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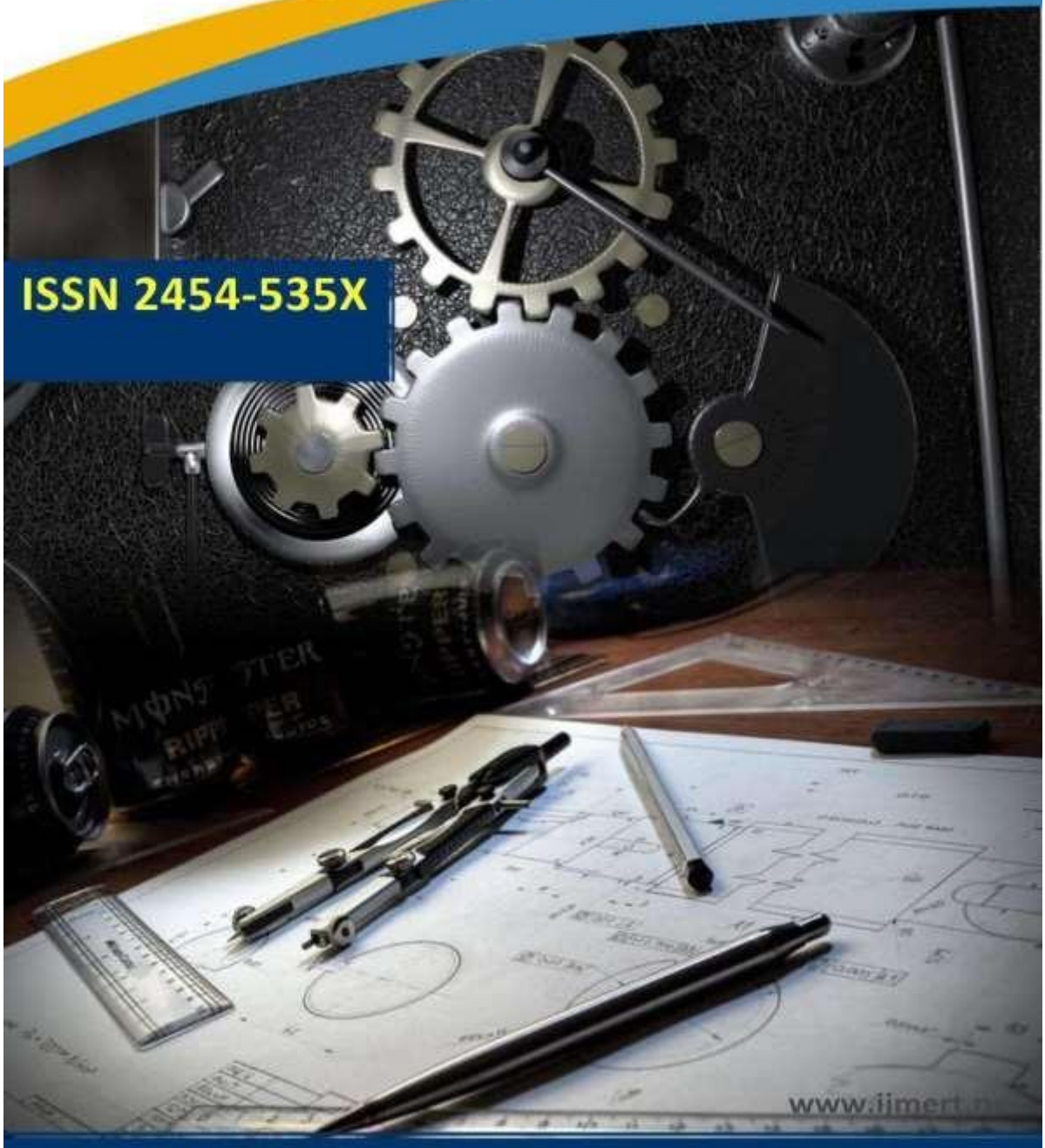

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Examination of Certain Mechanical Characteristics of Ternary Polymer Blends Utilizing Polypropylene as a Basis

Shalini, Shamala

ABSTRACT: The incompatibility of a polymer blend's constituent parts lowers the blend's mechanical qualities, which is one of the key issues that arise during preparation. Therefore, in this study, two sets of polymeric blends are created utilizing a twin-screw extruder and maleic anhydride grafted polypropylene (PP-g-MA) in limited proportions (1%), acting as a compatibilizing agent. In the initial group, the ratios of secondary materials (PMMA and UHMWPE) in each group of polymer blends were (5%, 10%, 15%, and 20%). In contrast, the second group's composition is (polypropylene (PP): X% Ultra high molecular weight polyethylene (UHMWPE):1% (PP-g-MA)). The findings demonstrated that the polymeric blends (PP: X%PMMA: 1%(PP-g-MA)) had greater values for hardness, elasticity modulus, and tensile strength than the polymeric blends.

