Comparing effect of adding LDPE, PP, PMMA on the mechanical properties of polystyrene (PS)

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Abstract

In this research three groups of polymer blends have been prepared *First group* included (Polystyrene (PS): Low density polyethylene (LDPE))While the *Second group*(included Polystyrene (PS): Polypropylene (PP)) and *Third groups* include (Polystyrene (PS): Poly methel methacrylate (PMMA)) are prepared in different ratios by melt blending technique which was carried out using a double screw extruder. The tensile, flexural, impact and hardness test are used to study mechanical properties of polymer blends. The results from this work show that the impact properties for blends system increases with increases each of (LDPE, PP and PMMA) content in polymer blends of (PS: LDPE), (PS: PP) and (PS: PMMA). The elongation property increases with increases LDPE and PP but decreases when adding PMMA in polymer blend.

مقارنة تاثير اضافة البولي اثلين منخفض الكثافة و البولي بروبلين و البولي مثيل ميثا اكريللك على الخواص الميكانيكية للبولي ستايرين

الخلاصة:

في البحث المنجز تم تحضير ثلاث مجاميع من الخلائط البوليمرية حيث ان المجموعة الاولى تتضمن (PS:LDPE)بينما المجموعة الثانية(PS:PP) و المجموعة الثالثة تشمل (PS:PMMA) تم تحضيرها بنسب مختلفة باستعمال الباثقة ثنائيه اللولب. تم اجراء فحص الشد والانحناء والصدمة والصلادة لدراسة الخواص الميكانيكية للخلائط البوليمري،تز نتائج هذا البحث بينت بان خواص الصدمة للخلائط تزداد مع زيادة نسبة محتوى كل من ال(LDPE, PP, PMMA) في الخلائط البوليمرية (PS:PMMA), (PS:PP), (PS:LDPE) . نسبة الاستطالة تزداد مع زيادة LDPE, PP ولكن تقل عندما نضيف PMMA الى الخليط البوليمري.

INTRODUCTION

Polymers blends play an important role in widen the plastics application because of their ability to produce new products with a wide range of properties interest with minimal investment and became one of the fastest growing segments of polymer technology in commercial applications and developments [1].

Polymer blends or alloys have been the subject of intense study for a long time, but in the recent years, totally immiscible blends are of interest to many polymer researchers with respect to making such blends/alloys compatible. Blending is an attractive method of creating new materials with improvement and flexibility in performance, and better properties than existing polymers. Typical example for immiscible polymer blends is blend of polypropylene (PP) and polystyrene (PS) which are two of the most widely used plastics in the world .PS is a brittle and amorphous polymer which belongs to the aromatic group whereas PP is a semi-crystalline and ductile polymer belongs to aliphatic group with straight carbon chains. To make both PP and PS compatible requires an intermediate substance which can bond them together while maintaining their respective properties [2]. **V. M. Thirtha et al.,** studied the glass transition for immiscible blends of polystyrene-polypropylene (PS/PP) and polystyrene-high density polyethylene (PS/HDPE) were prepared from by using melt processing (single screw Brabender lab extruder). The result shows the immiscible blends of PS/PP and PS/HDPE, variations in glass transition values. These variations appear to result from the combined effects of the morphology and the interactions between phases present. The Tg of polystyrene in PS/PP blends increases from the value of (100°C to 105.4°C) and to (106.5°C) in PS/HDPE blends [3].**V. Wantinee et.al,** studied the effect of composition and morphology on tensile Young's modulus and impact resistance for immiscible polymer blends of polystyrene-polypropylene (PS/PP) and polystyrene-high density polyethylene (PS/HDPE) were prepared by melt extrusion using a single screw extruder in the systems. The PS/HDPE system showed impact properties poor, whereas excellent impact resistance was noted in the PS/PP blends. Indeed, the (20%) PS in PP blend possessed an impact strength that was (127%) greater than the proportional value for this composition. The PS/PP blends appear to be first-rate engineering materials from the perspective of tensile modulus and impact resistance, especially in the range of (15 – 30%) PS, also 20% PS/PP blend possesses tensile modulus that is (38.2%) greater than neat PP and with an impact resistance that is (94%) greater [4]. **P.A. P. Mamza et al.,** studies the properties of Polystyrene (PS) and Poly (methyl meth acrylate) (PMMA), these blend was preparation by poured into an aluminum mould was placed into the compression-moulding machine, which was operated at temperature range of (150-160 °C). The results of mechanical test of the PS/PMMA blend showed a varying suitability in terms of end-use applications. However, PS/PMMA blend composition of (20/80) wt% at lower pressures had the best mechanical property with a tensile strength of $(5.0 \times 10^6$ MPa) [5]. **K. Kaniappan and S. Latha,** studied the characterized of Polystyrene (PS) / Poly (methyl meth acrylate) (PMMA) blends with different ratios were prepared by solvent casting from toluene. The FTIR results of polymer blends indicate that there are no shifts of the peaks of any group in PS/PMMA spectrum; this confirms the formation of physical blend. The immiscible character of the polymer blends was confirmed by DSC and the

