The Effect of PVP Addition on the Mechanical Properties of [84%LLDPE: 15 %((100-X) %PP: X%PVP): 1%Basalt Particle] Polymer Blend Composites

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ABSTRACT

Polymer blends composites were prepared according to the formula [84%LLDPE:15%((100-X)%PP:X%PVP):1%B.P] with weight ratios selected for X values (0,4,8,12,16 %), as strips by double screw extruder and use press process the strips to prepare the samples according ASTM specification, the mechanical properties were studied for all theprepared samples which are (tensile, flexural, compression, impact, hardness, and creep tests). The results are as following:- results showed increment of mechanical properties as PVP ratio increases except elongation, furthermore the results recorded highest values of fracture strength, young modulus, compressive strength, flexural strength, maximum shear stress, flexural modulus and creep modulus at PVP 8% wt. which are (31.32MPa, 0.14GPa, 27.4MPa,24MPa, 0.6MPa, 1.08GPa and 0.558GPa) respectively.

While the highest values of fracture toughness and hardness recorded at 12% wt. (1.4696Pa√m), and at 4% wt. (56.5) respectively.

Keywords: Polymer Blend composite, Basalt, Tensile test, Hardness.

دراسة تأثير أضافة (PVP) على الخواص الميكانيكيه للخليط البوليمري المتراكب: [84%LLDPE:15%((100-X)%PP:X%PVP):1%basalt particle]

الخلاصه

حضرت المتراكبات ذات أساس الخليط البوليمري الثلاثي, وفق الصيغة [84%LLDPE:15%((100-X)%PP:X%PVP):1%B.P] وبنسب وزنية مختارة لقيم x 16,12 (0, 4, 8, %). وقد تم تحضيرها بشكل شرائط حضرت بعملية البثق بواسطة باثقة ثنائية اللولب واستخدمت عملية كبس الاشرطة لتحضير العينات وفق المواصفة القياسية (ASTM) , درست الفحوصات الميكانيكية للعينات المحضرة والمتمثلة (فحص الشد والانحناء والانضغاط والصدمة والصلادة والزحف) أظهرت النتائج زيادة في الخصائص الميكانيكية مع زيادة نسبة PVP باستثناء المطيلية وعلاوة على ذلك سجلت النتائج أعلى قيم لمقاومة الشد, معامل الرونة, مقاومة الانضغاط ومقاوة

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الانحناء واعلى أجهاد قص ومعامل مرونة الانحناء ومعامل الزحف عند نسبة PVP (8% wt) وهي على الترتيب (31.32MPa , 0.14GPa , 27.4MPa , 0.6MPa , 1.08Gpa , 0.558GPa) في حين سجلت أعلى قيم لمتانة الصدمة وقيم الصلادة عند نسبة PVP (12% wt.) (1.696 Pa√m) و 4%wt (56.5) على الترتيب .

INTRODUCTION

Recently, non-structural and structural components made of recycled plastics, both with and without reinforcement have appeared in the market. The increasing use of thermoplastics in many applications can be attributed to their cost of effectiveness, corrosion resistance, ease of fabrication and excellent impact and abrasion resistance [1]. Some of the recyclable thermoplastics used in large volumes by consumer, electronic, and automotive industries as: (a) High density polyethylene (HDPE) used in piping, automotive fuel tanks, bottles and toys. (b) Low density polyethylene (LDPE) used in plastic bags, cling films and flexible containers. (c) Polypropylene (PP) used in food containers, battery cases, bottle crates, carpets and automotive parts [2 and 3].

Polymer blending is one of the most common techniques employed for developing new polymeric materials, which two or more polymers are blended together to create a new material with different physical properties. They combine in an advantageous manner the properties of the alloying components and in some cases the properties of the blend are superior to those of the individual components. The properties of polymer blends strongly depend on their morphology which is determined by the size distribution and shape of distributed particles [4-7].

The development of polymer composites from blend polymer materials has been increased considerable during the last few years.Inorganic fillers are incorporated mainly to improve service properties depending on the source of fillers, type of filler, method of preparation and treatments [8-10]. One of the problems associated with blends and alloys is how to make the components adhere together.

One approach is to introduce a compatibilizer which creates interpenetrating polymer networks by providing a physical link between semi compatible materials. Most compatibilizers are block copolymers and they produce an interwoven matrix of physically inseparable, but chemically distinct polymers [11 and 12].

The objective of this study was to investigate the effect of polyvinylpyrrolidone (PVP) ratio on the degree of compatibility (to ensure proper adhesion at polymer blend) and the mechanical properties of polymer blends reinforced by 1% of basalt particle.