KEYWORDS: Ternary polymer blends, PP, (PP-G-MA), UHMWPE, mechanical properties

INTRODUCTION

Currently, a large number of polymer blends help create a variety of polymeric materials for use in many applications, especially in structural and medicinal fields where they can combine the key features of each blend component. Because no single polymer on the market can fulfill every need for a particular application. Blends of miscible polymers are frequently chosen over those with immiscible properties. Therefore, in immiscible blends, reducing interfacial tension and increasing adhesion between two phases typically result in adequate performance. A third component, such as block or grafted copolymers, can be added as a compatibilizer agent to increase the compatibility of immiscible blends. Alternatively, appropriate functionalized polymers that can promote particular interactions and chemical reactions in reactive systems can be added. Therefore, a fresh productionMaleic anhydride grafted polypropylene (PP-g-MA) was utilized as a reactive compatibilization to test the compatibility of these immiscible polymers. Using a twin-screw extrusion, all of the blends were made using the melt process. The morpholog of structures in binary and ternary mixes was examined through the use of atomic force microscopy (AFM) and scanning electron microscopy (SEM). The compatibility of the binary and ternary blends was shown to be significantly impacted by the PP-g-MA grafting process [5]. The mechanical characteristics of the binary polymer blends [(HDPE: PVC), (HDPE: PP), and (HDPE: SAN)] that were made using the friction stir processing method were improved in a subsequent investigation. The highest values for the polymer blends (HDPE: 15%PP) and a significant increase in flexural strength and fracture toughness qualities were reported by the researchers.

MATERIALS AND METHODS

MaterialsMaterials used in this work are polypropylene (PP) in a pellet form grade (500P), provided from Sabic Company, PMMA material supplied from China (Xlamen Keyuan Plastic Co., Ltd.) has density (1.18- 1.19 Kg/m^3) and melt flow rate (2-3 g/10 min), ultra-high molecular weight polyethylene (UHMWPE) supplied from China in a pellet form have specific gravity (0.9 g/m^3) and melt flow rate (2 g/10 min) and (polypropylene-grafted-maleic anhydride (PP-g-MA)) provided from China in a powder form with a melt temperature of 150 °C.

Experimental procedures

In this work, two groups of ternary polymeric blends were prepared by melt-mixing technique using twin-screw extruder. The first group contains (PP: X% PMMA: 1% (PP-g-MA)), and the second group consists of (PP: X% UHMWPE: 1% (PP-g-MA)). The ratios of secondary materials (PMMA and UHMWPE) in each group are (5%, 10% 15%

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and 20%). Blends were mixed based on the selected ratios shwon in Table (1) The extrusion parameters are shown in Table (2), the obtained samples were as plates with thickness 5 mm, and the prepared plates were cut according to the international specifications of each test.

Table 1. The weight percentages for components of polymeric blends.

Polymer blends	**Weight Percentages**			
Neat PP	**(100%)**			
PP: UHMWPE: (PP-g-MA)	94: 5: 1	89: 10:1	84: 15: 1	79: 20: 1
PP: PMMA: (PP-g-MA)	94: 5: 1	89: 10:1	84: 15: 1	79: 20: 1

Table 2. Extrusion parameters

Polymer systems	Temperature (ºC)			Screw speed (rpm)
	Zone1	Zone 2	Zone 3	
Neat PP	190	200	210	45
PP: UHMWPE: (PP-g-MA)	190	200	210	45
PP: PMMA: (PP-g-MA)	195	205	210	45

Mechanical and physical tests

The FTIR test was performed according to the international measurements (ASTM E1252) [9], by using Fourier infrared spectrometer manufactured by Bruker Optier Company type (TENSOR-27). The Infrared spectrum was used within a range of (400- 4000) cm^{-1}.