results evidenced that blend system was heterophase due to two distinct glass transitions [6].

The aim of this work is to study the effect of the (LDPE, PP, and PMMA) with different ratio (5, 10, 15 and 20 wt %) on the mechanical properties (tensile, flexural, impact and hardness test) of polymer blends prepared.

Material and Experimental Procedure

In this research four polymer materials were used which provided from the National Company for Plastic and Chemical Industries. The polymer materials are polystyrene, low density polyethylene, polypropylene and poly methyl methacrylate Supplier all polymers were supplied from the supplier in a pellet form and selected physical properties data for each polymer is given in Table (1).

Table (1): physical properties of polymers used as obtained from supplier.

Polymer	Melt flow index (gm/10 min)	Density(g/cm^2)	Elongation at break	Supplier
PS	2.5	1.05	3%	Sabic Company
LDPE	0.3-14	0.917-0.921	300%	Dow Company
PP	11	0.908	100 %	Sabic Company
PMMA	0.8	1.18	1.5%	Bast Company

Blending

Polymer blends were mixed according to the ratios displayed in Table (2) and subsequent melt processed in double screw extruder machine in (Materials Engineering Department /University of Technology) to form long plate of polymer blends (almost 4 mm thickness) with a screw L/D of 30:1 and the extrusion speed was (50 rpm) with barrel temperature of (195, 195 and 200 ºC) from the feeding to compression and metering zone respectively, for all groups of polymer blends materials.

Table (2): Blends Composition.

PS:LDPE	95:5	90:10	85:15	80:20
PS:PP	95:5	90:10	85:15	80:20
PS:PMMA	95:5	90:10	85:15	80:20

Mechanical Tests

Samples were prepared for the tensile test in accordance with ASTM D638 [7] with computerized universal testing machine model (WDW-50E). The test was conducted at a constant strain rate of the order 5 mm/min at room temperature. Tensile stress was applied till the failure of the sample and stress -strain curve was obtained, each sample was tested for (3 times) and average results have been reported.

The flexible modulus measured by three point test, this test is performed according to ASTM D790 at room temperature each sample was tested for (3 times) and average

results have been reported [8]. The flexural strength, flexural modulus and mix shear stress can be calculated by following equations: [9].

$$\sigma_{bend} = \frac{3\,FL}{2wh^2} \qquad\qquad \cdots (1)$$

$$E_f \;\; = \;\; \frac{FL^3}{4\partial wh^3} = \frac{mL^3}{4wh^2} \qquad\qquad \cdots$$

(2)

$$\tau_{max} = \frac{3F}{4wh} \qquad\qquad \cdots (3)$$

Where:-

         σ_{bend}: Flexural strength (MPa).

         E_f: Flexural modulus (GPa).

         ∂ : Is the deflection of the beam when a force F is applied.

         τ_{max}: Maximum shear stress (MPa)

         F: is the fracture load (N).

         L: is the distance between the two supported points (m).

         W: is the width of the specimen (m).

         H: is the thickness of the specimen (m).

Impact test is performed at room temperature according to ISO 179 each sample was tested for (3 times) and average results have been reported [10], by using measurement test machines; XJU-22 Time group.

