Study of tensile strength and compression strength of binary polymeric blends (High Density poly ethylene /polycarbonate).

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Abstract:

In this work, HDPE/PC binary polymeric blends has been made by using the single screw extruder machine .
The tensile strength measurements showed that this blend have higher results reflects the homogeneity of the mixture and higher strength compared with that of single material the strength like HDPE or PC alone and these values increase when blending with ratio (80/20) of (HDPE/PC); and increase more when reinforcing with E-glass fibers (1%). Also in the compressive strength increases for blends of (80/20%) (HDPE/PC) furthermore, a composite of these blends with E-glass fiber these values are increased more .

Key words : tensile test, compression test ,polymer blends , high density poly ethylene ,poly carbonate

الخلاصة

في هذا البحث تم تصنيع الخلائط البوليمرية الثنائية (البـولي اثلـين عـالي الكثافـة /البـولي كاربونات) بطريقة ماكنة البثق الأحادية اللواب .
حيث أظهرت قياسات مقاومة الشد نتائج عالية تعكس أمتزاجية الخاط ومقاومة عاليـة لمقارنـة بالمواد الأساسية بصورتها المنفردة مثل مادة البولي أثلين عـالي الكثافـة والبـولي كاربونـات لوحدهما .وان هذه القيم تزداد عند الخلط بنسبة (80/20%)من البولي أثلين عالي الكثافة /البولي كاربونات كما تزداد هذه القيم أكثر عند التدعيم بألياف الزجاج من نوع E وبنسبة (1%),كما أن قيم مقاومة الانضغاط تزداد عند الخلط بنسبة (80/20%)من البولي أثلين عالي الكثافة /البـولي كاربونات وتزداد هذه القيم أكثر عند التدعيم بألياف الزجاج.

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1- Theoretical approach:

The conventional stress – strain test is used frequently to describe the (short - term) mechanical properties of plastics. In many aspects, the stress- strain graph for plastics is similar to that for a metal. At low strain values, there is an elastic region, where, as at high strain values there is a non – linear relationship between stress and strain and there is a permanent element to the strain [1].

Compression stress –strain in service conditions are of this type. A compression test is conducted in a manner similar to tensile test except that the force is compressive and the specimen contracts along the direction of the stress.

Compressive tests are used when a material behavior under large and permanent strains is to be studied as industrial application or when the brittle material is in tension. [2]

Polymer blends are widely used for both structural and non-structural applications including aerospace, automotive, electrical and electronic, building, and domestic industries. Advantages are their low processing cost, low density, insulation properties, and chemical resistance to aggressive media, large polymeric articles that can not be molded require joining. There are a variety of methods available for joining of polymers, e. g. Mechanical fasteners, adhesives, and welding [3].

The scientific and commercial progress in the polymer blends during the past two decades has been tremendous and is driven by realization that new molecules are not always required to meet needs for new materials .Also ,the blending can be typically implemented more rapidly and economically than the development of new chemistry. However, successful blend technology requires a rigid scientific basis. [4]

Polyethylene represents a series of polymers each required for a different set of the end uses. However, two principal categories of polyethylene have been recognized; low density polyethylene and high density polyethylene.

The density of HDPE varies from (0.95-0.97 g/cm^3). Pure ethylene can be obtained by cracking petroleum gas, where it can be separated from other hydrocarbons.

Poly carbonates are polyesters

$$H\left(-ORO\overset{\overset{\displaystyle O}{\|}}{C}- \right)_n OROH$$

derived from the reaction of carbonic acid or its derivatives with dihydroxy compounds (aliphatic, aromatic or mixed type compounds).[1]

Polycarbonates are almost unaffected by water and many inorganic and organic solvents. These properties allow these polymersto meet many applications, especially in view of their attractive mechanical properties. The stability of polycarbonates is good below (250^{o}C) and this property has been reviewed first persone prepared polycarbonates by the Scotten – Baumann reaction of phosgene with either hydroquinone or resorcinol in pyridine

in (1997) Tsonga S. and Xu S. [6] who prepared blends consisting of ductile polycarbonate (PC) and brittle poly (methyl methacrylate) (PMMA) polymers in a twin screw extruder followed by injunction molding. The mechanical properties of the blends were studied by tensile varying and impact testing. The tensile test showed that the elongation and fracture energy at break. and the elastic modulus of (PC) rich blends deviate positively from the line predicate by the rule of mixtures. This implies that (PC) can be toughened by the incorporation of brittle PMMA particles in the matrix without sacrificing stiffness. However, the PC-PMMA blends showed a negative result for impact test. This was caused by the formation of large dispersed particles..

