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# Preparation and Studying of Some Mechanical Properties of Polymer Blend

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***Abstract:***
In the modern polymers' industry, polymer blends are widely used, due to their wide range of properties as compared to individual polymers, where it applied in the design of composite and biocompatible materials, adhesion and colloidal stability... etc. This work investigate possibility of improving mechanical properties of epoxy resin EP by blending with polycarbonate PC, with different weight fractions, (5, 10, 15, 20, 25) %, by mechanical mixing technique, the mechanical tests that depended in this work were; tensile test, bending and flexural strength test, and impact test. The results show development of mechanical behavior with increasing PC content in blend from brittle to ductile, where the experiments show increasing values of elongation, young modules, flexural strength, flexural modules, impact strength, and fracture toughness, while decreasing of ultimate tensile strength comparing with that of pure epoxy.
***Keywords:*** *polymer blend, mechanical properties, tensile test, bending and flexural strength.*

## I. INTRODUCTION

Epoxy resins are widely utilized due to their relatively high properties, like high modulus of elasticity, creep resistance , and sensible high temperatures performance [1].Today epoxy resins have extensively application in many fields like; composites materials which reinforced by fibers, glues, and paints industries [2] .Mohan [3]studied the property of epoxy is results the effects of their constituents, for example, adhesion property is result of existence of epoxy and hydroxyl groups, the chemical stability is result of quality of ether linkage and one next to the other, rigidity is result ofexistence of bisphenol. However, epoxy resins have main drawback of being brittleness, and easy to failure under effect of impact load as result of high cross-linking of structural polymer chains, pure resins have relatively low fracture toughness varying from (80 to 200) j/m2[4,3,1] . Severaltechniques have been proposed to improve epoxy resins toughnessinclude hard particulate materials such as inorganicglass particles, as well as elastomers or functionalization rubber for example, carboxyor amino-ended butadiene-acrylonitrile copolymers which are solvent in the uncured resin, addition to blending withother thermoplastics resins[3].

Polycarbonate PC is one of important engineering polymer, which has unique properties like; toughness, high stability at elevated temperatures, and transparent to light, make it widely used in may industry application like car-parts, lighting, electric application, glazing, packaging...Etc. However, PC has some downside, which limited possibility to apply it in may request like; high viscosity even at elevated temperatures which consider a problem when thin-wall products are requested by injection method, while too thick section of PC has lower toughness and display brittle fracture failure [5](van Vught5). This work investigates the effect of blending epoxy resin

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with PC with different percentage into toughness and some other mechanical properties.

## II. EXPERIMENTAL PART

Work procedure include preparation of blend samples of EPresin with different PC weight fractions, (5%, 10%, 15%, 20%,25%), addition to pure epoxy specimens, and implementing of tensile strength, bending , flexural strength and impacttests to evaluate mechanical properties.

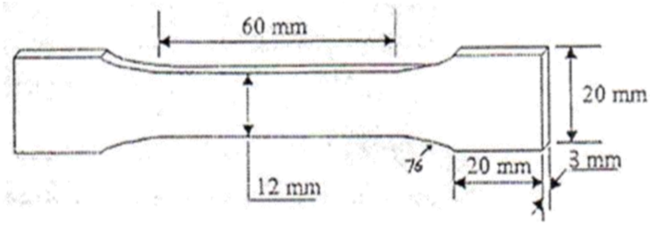
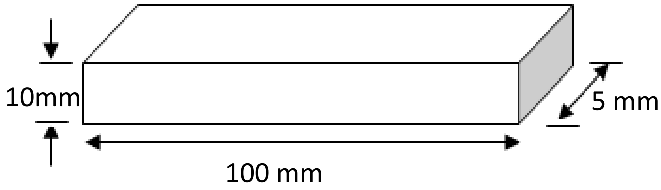
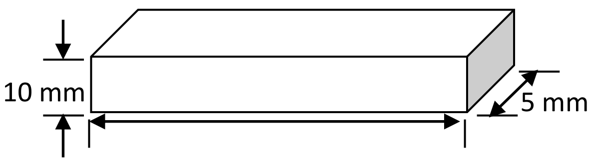
## III. MATERIALS