Impact strength: - can be calculated from the following relationship [11]:-

$$G_c \;\; = \;\; \frac{U_c}{A} \qquad\qquad \cdots$$

(4)

Where:-

         G_c: Is the impact strength of the material (KJ/m^2)

         U_c: Is the required energy for sample fracture (KJ).

         A: Is the cross section area of the sample (m^2).

Fracture toughness: - can be calculated as follows [11]:-

$$Kc = \sqrt{G_c\,E_f} \qquad\qquad \cdots (5)$$

Where:-

         K_c: Is fracture toughness of the sample (Pa$\sqrt{m}$).

         G_c: Is impact strength of the material (KJ/m^2).

         E_f: Is Flexible modulus (GPa).

Hardness test carried out at room temperature on a durometer D scale ASTM D 2240 specimen dimension ($10 \times 10 \times 4$) mm each sample was tested for (5 times) in different regions and average results have been reported [12].

## Results and Discussion
Result of tensile test

Figures (1, 2 and 3) show the (stress –strain) curves of the first, second and third groups of polymers blends which consists of (PS: LDPE), (PS: PP) and (PS: PMMA)

respectively, with different ratios of LDPE, PP and PMMA (5%, 10%,15% and 20%) in the first, second and third group of polymer blends respectively.

It has been observed from these figures, there are difference in the behavior of (stress-strain) curves for each of three groups of blends (PS: LDPE, PS: PP and PS: PMMA). It was found from theses curves the behavior change from soft and tough for the polymer blends (PS: LDPE) to hard and strong for the polymer blends (PS: PMMA) as well as with increasing percentage ratios of LDPE or PP in polymer blend content the behavior change from hard to soft for (PS: LDPE) and (PS: PP), whereas the behavior change from soft to hard with increasing percentage ratios of PMMA in blend content of polymer blend (PS: PMMA). As well as it was shown from these curves for first and second groups samples in the begging of the load show the elastic behavior then the behavior change with increasing the load in to plastic deformation behavior until to fracture but for third group (PS: PMMA) show the elastic behavior until to fracture. Also from Figure (1) shows that sample of ratio (90%PS : 10%LDPE) of the first group bear maximum stress at fracture and medium elongation as compared to samples of other ratios. This ratio could bear stress (32.5 MPa) with an elongation (4.3%).

As well as from Figure (2) shows that the sample of the second group with ratio (95%PS:5%PP) bear maximum stress at fracture and less elongation as compared to samples of other ratios. This ratio could bear stress (37.5 MPa) with an elongation (2.45%).

It was found in Figure (3) that the sample of ratio (85%PS:15%PMMA) of the third group bear maximum stress at fracture and medium elongation as compared to samples of other ratios. This ratio could bear stress (49 MPa) with an elongation (1.62%).
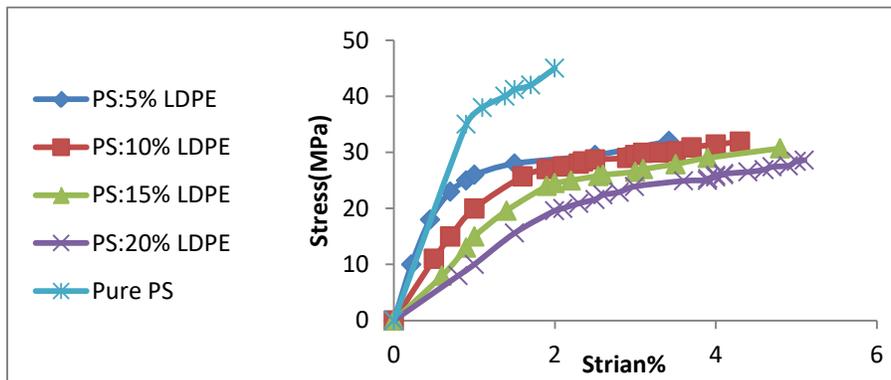
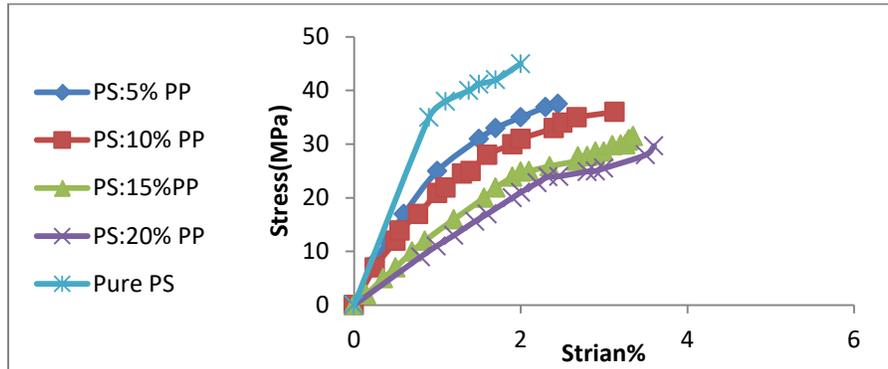**Figure(1): Stress-strain curve of the polymer blend (PS: LDPE).**