At (2006), Kummel W.[7], prepared polymer blend of polypropylene (PP) and polycarbonate (PC) with carbon black (1%). Mixing of PP, PC and carbon black was carried out then the mixture was further mixed using mixing machine and single – screw extruder operated at a temperature ranging from (120-200) °C. In order to determine the performance of polymer blend prepared in this work several mechanical and physical tests were carried out before and after exposing the sample to weathering test.The results obtained indicat that most mechanical properties such as (tensile strength, impact, hardness, and elasticity) except percentage of elongation at break increase after reinforcement with (1%) of carbon black.

2- <u>Experimental technique:</u>

Poly carbonate polymer (Makrolon 2800, Bayer AG, Lever kusen provided by general company of chemical industries) Poly carbonate polymer, it is characterized as [transparent, thermal resistance up to 130^{o}C. Elastic stability up to 150C^{o} without any stabilizer to elasticity. Less absorption to water, acids, oil and cock (allophonic cock), but it absorbed the moisture of air, the heat could not effect on it has good electrical properties even if the temperature arrived to 150C^{o}.

Stability of PC polymerized dimension makes it an excellent material mould of goods required thermal resistance. It have higher impact strength, creep cracks resistance, ease of mixing with colors, and safe when yoached with foods (any type of foods& liquids), it firing is slow and degrad slowly giving up co_2 and water [6].

High density polyethylenes (Exxon Mobil HDPE HMA 035 provided by general company of chemical industries) have good mechanical and, chemical properties, good electrical properties, and chemical resistance for alkaline and acidic solvents, transparency, many applicable forming methods. But these properties are affected by:

1. Addition of other materials.
2. The polymerization methods, and this willresults in:
   - a- Crosslinking degree (Crystallization and density).
   - b-
   - c- Middle Molecular weight.
   - d- Distribution of molecular weight.

   It has good tensile strength, good thermal and chemical resistance and

(2-1) <u>Extrusion Method</u>

Extrusion moulding is employed to produce continuous shaped like sheets, tubes and rods, channels and films. The extrusion process makes use of a screw that advances the polymer from the point of entry through melting zone and then forces it out through an orifice that defines the shape of the moulded product. The screw of an extruder is divided in to several sections, each with a specific purpose. The extrusion screw provides heat of friction in the material and supplies the force to mould the desired shape in the die with sufficient pressure to obtain the required product density. The feed section pick up the finally powdered polymer from the hopper and forces it in to the main part of the extruder. Then the loosely packed feed is compacted, melted and formed in to a continuous steam of molten plastics. Additional external heat may also be supplied; sufficient pressure is built up in the polymer melt to force the plastic through of the extruder and out of the die. [2]

3-<u>Resultsand iscussion</u>:

(3-1)<u>Tensile Test Results:</u>

Tensile test has been measured for all type of blends, with composites, Fig.(1) shows the (stress- strain) curves of pure polymers (100% HDPE, 100% PC) as (P_1, P_2) respectively, it is generally known that the (PC) is a hard polymer, and the fracture mode of this type of thermo plastic polymers brittle mode, and that shows how this material will behave under load extension test. The bonding of polycarbonate makes it higher strength than polypropylene and high density polyethylene. But (high density polyethylene) (HDPE) shows plastic behavior, so it has low tensile strength and higher elongation. Table (1) shows the tensile propertiesof single polymers.

Fig. (2) shows stress – strain curve of blends which consists of (HDPE/ PC) different with ratios from (90%-10%) HDPE & from (10%- 50%) PC. In these blend it is observed that the value of tensile strength decreases from B_{21}- B_{25} because of the variation in mixing ratio to prepare HDPE and PC blend, and as we noted in Fig.(1) these values are different form singlepolymer compared with other blends and according to rule of mixture these values decrease, because of the nature of both polymer which is used in these blends, and these curves show the brittleness of PC as its ratio of mixing increases with percentage of HDPE and, has low strain, low tensile strength, and shows the fracture stress without yielding so that leads to change in mode of fracture from ductile to brittle mode. The tensile properties are shown in Table (1). This means that the increase in mixing ratio will change the nature of material from ductile with flexible behavior to brittle behavior. Table (2) show the polymers blends tensile properties