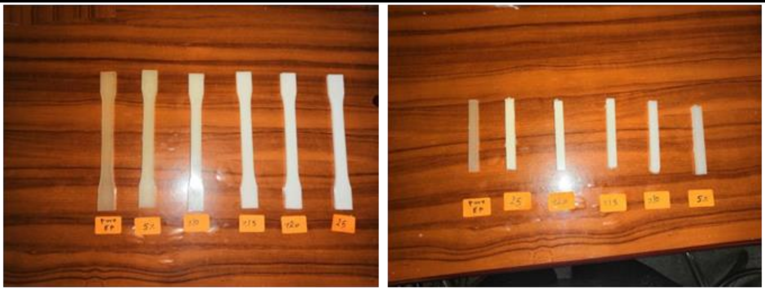
The materials, which used in work, are Epoxy resin, (produced by Quick mast 105made in Jordan), compose from two part (uncured epoxy and hardener), and polycarbonate , manufactured by teijin human chemistry–japan company,(model :PC/L-1250Y), with particle (size: 60 meshes).

## IV. SPECIMENS' PREPARATION

Blending EP resin with PC powderhad been performed after several experimental trials to dissolve PC powder and get homogenouse mixture, where the best results had obtained after (30) minute of mixing. The next step was adding EP hardener to mixture , (3 parts of epoxy: 1 part of hardener) in weight fraction.Then mixture was poured into flexible mold, have specimens' cavities with specific shapes and dimensions, (according to tensile, impact, and hardness specifications), after (24) hours, specimens were removed from mold and heat treated by ordinary oven at (50) C° for (2) hours. Table (1) shows schematic shapes and dimensions of specimens,figure (1) shows the prepared specimens.

Table 1: The standard specifications of the samples for the tests [6, 7].

| Specifications | Sample's dimensions | Test |
| --- | --- | --- |
| ASTM-D638 |  | Tensile |
| ASTM-D790 |  | Bending & flexural strength |
| ISO-179 |  | Impact |

(A) (B)

(C)

Figure. 1: Thespecimens of (A) Tensile test (B) bending test (C) impacttest

## V. TESTING PROCEDURE

Development of mechanical properties was judged by three kinds of tests, tensile tests, bending tests, and impact tests. Tensile and bending tests have been performed by computerized universal testing machine, type (LAREE), maximum capacity 50 tan, according to ASTM – D638, and ASTM–D 790 respectively, while impact tests wasexecuted according to ISO-179 by using impact instrument, type (Time group Inc.).

## VI. RESULTS AND DISCUSSION

Tensile tests

the stress - strain curve and the most important mechanical characteristics of epoxy/polycarbonate blends is shown in figure (2) and Table (2). it can be noticed gradually changing in mechanical performance of polymer blends from brittle without plastic deformation behavior of pure epoxy to less stiffness and more ductilty with increasing PC percentage in blend. The changing in mechanical behavior can be discussed by depending the altering in microstrcture and the dominant kind of bonding. Pure epoxy specimen has one phase strcture and its strength is mainly depended upon cross linked bonds between the chains, while blends have dual phases strcture of epoxy matrix and

dispersed toughned phase of PC, where final mechanical strength is strongly depending upon percentage of each phase, particles size and distribution of PC in epoxy matrix, addition to