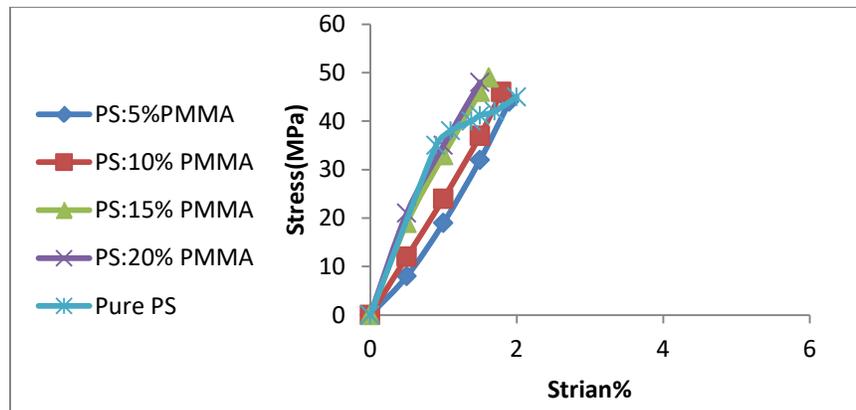**Figure (2): Stress-strain curve of the polymer blend (PS: PP).**

Figure (3): Stress-strain curve of the polymer blend (PS: PMMA).

The fracture strength, young's modulus and elongation percentage at break for the three groups sample of polymer blends are shown in Figures (4, 5 and 6) respectively. It was noticed from these figures that the samples of polymer blends (PS: LDPE) and (PS: PP) get lower values of fracture strength and the young's modulus but high elongation as compared with the counter parts of the polymer blend (PS: PMMA) samples. Also can be observed that the addition of (15%) PMMA to PS of polymers blends have higher value for young´s modulus than other ratio in the polymer blends [13].

  That the fracture strength and young's modulus of the polymer blends (PS: PMMA) samples increase with increase PMMA content in blend and reach to maximum values (49 MPa) and (3.7GPa) at (15%) ratios respectively. While the elongation percentage decreased. Whereas the fracture strength and young's modulus value for the first and second groups samples decrease with increasing LDPE or PP ration in the polymer blend content, while the elongation percentage of these group samples increase with increase LDPE or PP content in the blend. The above results refer to the nature of polystyrene microstructure; the presence of the phenylene ring on every other carbon atom of the main chain of polystyrene produce a rigid bulky configuration with sufficient steric

hindrance to make the polymer blends very inflexible [14]. As compared to the methyl group on every second carbon atoms of the polypropylene, whereas the substation of the meth and methacrylate groups on every other carbon atom of the main carbon chain of PMMA provides considerable satiric hindrance and thus makes polymer blend (PS: PMMA) rigid and relatively strong [15].

