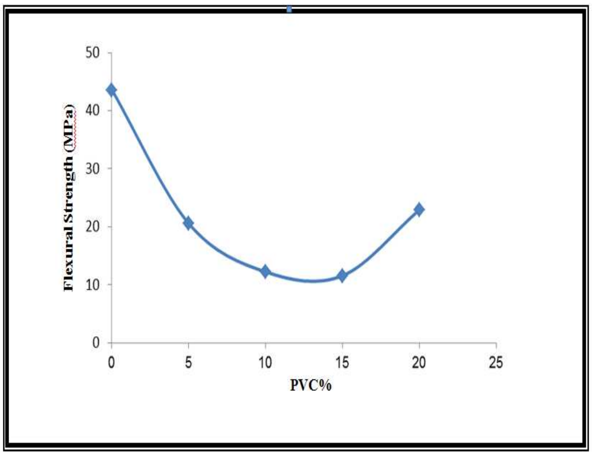


Fig. 6. Effect of weight percentages of (PVC) on the flexural strength values for (EP/PVC) polymer blend.

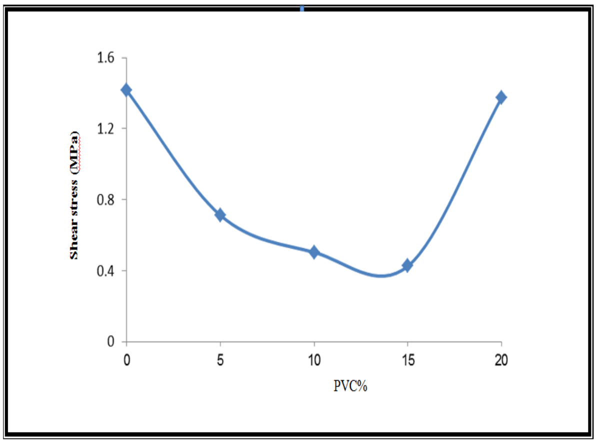


Fig. 7. Effect of weight percentages of (PVC) on the shear stress values for (EP/PVC) polymer blend.

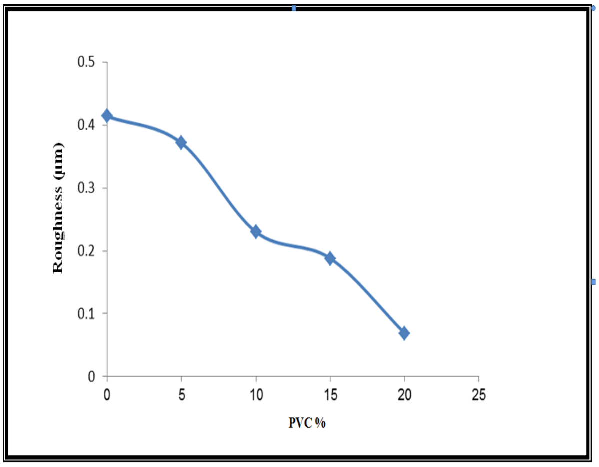


Fig. 8. Effect of weight percentages of (PVC) on the roughness values for (EP/PVC) polymer blend.

4. Conclusions

1- It can be concluded that PVC which is thermoplastic polymer acts a modulating material for the properties of epoxy resin.
2- The plastic strain increases obviously after blending epoxy with PVC at the ratio (15%).
3- It is found that the percentage (20%) of PVC gives the highest value of tensile strength compared with other percentages of mixing for (EP/PVC) blends. This conclusion is benefit indication for future works in this field.
4- We can reach to the results which show that epoxy sustains larger plastic deformations when it exposed for certain stresses, this obtains after mixing it with PVC.
5- Stress-strain behavior provides further evidence, showing that (PVC) indeed acts as a plasticizer factor for epoxy.

5. References

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المورفولوجيا والخواص الميكانيكية لخليط (الايبوكسي/ بولي كلوريد الفاينيل)

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الخلاصة

في هذا البحث تم دراسة المورفولوجيا والخواص الميكانيكية لخليط بوليمري ثنائي. وقد حضر خليط من (الايبوكسي/ بولي كلوريد الفاينيل) بواسطة الخلط اليدوي لراتنج الايبوكسي مع نسب وزنية مختلفة من البولي كلوريد الفاينيل بعد اذابته في مذيب السايكلوهكسانون. وحضرت في هذه الدراسة خمسة الواح بنسب وزنية شملت (٥،١٠،١٥،٢٠،٠) % من ال PVC عند درجة حرارة الغرفة. اجريت مجموعة من الاختبارات لدراسة الخواص الميكانيكية لتلك الخلائط وقورنت مع خواص الايبوكسي النقي . تم فحص المورفولوجيا للمواد المحضرة لغرض دراسة طبيعة التوافق بين البوليمرين قيد البحث. وقد وجد بان النسبة الافضل للاضافة هي (20%) من PVC علاوة على ان هذه النسبة المئوية تعطي القيمة الاعلى لمقاومة الشد مقارنة بنسب اخرى للخلط .