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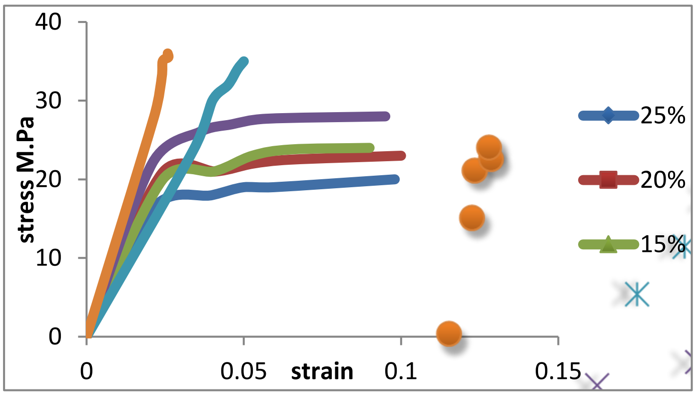
nature of bonding between the two phases [8]. However, The toughening mechanism can compare with that of rubber toughened epoxy, which reported in the literature [9]

Table 2: the most important mechanical properties of EP/PC blends

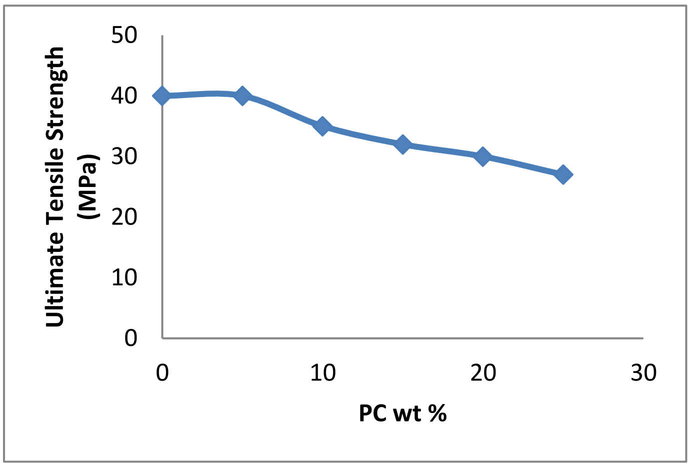
| PC % | Ultimate tensile stress | modules of elasticity | Elongation |
|---|---|---|---|
| 0 | 40 | 0.7827 | 1.501 |
| 5 | 40 | 0.89175 | 1.598 |
| 10 | 35 | 0.88304 | 1.654 |
| 15 | 32 | 0.875 | 1.7453 |
| 20 | 30 | 0.85 | 1.85 |
| 25 | 27 | 0.7782 | 1.925 |




Figures (2): Stress-straincurve for the polymers blend (EP/PC) as a function of PC (wt.%)

Tensile Strength

After yielding point , more stress should applied to maintain increasing in plastic deformation, the applied stress increase till reaching maximum value, beyond this point the required stress to sustaindeformation decrease as reduction in cross section area of specimene, this processing is continue till failure occure. Tensile strength is the highest stress value on stress-strain curve [10]. Figure (3) shows varying in tensile strength of EP/PC blends with changing PC wt. %. It can be noticed decreasing tensile strength with the increase of PC when PC wt.% content acceed 5%, This behavior may be related to change mechanical behavior from entirely strong and britlle, to ductile and tougth behavior, with increasing PC %, where plastic deformation can occure and the number of cross linked bond decrese [8].




Figures (3): Tensile Strengthof the polymers blend as a function of PC (wt.%)

Young Modulus

Young's modulus is a measure of the stiffness of a component[11], it represents materials resistance to elastic deformation [10]. Figures (4) shows the effect of PC percentages on the Young modulus values of the polymer blends,It can be observed that the blend with 5 wt.% of PC has maximum young modules, where higher strengthening may be achived by creation a new homogenous blend has better strength than parentsmiscible polymers. However, beyond 5% PC, young modules is decreasing with increasing of PC percentage on blend, the reasons of this behavior may be related to development of hetrogenouse blend's strcture of two phases [12], in this case blend modules of elasticity will depend upon modules of each phase and bonding nature between them. However, this results agree with someprevious studies [13].