On other hand LDPE has branched chain structure that lower its degree of crystallinity and also lower the strength of polymer blend (PS: LDPE) because the addition of LDPE to PS reduce intermolecular bonding forces of these blends [16&17].
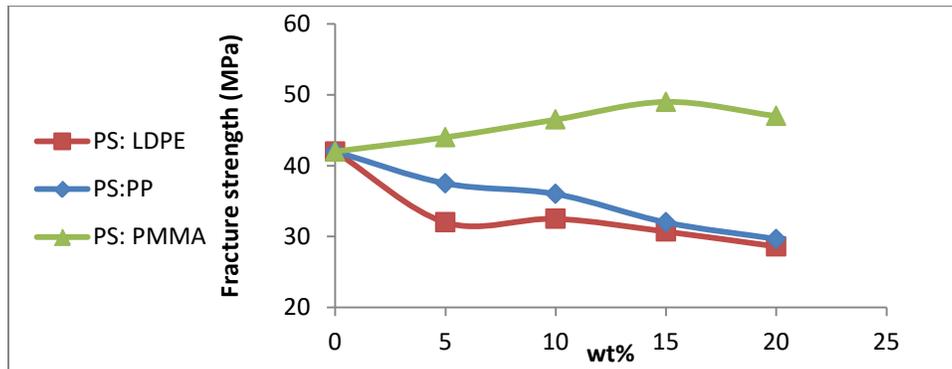
**Figure(4): Fracture strength for the polymers blends (PS: LDPE), (PS: PP) and
(PS:PMMA) as a function of (LDPE), (PP) or (PMMA) content in blend.**
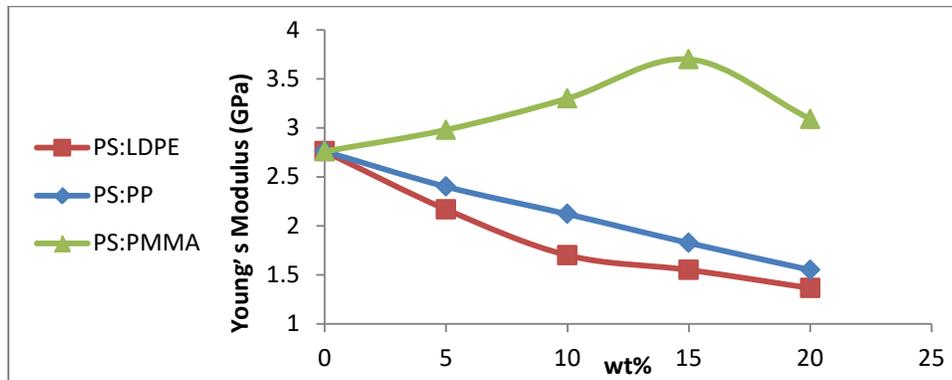