Fig.(3) shows composite behaviors The same blends, with optimum mixing ratio (OMR), have been reinforced with E- glass fibers. It is known that a composite is a mixture of two (or more) materials which can blend in a way to enable users to make better use of its virtue or in other words, making it an important class of engineering materials [8]. It is generally accepted that the adhesion between the fiber and the matrix has an appreciable effect on the mechanical properties of fiber - reinforced polymer composite. Thus, the interfacial adhesion plays an important role in improving these properties, particularly, the tensile strength of the composite because it is affected by efficiency of load transfer from the matrix to fiber via shearing the interface [9].This reflect the importance of measuring the tensile strength of the blends under the investigation. Table (3) shows the composite tensile properties

(3-2) Compressive Strength Test Results:

Brittle materials such as PC are recognized by the fact that their compressive strength value is more than their tensile strength value. When a brittle material is subjected to a tensile load, its internal deformation would increase in the same direction of the tensile load, while during compression, the defects or voids are going to be restrained. Fig.(4) shows the compressive test results of plain polymer where HDPE has lower compressive strength, because (HDPE) is ductile polymer, and this polymer have ability to expand in tension and make higher elastic strain than PC, so the effect of compression on the HDPE is noted as ductile polymer will fail at lower compressive strength value. Table (4) shows the compression strength of single polymers.

Fig. (5) Shows compression (stress-strain) curves of (HDPE/ PC) blend. it shows that the behavior of samples which have higher ratios of (PC)leads to increase compressive strength and the elastic strain is higher because of presence of HDPE in this blend such that the best ratio in this blend gives a good compressive strength with ratio of (80% HDPE/ 20% PC). Composite compressive strength is more dependent on the matrix properties and the test method. The matrix properties usually control the failure mode [10].The applied load could be longitudinal or transverse (parallel or perpendicular to the fibers mat direction); In the case of longitudinal loading, there is a tendency for the fibers to buckle. If buckling becomes extensive, then it will cause general collapse [11].

Fig.(6): shows that E- glass strengthens the Polymer Blends. The reason of this strength is due to that E- glass fibers act to distribute load over more volume of the sample under test. Figure (6) is compared with Fig. (3); it can be noted that tensile strength is more than compressive strength because of buckling failure would happen during compression and not during tension. Table (5) shows the polymer blends and its composites compression strength.

4- Conclusions

The following conclusions can be drawn:

1. The binary polymeric blends, in this study, exhibits better tensile strength
2. The testing blends exhibits lower ultimate compression strength than the material alone specially (HDPE)
3. The reinforcing with E-glass make the blends exhibits higher strength of tensile and compression .
4. Polycarbonate polymer must be add with low percent with other polymer .
5. The extrusion of these materials must be done with higher temperature.

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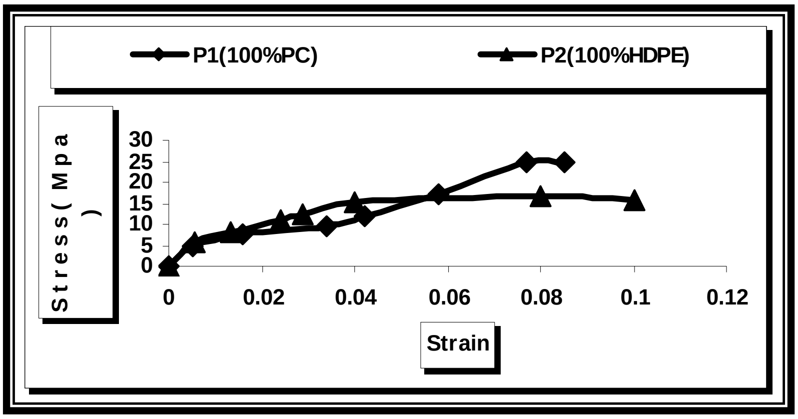

Fig.(1) Tensile (stress-strain) curves of single polymers

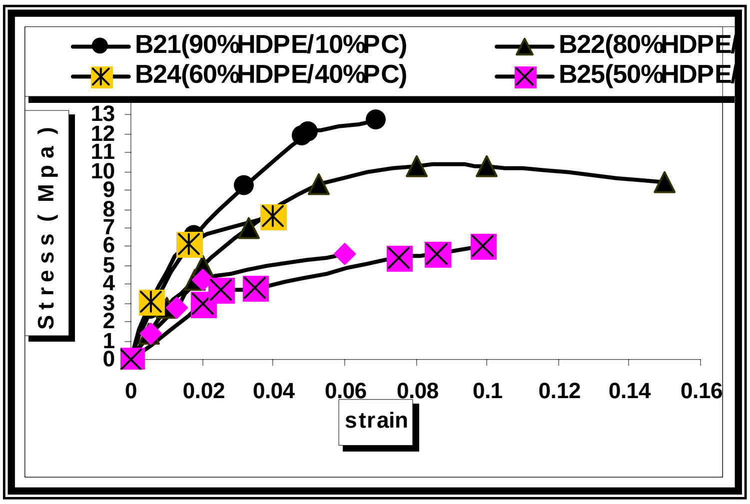

Fig.(2)Tensile (stress-strain) curves of polymer blends.