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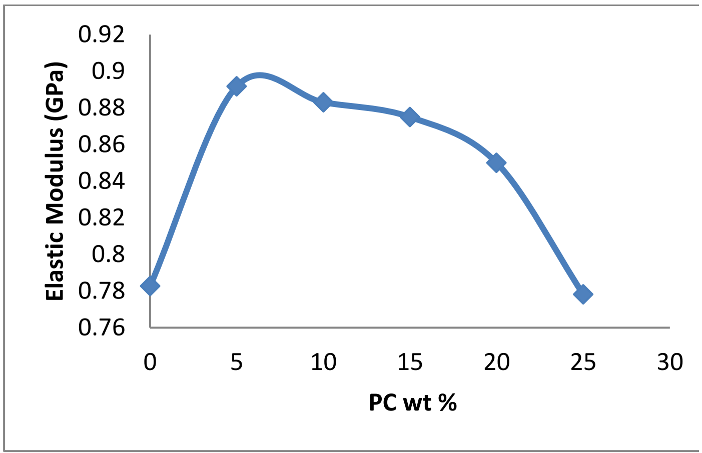
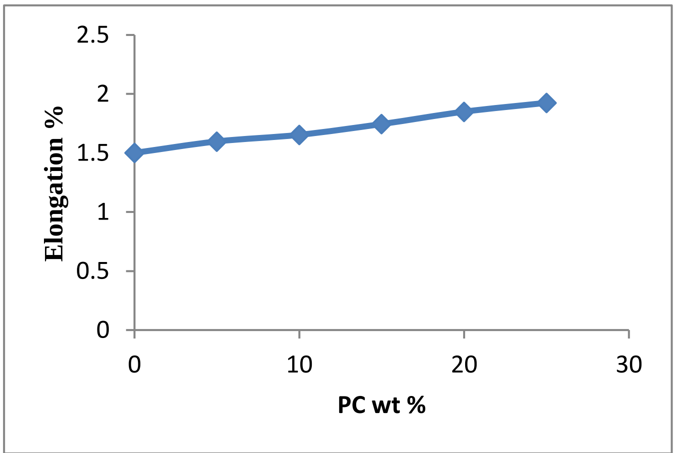



Figures (4): Elastic Modulus for the polymers blend (EP/PC) as a function of PC (wt.%)

Elongation Percentage at break

The elongation percentages at break of specimens are shown in figure (5). It can be observed slightly uniform increasing in elongation percentage with increasing the PC content in blend, this increasing relates to the changing in microstcture of blends which associated with altering in mechanical behavior as mention above.




Figures (5): Elongation percentage for the polymers blend (EP/PC) as a function of PC (wt.%)

Bending and flexural strength test.

Flexural strength is oneof the important parameters in evaluation of the mechanical strength and rigidity of the material[14]. There are many aspects deciding the flexural strength behavior like; stresses gradient within specimen, where compressive stresses at loaded surface decreases to reach zero at nutral axis then convert to tesile stresses at opposite surface, also the polymer base materials doesn't show perfact linear elasticity behavior, finally outer layers of specimen have specific form of stresses comparing with specimen's core, which acts vital role in this test [15].

lexural strength.

According to previouse facts, maximuim flexural strength is highly depending upon modules of elsticity, tensile strength and other mechanical characteristics of blend. The relationship between the flexural strength and weight fraction of the PC in blend is shown in table (3) and figure (6). it can be observed that flexural strength curve get maximum value at 5 wt % of PC, before declining with increaing PC wt %. This behavior can be discussed depending the factsthat the specimen, which have 5 wt% of PC, has maximuim tensile strength and young modules as displayed in figure (3) and figure (4), so that it has maximuim failure resistance under flexural stresses.