**Figure (5): Young´s modulus for the polymers blends (PS: LDPE), (PS: PP) and
(PS: PMMA) as a function of (LDPE), (PP) or (PMMA) content in blend.**
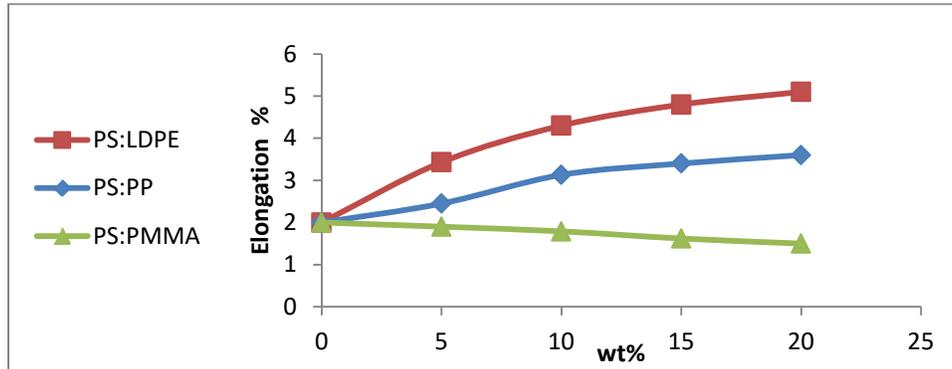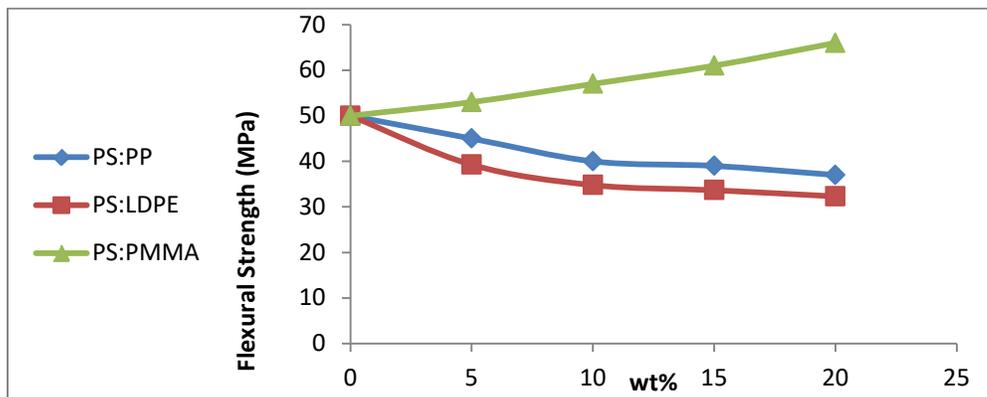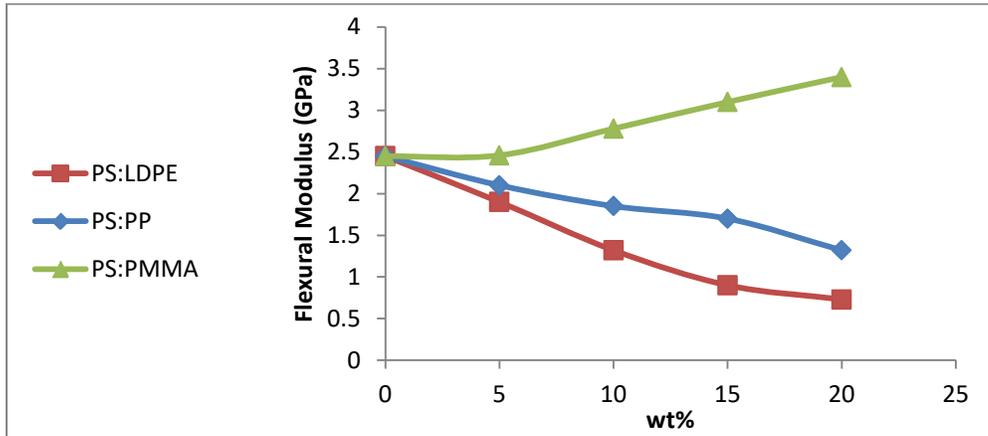
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Figure (6): Elongation percentage at break for the polymers blends (PS: LDPE), (PS: PP) and (PS: PMMA) as a function of (LDPE), (PP) or (PMMA) content in blend.

Result test flexural test

From Figures (7, 8 and 9) it was noticed that decrease the flexural strength ($\sigma_{bend.}$), flexural modulus (E_f) and maximum shear stress (τ_{max}) respectively, for polymer blends (PS: LDPE) and (PS: PP) with increase contain of (LDPE or PP) in polymer blends, PP is a semi-crystalline and ductile polymer belongs to aliphatic group with straight carbon chains [18]. But these properties increase for polymer blend (PS: PMMA) with increases contain of PMMA in polymer blends.