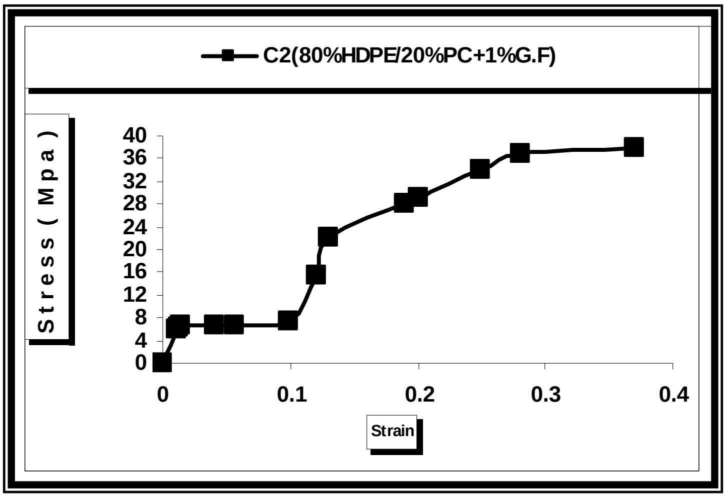

Fig.(3) Tensile (stress-strain) curves of polymers composite .

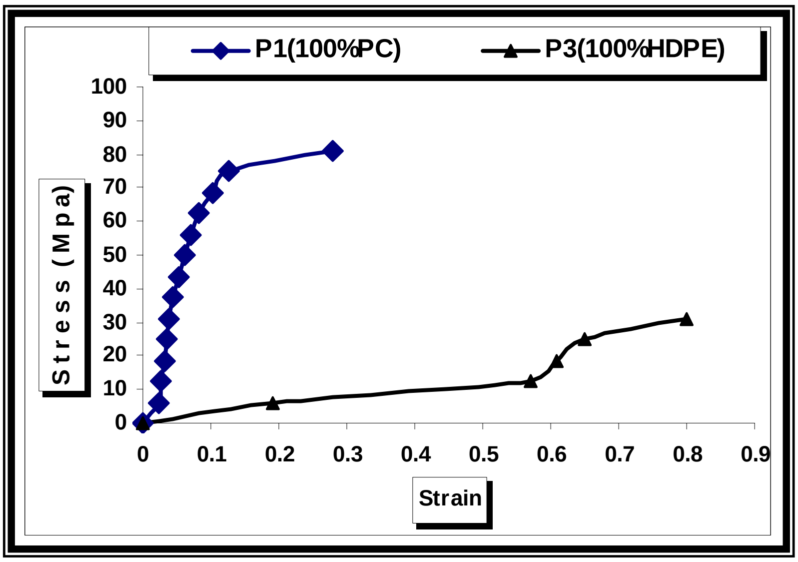

Fig.(4) compression (stress-strain) curve of single polymers

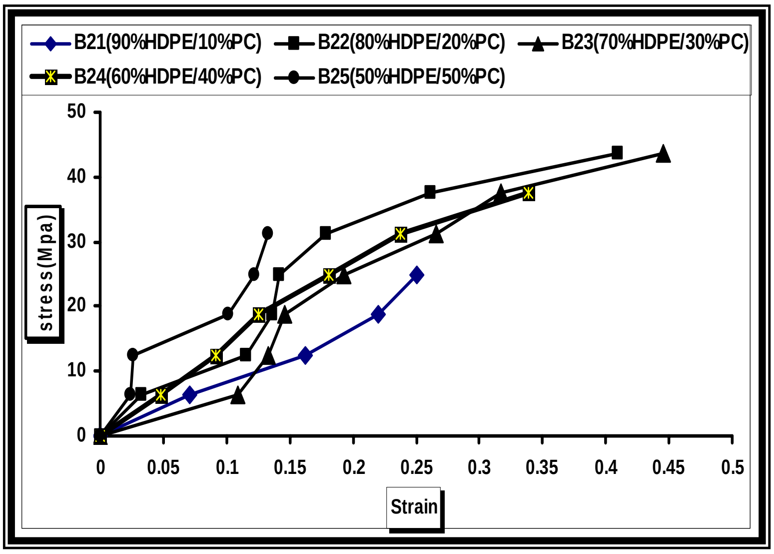

Fig.(5) compression (stress-strain) curve of polymer blends.