EXPERIENTIAL PART

Materials

In this research three types of polymer materials used, two of them were provided from National Company for Plastic and Chemical Industries, Zaffrania-Baghdad. These polymer materials are linear low density polyethylene (LLDPE) was produced from (Dow Company); the trade name of the LLDPE used is "Dowlex 2042/2045". Isotacticpolypropylene (PP):which was supplied from Sabic Company, Saudi Arabia, and has a trade name of *"520LPP*". "520LPP" have melt flow rate [10(g/10min)] and E-modulus [1600(N/mm²)].

Polyvinylopyrrplidone (PVP) type (k-30) produced from "Sinopharm chemical reagent company", in the china and has trade name "Luviskol or Kollidon" its polymer structures $[C_6H_9No]_n$.

Basalt particles (B.P) were used as a filler material for the polymer blend composite: Basalt particles were produced from basalt stones which were obtained from "That Al-SawaryState Company for Chemical Industries", basalt stones have different colors from gray to black.

Sample Preparation

Basalt stones were washed thoroughly with detergent powder and then with hot distilled water in order to remove dust and mud, after that these stones were dried in a hot air oven at 60 ^{0}C for 3 hours,and then crushed by cracking machine to small grains then the basalt grains were ground by porcelain mill for several times, each time was done for three hours, until grainsbecome fine particles, then the grinded particles garbled by sieving process to get very fine particles, particles size distribution of basalt particles was carried out using laser diffraction particle size analyzer type (SHIMADZU SALD—2101) in the Ministry of science and Technology. The result of particle size distribution is shown in Figure (1). The mean diameter was (4.848 μm)and the median value was (5.872μm).

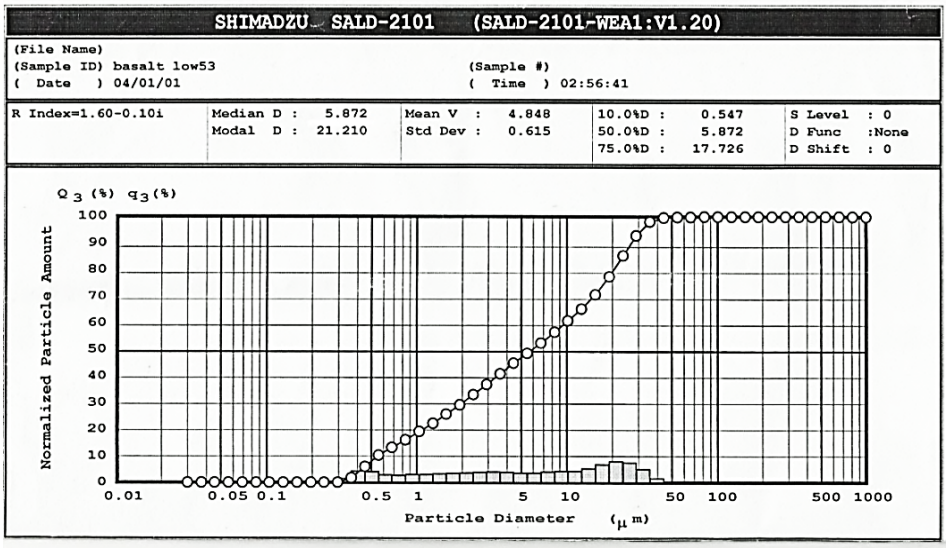

Figure (1) shows particle size analysis of basalt.

Pellets of polymer materials and particle of reinforced material were weighed according to select ratios to prepare the batches for extrusion. For optimum distribution the polymer and reinforced materials weighted, were mixed together in dry condition at room temperature for 20 minutes by mill made of porcelain material.Polymer blends composites were prepared according to the formula [84%LLDPE:15%((100-X)%PP:X%PVP):1%B.P] with weight ratio selected of X values (0, 4, 8, 12, 16%), were melted in double screw extruder machine with a screw L/D of 30:1, the extrusion temperatures for three zone (feed zone, compression zone and melting zone) 170c°, 170c°, and 160c° respectively with the screw speed 50 r.p.m.

At the end of the extruder, the melt passes through a die to produce an extrudate as a strip with 1.5mm thickness.

Then the sample prepared by compression moulding technique including strips of previous extrude polymer blend (3-4 strips) are placed in mold made of steel (115 × 50 ×5 mm^3) to have a suitable thickness for inspections which is previously heated at 150°c for one hour, compression technique carried out at pressure 350kg/cm^2 for 10 minutes.

Mechanical test

Samples were cut according to ASTM D638 [13],the machine used for the testing of tensile properties is micro computer controlled electronic universal testing machine (model WDW 200 E) made in china. The test was conducted at velocity of (1 mm/min) at ambient temperature, tensile stress was applied till the failure of the sample and stress-strain curve was obtained. Each sample was tested 3 times and average results have been reported.