Figure(7): Flexural strength for the polymer blends (PS: LDPE), (PS: PP) and (PS: PMMA) as a function of (LDPE), (PP) or (PMMA) content in blend.
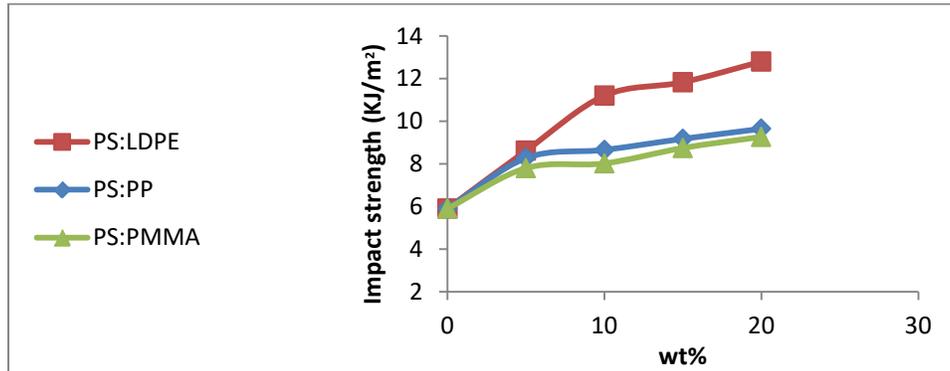
Figure(8): Flexural modulus for the polymer blends (PS: LDPE), (PS: PP) and (PS: PMMA) as a function of (LDPE), (PP) or (PMMA) content in blend.
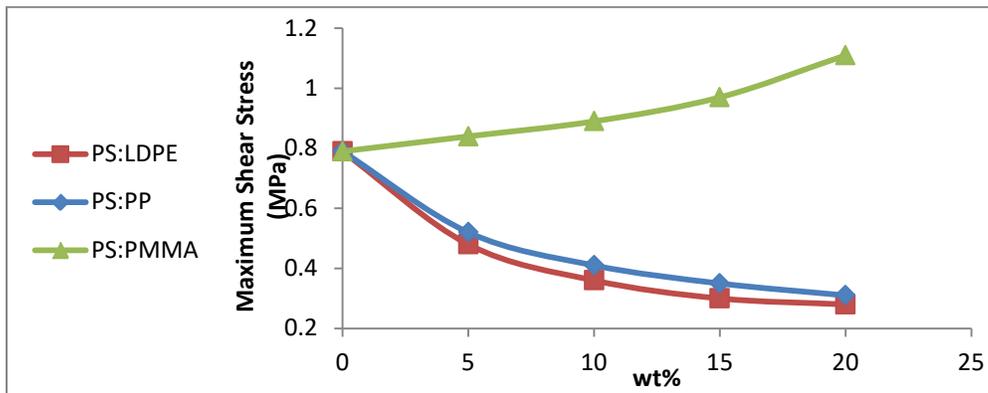
Figure(9): Maximum shear stress for the polymers blends (PS: LDPE), (PS: PP) and (PS: PMMA) as a function of (LDPE), (PP) or (PMMA) content in blend.

Results of impact test

From Figures (10 and 11) it was noticed that the impact strength and fracture toughness respectively of polymers blends increases with the increasing of LDPE, PP and PMMA content in blend, Furthermore, it was observed from Figures (4.52 and 4.53) that the impact strength and fracture toughness of the polymer blends (PS:LDPE) have higher values as compared with their counter parts of the other groups samples of polymer blends (PS:PP) and (PS:PMMA), whereas the polymer blends (PS:PMMA) have the lower values this is refer to flexibility of polymer blends (PS:LDPE) make it more energy absorption, the above results are related to the chemical structure of PS chain, the presence of a benzene ring on every other carbon atom of the main chain, and this is cause of PS fairly rigid polymer, the addition of another polymer having less flexible structure likes LDPE and PP, so the producer polymer blend has less flexible strength compare to PS alone or to polymer blend (PS:PMMA).

Figure(10): Impact strength for the polymers blends (PS: LDPE), (PS: PP) and (PS: PMMA) as a function of (LDPE) or (PP) and (PMMA) content in blend.
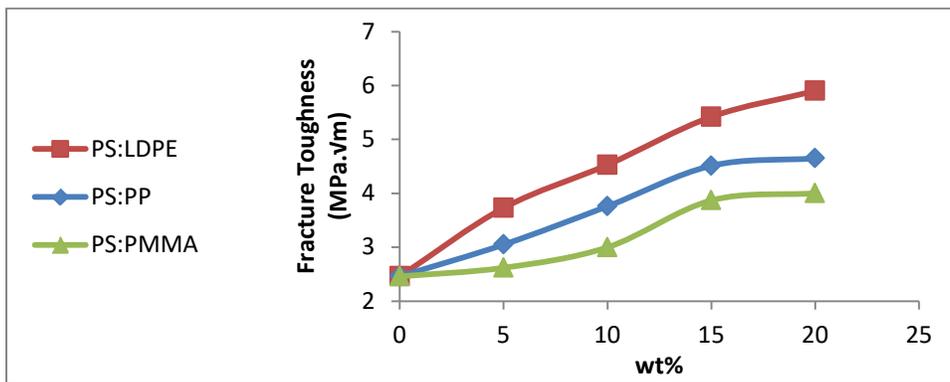