Table 3: The flexural strength according to weight fraction %PC

| Polycarbonate % | Flexural strength (MPa) |
|---|---|
| 0 | 42.08 |
| 5 | 56.25 |
| 10 | 52.5 |
| 15 | 41.666 |
| 20 | 35.415 |
| 25 | 21.65 |

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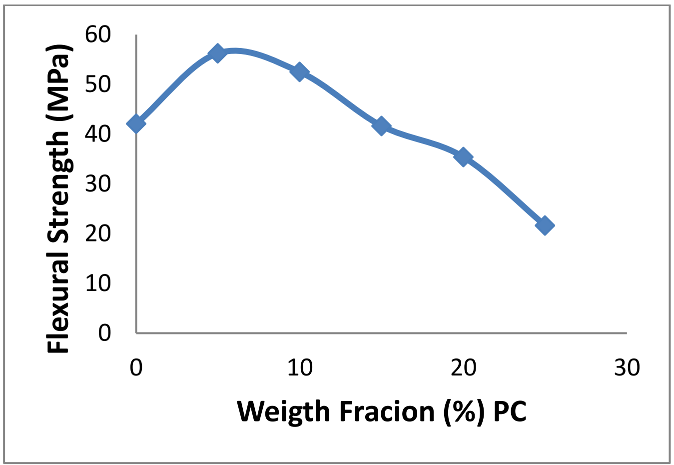


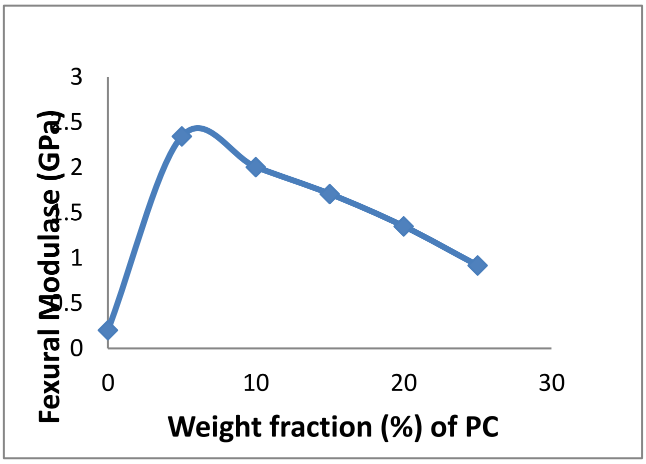

Figures (6): Flexural strength for the polymers blend (EP/PC) as a function of PC (wt.%)

Flexural modulus

Flexural modulus is used as a sign of a material's stiffness when bent [16].The relationship between the flexural modulus and weight fraction of the epoxy and PC blend is shown in table (4 ) and the figure (7), it can be noticedthat there is sharp increase in flexure modules at 5 wt. %, followed bydecreasingwith increasing PC %. High flexural modules of blend at this point is due to high stiffness, or high modules of elasticity, of blend with 5 wt. % of PC, as previously discussed, comparing with pure epoxy and other blends specimens. The reason behind this behavior is attributed to the fact which in the two-phase systems case, if the modulus of the dispersed phase is lower than the continuous phase,the modulus of the mixture will be lower than the continuous phase. Conversely, if the modulus of the dispersed phase is greater than the continuous phase[17]. This behavior had an agreement with this study[13].

Table (4): Theflexural modulus according to weight function of PC (wt.%)

| Polycarbonate % | Flexural modules |
|---|---|
| 0 | 0.1 |
| 5 | 2.4 |
| 10 | 2 |
| 15 | 1.65 |
| 20 | 1.4 |
| 25 | 0.9 |




Figures (7): flexural modulus for the polymers blend (EP/PC) as a function of PC (wt.%)

Impact strength

The impact test differs from other mechanical tests since it is very fast, where the specimen is exposed to the rapid stress. highImpact strength mean more absorbed energyrequired to perform fracture. Figure (8)and table (5)show in varying impact strength of blends with varying PC wt. %. It can be observed increasing of impact strength with increasing PC wt.%. Maximum impact strength was recorded at 20 wt. % PC. Basically impact strength is highly depending upon both tensile strength and ductility values, so improving in these properties could greatly improve impact strength. So development of blend characteristics tword mor ductility and strength with increasing PC wt.% could explain the improvement of impact strength with increasing PC wt.%. In other words, PCbehavesas a modifier of epoxy properties[8].