Bending behavior of the prepared sample was tested using a three point test instrument, (model WDW 200 E) this test is performed according to ASTM D-790-78 [13 and 14], at room temperature with velocity (5mm/min) until the failure of the specimen occurs. Each sample was tested 3 times and average result have been reported, the value of fracture load (F) is read from the gage. The flexural strength (σ_{bend}.) and maximum shear stress (τ) and flexural modulus are valued from the relationships (1-3) respectively.

Flexural strength for three - point bend test= $\sigma_{bend} = \frac{3FL}{2wh^2}$ ..... (1)

where F is the fracture load, L is the distance between the two outer points, W is the width of the specimen, and h is the thickness of the specimen.

Maximum shear stress $\tau = \frac{3F}{4wh}$ ..... (2)

Flexural modulus = $E_f = \frac{FL^3}{4\delta wh^3} = \frac{mL^3}{4wh^3}$ ..... (3)

where δ is the deflection of the beam when a force F is applied, m is the slope of the load (F) /deflection curve.

Compressive test is performed at room temperature a according to Din 695 [13] with dimensions (8x4x4) mm^3. A computerized universal testing machine made in china and its model (WDW 200E), compression stress was applied till the failure of sample. Each sample was tested 3 times and average results have been reported.

Impact test is performed at room temperature according to ASTM ISO 179 [14]. Izod charpy impact (measurement test machines Inc, Amityville-New York).

Hardness test carried out on a murometer shore D scale a according to (DIN-53505) [13].

A creep test is performed under a constant applied load (1500gm) at room temperature according toBS 1178 [14].Creep modulus has been calculated by applying the formula (4). Each sample was tested two times and average results have been reported.

$E = \sigma / \epsilon(t)$ ·····(4)

where:-

σ: Is the initial applied stress.

∈: creep strain after a particular time and constant.

RESULTS AND DISCUSSIONS

Tensile inspection was carried out mainly to investigate the effect of addition PVP on behavior of stress-strain curve for polymer blends composites.

Figure (2)shows the stress-strain curves of the composite [84%LLDPE:15%((100-X)%PP:X%PVP)%:1%B.P] with different ratios of PVP where X having the values (0, 4, 8, 12, 16%), as shown from these curves all the prepared samples show plastic behavior with tensile load, and the behavior changes from weak and soft for [84%LLDPE:15%PP:1%B.P] composite to strong and tough with addition of PVP in 8%wt ratio.

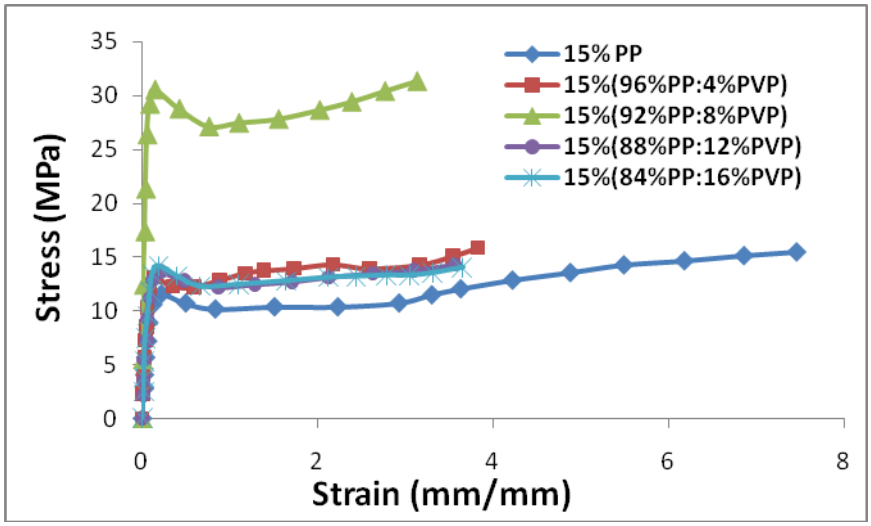

Figure (2) The stress-strain curve of [84%LLDPE:15%((100-X)%PP:X%PVP):1%B.P] as a function of PVP content in the composites.

Figures (3) and (4) illustrate the effect of PVP on the fracture strength and young modulus values respectively of the prepared composites, these figures indicate that the addition of PVP to the basic polymer blend composites (without PVP) increase the fracture strength and young modulus values of these composites, and the rate increases with increased PVP ratio in the blend and reaches maximum values at PVP 8% wt. where (31.32 MPa) and (0.14 GPa) respectively, then an increase in PVP content larger than 8% ratio produces sharp decrease in these values to less than the values of the basic composite (without PVP), and that is related to the characteristics of PVP which may act as agent to improve the compatibility between constituents of polymer blend composite specially at slight ratio of PVP content, as well as PVP may promote optimum dispersion of particle phase in the composites[13 and 15].