Figure (11): Fracture toughness for the polymers blends (PS: LDPE), (PS: PP) and (PS: PMMA) as a function of (LDPE) or (PP) and (PMMA) content in blends.

Results of hardness test

   Hardness (Shore D) was taken for the base polymers blends (PS:LDPE), (PS:PP) and (PS:PMMA), the results are shown in Figure (12) it was noticed from this figure that the hardness values for the polymer blend samples (PS:PMMA) having higher values as compare to the others counterparts of the polymer blends (PS:LDPE) and (PS:PP) moreover the hardness was decreased with the addition of LDPE or PP to the polymer blends content whereas slightly increase with increase PMMA contain, as well as the hardness values of (PS:PP) samples is higher than hardness of (PS:LDPE), this concerning to molecular structures of LDPE which have more side branches also can be formed than cause loose packing of the molecular chains, branching of linear polymers thus weakens secondary bond between the chain and lower the tensile strength as well as the hardness of the bulk polymeric material, as compare to the PP or PMMA which have two side groups structures, methyl and methacrylate groups which provides considerable steric hindrance and thus make polymeric material rigid and relatively strength [19& 20].
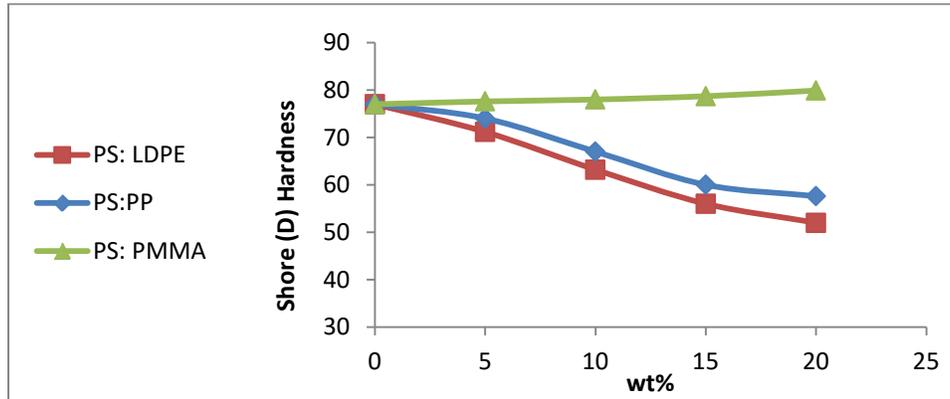
Figure(12): Shore (D) Hardness for the polymers blends (PS: LDPE), (PS: PP) and (PS: PMMA) as a function of LDPE, PP or PMMA additions to the blend.

Conclusion

In the present work, attempts are made to develop a polymer blend composites with desirable properties; by extruding PS with LDPE (PS: LDPE), with PP (PS: PP) and with PMMA (PS: PMMA) in different weight ratios of LDPE, PP or PMMA (5, 10, 15, 20 wt %),

1-   The mechanical properties such as (fracture strength, young's modulus, flexural strength, flexural modulus, maximum shear stress and hardness) for polymer blends decrease with increase the weight percentage of LDPE or PP content in polymers blends expect elongation percentage, fracture toughness and impact strength increase with increasing the ratio of LDPE or PP but these mechanical properties change when increase content of PMMA in polymer blends.

2-   The elongation percentage, impact strength fracture and toughness are higher values for polymer blend (PS: LDPE than PS: PP) as compared with polymer blends (PS: PMMA)**.**

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