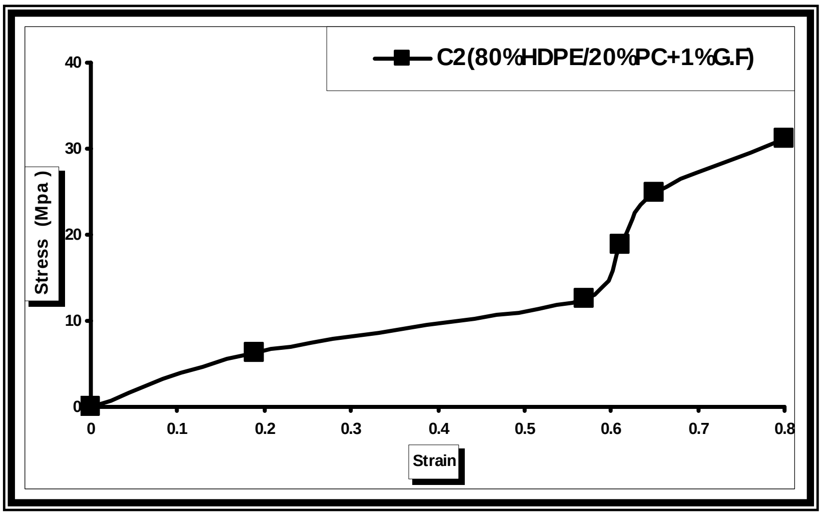

Fig.(6) compression (stress-strain) curve of polymers composite.

Table (1) tensile properties of Single polymers

Pure Polymer	Ultimate Tensile Strength (MPa)	Proof Stress (MPa)	Fracture Stress (MPa)	Ultimate Shear Stress (MPa)	Yield Shear Stress (MPa)	Elongation (%)	Young's Modulus (MPa)	Toughness Modulus (MPa)	Resilience Modulus (MPa)
PC	**25**	**5**	**24.9**	**20**	**2.9**	**5.2**	**233**	**1.275**	**0.010**
HDPE	**16**	**6**	**14.2**	**12.8**	**3.98**	**17.7**	**235**	**1.122**	**0.012**

Table (2) tensile properties of the polymer blends

Blends content	Ultimate Tensile Strength (MPa)	Proof Stress (MPa)	Fracture Stress (MPa)	Ultimate Shear Stress (MPa)	Yield Shear Stress (MPa)	Elongation %	Young's Modulus (MPa)	Toughness Modulus (MPa)	Resilience Modulus (MPa)
10%PC/90%HDPE	12.76	4	12.76	10.208	2.32	4.49	239	0.57	0.0083
20%PC/80%HDPE	10.6	4	8.4	8.48	2.32	14.83	232.71	0.73	0.0086
30%PC/70%HDPE	5.58	1.5	5.58	4.464	0.87	3.59	211.07	0.084	0.0035
40%PC/60%HDPE	7.64	3	7.64	6.112	1.74	2.36	238	0.099	0.0063
50%PC/50%HDPE	5.8	3.5	5.8	4.64	2.03	6.30	210	0.460	0.0083

Table (3) tensile properties of the polymer composite

composite	Ultimate Tensile Strength (MPa)	Proof Stress (MPa)	Fracture Stress (MPa)	Ultimate Shear Stress (MPa)	Yield Shear Stress (MPa)	Elongation %	Young's Modulus (MPa)	Toughness Modulus (MPa)	Resilience Modulus (MPa)
C2	40	23	35	32	13.34	1.1	449.8	8.15	0.588

C= HDPE/PC) (80/20) %

Table (4) compression strength of single polymer

specimen	Ultimate compressive strength (UCS) (Mpa)
PC HDPE	90 40

Table (5) compression strength of the polymer blends and it's composite

specimen	Ultimate compressive strength (UCS) (Mpa)	
	Blends	Blend + E glass fiber
HDPE/ PC (80/ 20)%	43.75	31.02