However, amounts of PVP larger than 8% ratio may produce accumulation in the dispersed phases and this makes passive behavior in mechanical properties of prepared composites.

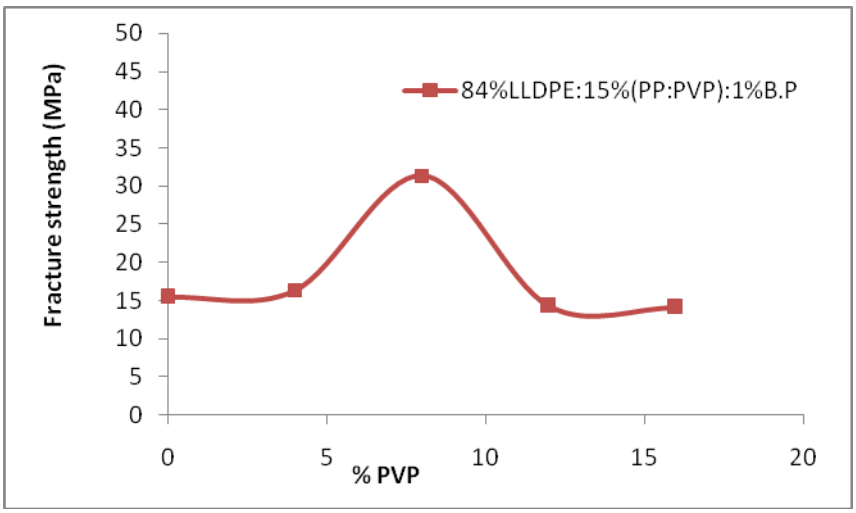

Figure (3) Fracture strength of [84%LLDPE:15%((100-X)%PP:X%PVP:1%B.P] as a function of PVP content in the composites.

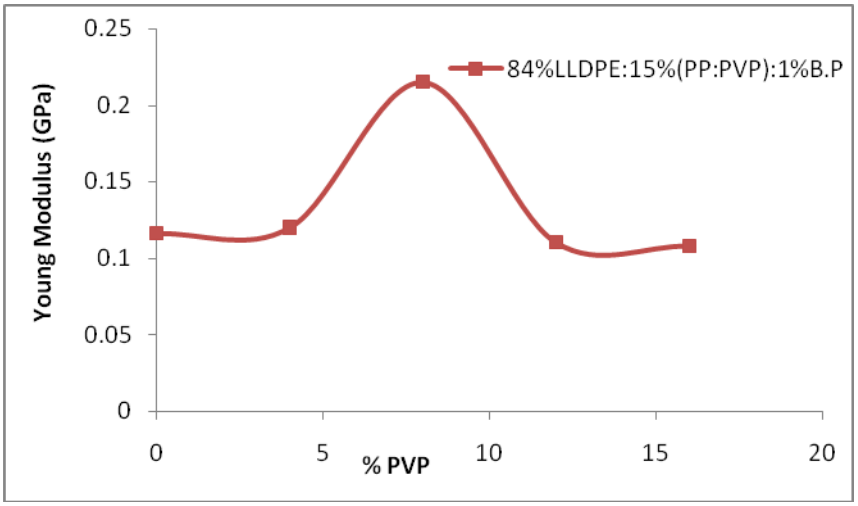

Figure (4) Young modulus of [84%LLDPE:15%((100-X)%PP:X%PVP:1%B.P] as a function of PVP content in the composites.

While from Figure (5) the % elongation values of polymer blend composites decrease with increase in PVP content in the polymer blend, and that is related to the properties of PVP which may increase the interfacial adhesion between the composite content and improves the stability and decreases chain sliding [11].

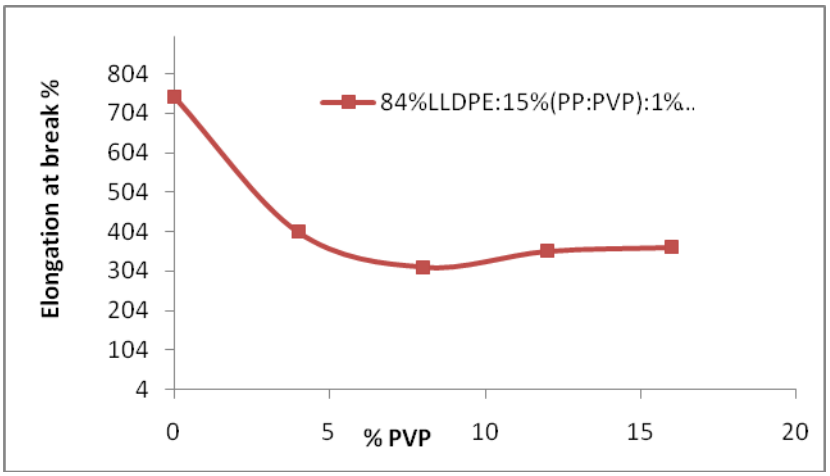

Figure (5) Elongation of [84%LLDPE:15%((100-X)%PP:X%PVP):1%B.P] as a function of PVP content in the composites.