Table 5: Impact strength according to weight function of PC (wt.%)

| polycarbonate % | Impact strength |
|---|---|
| 0 | 1.8 |

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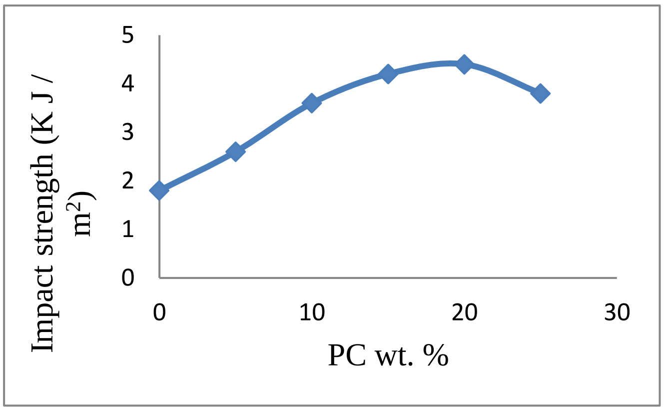
| | |
|---|---|
| 5 | 2.6 |
| 10 | 3.6 |
| 15 | 4.2 |
| 20 | 4.4 |
| 25 | 3.8 |




Figures 8: Impact strength for the polymers blend (EP/PC) as a function of PC (wt.%)

Fracture toughness

The Fracture toughness value depends on the impact strength and flexural modulus of samples[18]. Figure(9) and table (6) show the varying of fracture toughness of blend with PC wt. %. Generally, the fracture toughness increase with increasing the PC wt.% and reach to a maximum value at 10wt. % PC, then fracture toughness values slightly decrease with increase of PC content. The increase of toughness is due to the incorporation of ductile PC chains into the epoxy networkthrough the melt-blending therefore, the capability of the plastic deformation was increased[19]. The decrease in fracture toughnessrelatedto decline in flexural modules at high PC content as shown in figure (7)

Table 6: TheFracture toughness according to weight function of PC (wt.%)

| PC% | KC (Mpa.M1/2) |
|---|---|
| 0 | 19.23 |
| 5 | 78.1 |
| 10 | 85.58 |
| 15 | 85.43 |
| 20 | 76.74 |
| 25 | 70.98 |

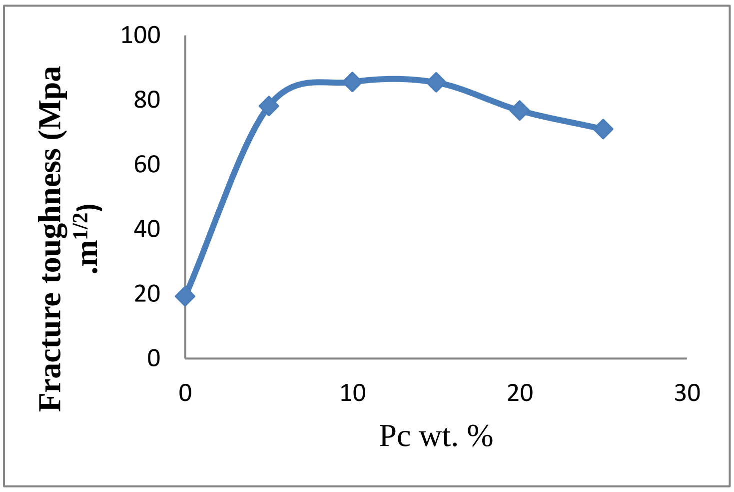



Figure 9: Fracture toughness for the polymers blend (EP/PC) as a function of PC (wt.%)

## CONCLUSIONS

1. Epoxy resin / polycarbonate can be blended successfully by using mixing technique at room temperature.

2. High brittleness behavior of epoxy resin can be remarkably modified by blending with polycarbonate.

3. Blending of epoxy with polycarbonate can improve elastic modules, elongation, flexural strength, flexural modules, flexural modules, impact strength and fracture toughness of epoxy resin.

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