From the results of stress-strain curves for compression test prepared composites, it is found that the compressive strength (as shown in Figure (6)) increases with addition of PVP to the basic polymer blend composites (without PVP), and the rate increases with the increase in PVP ratio in the polymer blends it reaches its maximum values at PVP 8%wt (27.4MPa). An increase in PVP content in polymer blends composite larger than 8% ratio decreases the compressive strength values, and becomes nearly stable at PVP content larger than 12%wt in the polymer blends composite, as well as these values remain larger than the values at the basic composites (without PVP). And as mentioned before it is related to the characteristics of PVP which may act as a good adhesive agent to improve the compatibility between constituents of prepared composites [13, 15 and 16].

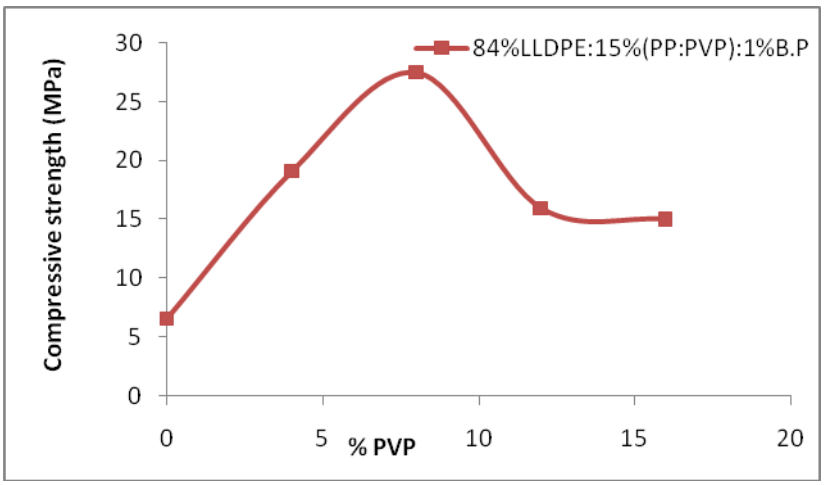

Figure (6) The compressive strength of [84%LLDPE:15%((100-X)%PP:X%PVP):1%B.P] as a function of PVP content in the composites.

The flexural strength and maximum shear stress values as a function of PVP content are shown in Figures (7 and 8) respectively. From theseFigures it is found that there are slight increases in flexural stress and maximum shear stress values with the increased PVP content in the polymer blend composites.

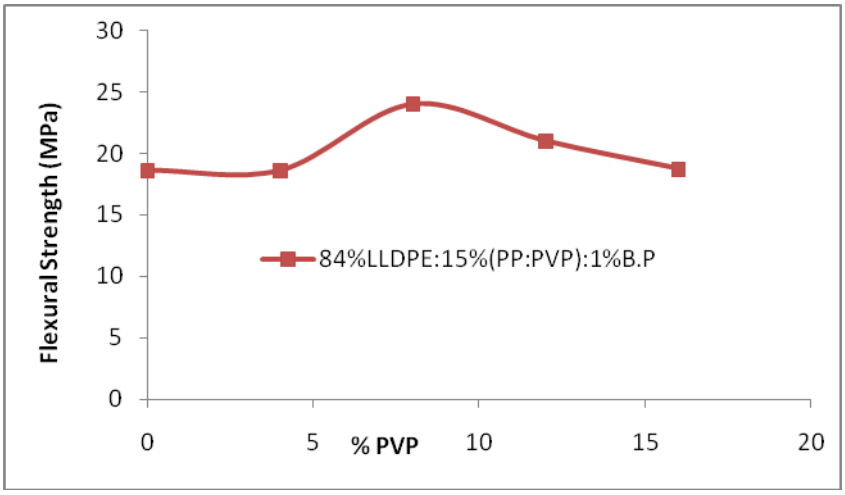

Figure (7) Flexural strength of [84%LLDPE:15%((100-X)%PP:X%PVP):1%B.P] as a function of PVP content in the composites.

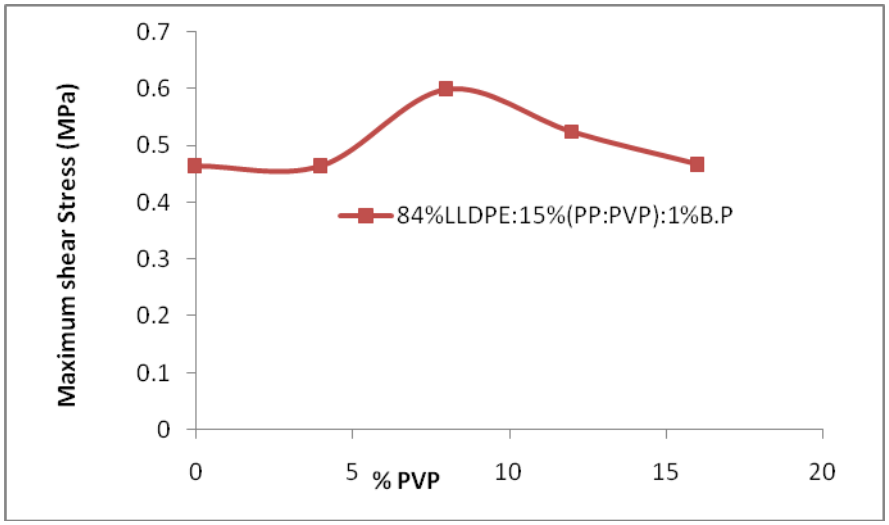

Figure (8) Maximum shear stress of [84%LLDPE:15%((100-X)%PP:X%PVP):1%B.P] as a function of PVP in the composites.

The addition of PVP in the basic polymer blend composites increases the flexural modulus values of the polymer blend composites as a shown in Figure (9), and the rate of increment of flexural modulus increases with increased PVP ratio until it reaches its maximum value (1.08GPa) at PVP ratio of 8%wt for the polymer blend composites. Increasing PVP ratio to larger than 8%wt decreases the flexural modulus values for the polymer blend composites.

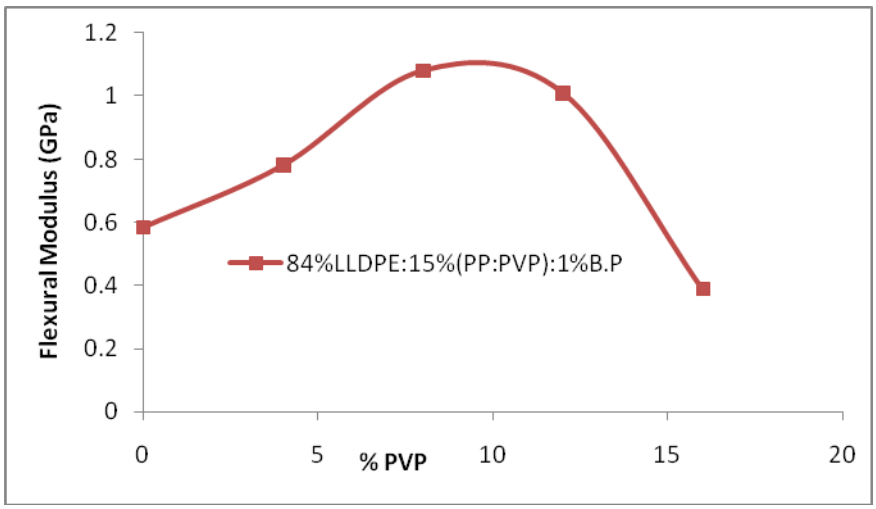

Figure (9) Flexural modulus of [84%LLDPE:15%((100-X)%PP:X%PVP):1%B.P] as a function of PVP content in the composites.

Figures (10 and 11) show the effect of PVP ratio on the impact strength and fracture toughness of polymer blend composites (no break). The impact strength is nearly stable with lightly addition of PVP to the basic polymer blend composite until reaching 8% PVP the impact is increases with increased PVP content in the polymer blend, whereas the fracture toughness values slightly increase with increased PVP ratio to 12% PVP ratio then the fracture toughness decreases with increased PVP ratio [17].

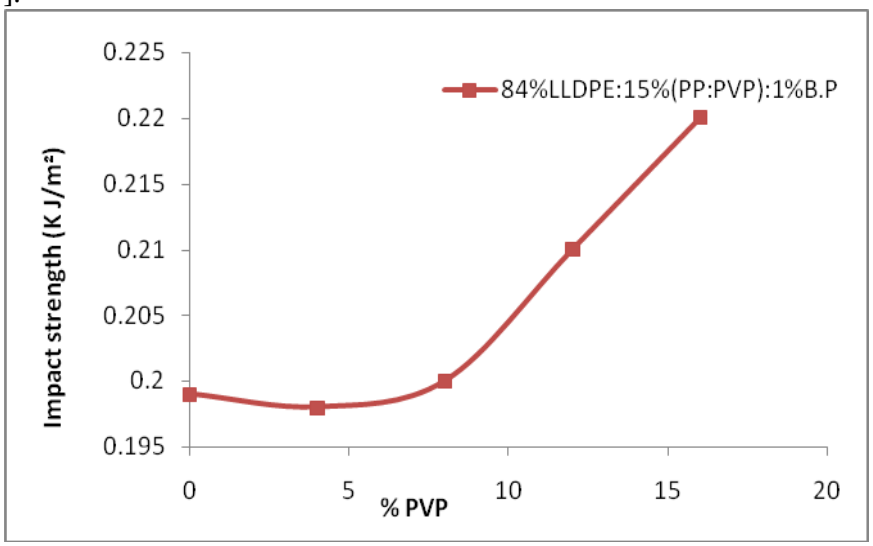

Figure (10) Impact strength of [84%LLDPE:15%((100-X)%PP:%XPVP):1%B.P] as a function PVP content in the composites.

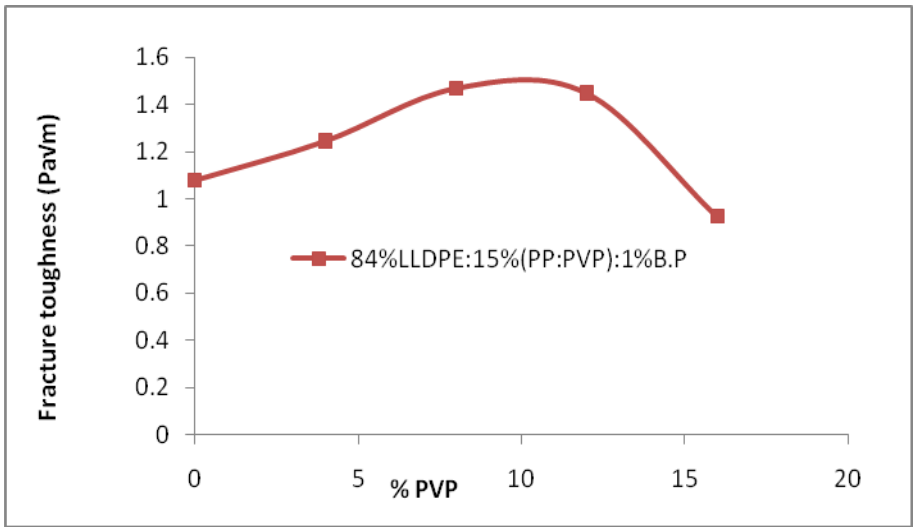

Figure (11)Fracturetoughness of [84%LLDPE:15%((100-X)%PP:%XPVP):1%B.P] as a function PVP content in the composites.

The effect of addition PVP on hardness values of the polymer blend composites are shown in Figure (12). From this figure it is found that the hardness values for composite slightly increase when addition PVP ratio into polymer blend composite to 4% PVP then the hardness decreases with increased PVP ratio, and becomes nearly stable at PVP content larger than 8%wt. in the polymer blend composite, as well as these values remain larger than the values at the basic composites.

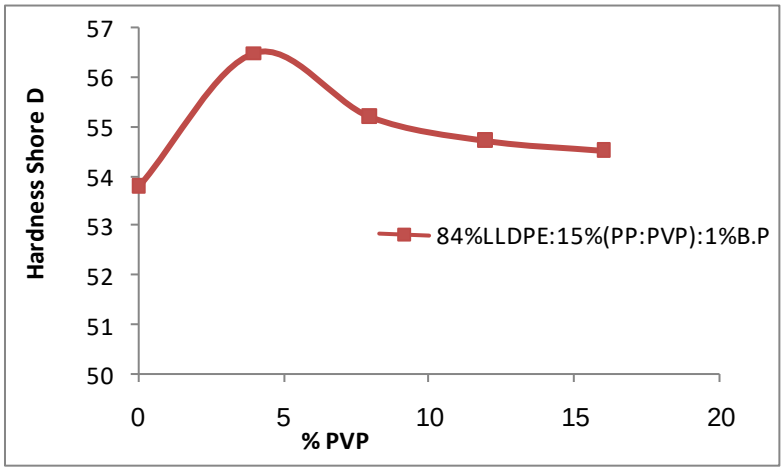

Figure (12) Hardness Shore D of [84%LLDPE:15%((100-X)%PP:X%PVP):1%B.P] as a function of PVP content in the composites.

The major difference between plastics material and the more traditional materials is the time dependent behavior of polymers. Figure (13) show (strain-time) curves of polymer blend composites. These figures indicate that the creep rates at room temperature and at constant tensile stress increase rapidly with the time for all

prepared samples, but after 400 min the creep rates slightly increase with time, and it can also be observed from these Figures that the creep rates depend on the PVP content.

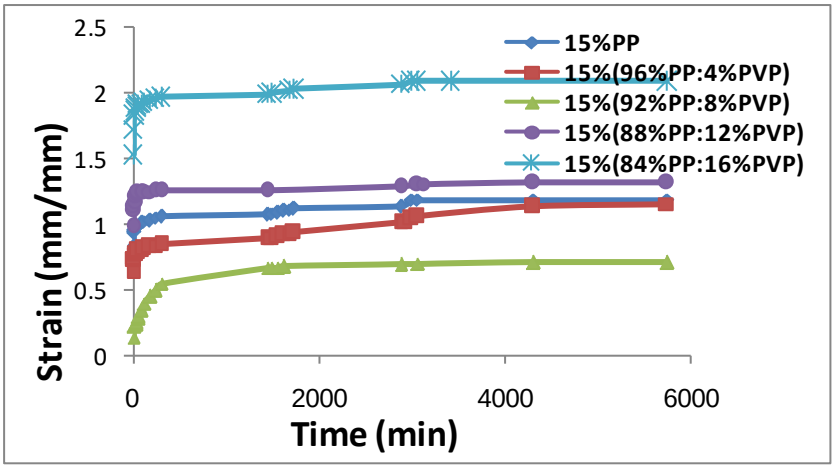

Figure (13) Creep behavior of [84%LLDPE:15%((100-X)%PP:X%PVP):1%B.P] as a function of PVP content in the composites.

The effect of PVP content on the creep modulus (the ratio of the initial applied stress to the creep strain ϵ (t) after a particular time and at constant temperature testing [14]) for different creep times (240, 2880 and 5760) and at room temperature are shown in Figure (14).

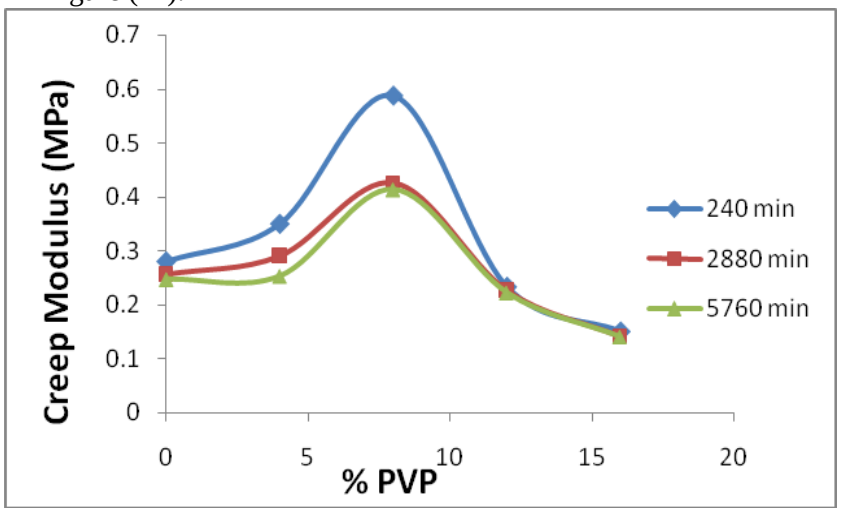

Figure (14) creep modulus of [84%LLDPE:15%((100-X)%PP:X%PVP:1%B.P] as a function of PVP content in the composites.

This figure illuminate that the creep modulus slightly increases with addition of PVP to the composites and the rate of increment in creep modulus increase with increased PVP content in the composites, and depend on the creep time, and reach maximum values at 8%wt PVP and at creep time 240 min, thus the maximum value

of creep modulus for composites were reaches to (0.588GPa), then these values decrease rapidly with the increased PVP ratio in the polymer blend to reach less than its values in the basic composites (without PVP) for the same creep time, and that is related as mentioned in item (tensile) to the characteristics of PVP which may causes (when it is at light ratio) good compatibility between polymer blend composites constituents.

CONCLUSIONS

The mechanical properties of [84%LLDPE: 15% ((100- X) %PP : X% PVP)%: 1% B.P] Polymer blend composites increase with increasing the ratio of PVP to certain PVP content; then decrease slightly, while the elongation rates decreases with increasing PVP ratio, the results recorded highest values of fracture strength, young modulus, compressive strength, flexural strength, maximum shear stress, flexural modulus and creep modulus at PVP 8% wt. which are (31.32MPa, 0.14GPa, 27.4MPa,24MPa, 0.6MPa, 1.08GPa and 0.558GPa) respectively.

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