Tensile test specimens were prepared according to ASTM standard D638-87 [10]. The machine used (model WDW 200 E) made in China. The test was conducted at velocity of (2 mm/min) at ambient temperature, and tensile stress was applied till the failure of the sample.

Compression test specimens were prepared according to ASTM standard (D 695) [11]. The test was conducted at a velocity of (0.5 mm/min) at ambient temperature, by using machine (model WDW 200 E) made in China. The load was applied gradually to the longitudinally fixed sample, the increasing of the load continued until the failure of the specimen occurred.

Shore D was used to measure the hardness of samples, in this test, specimens having dimensions (10 × 10 × 5) mm^3 were used. This test was carried out on a Durometer Shore D scale according to ASTM standard (D2240) [12]. To obtain a high accuracy in this test, the average of ten readings was taken in the different locations of each sample and taking into account that the samples are not subjected to any to mechanical vibrations during the test.

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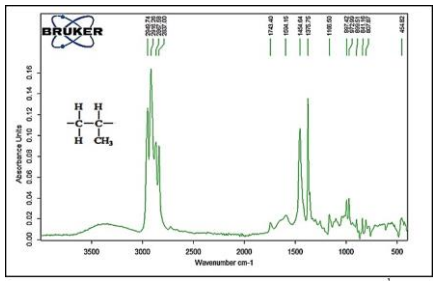
RESULTS AND DISCUSSION

Fourier transforms infrared spectroscopy (FTIR)

Fourier transformation Infrared spectrum FTIR) was used to obtain a fully characteristic information about the chemical bonds and molecular structure for two groups of polymeric blends, the spectrum was run by applying the range of frequencies from (4000 - 400 cm^{-1}). Figure (1) shows the characteristics of FTIR spectrum for neat PP material, the bands observed at 2916.26 and 2837.48 cm^{-1} confirms the presence of CH_2 stretching band [13, 14]. The peak at 1454.64 cm^{-1} confirm the presence of asymmetric in plane of CH_3 bending and peaks at



1166.50 cm^{-1} attributed to CH_3 wagging, and the peaks at 997.42, 972.99 and 841.16 cm^{-1} are attributed to CH3 rocking, CH_2 rocking and C-C stretching, respectively, the infrared spectrum of neat PP in Figure (1) is quite similar to that reported by [14,15].

Figure 1. FTIR spectrum for neat polypropylene material

The FTIR spectra of polymers blends (PP: X%PMMA: 1 %(PP-g-MA)) with different ratios of PMMA (0, 5 and 10%) are shown in Figure (2). From this figure, it is observed that all the characteristics vibration bands of polyp reover, several peaks relate ain characteristic band relate band. The vibrations bands 4 cm^{-1}) and (1375.75 cm^{-1} ning modes [16]. The bands 0.87 cm^{-1}) are due to the C PP: X%PMMA: 1 %(PP-g- is a clear decrease in peak of physical bonds and the ab ng process

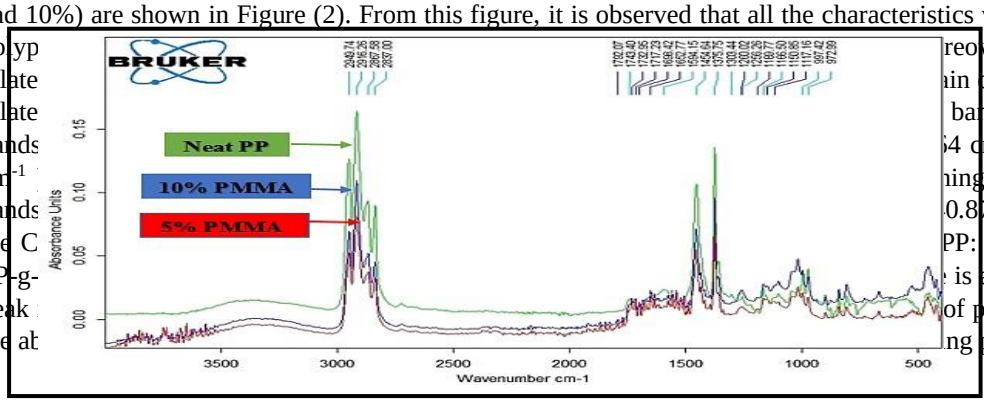


Figure 2. FTIR spectrum of polymeric blends (PP: X%PMMA: 1 %(PP-g-MA)) as a function of PMMA content in blend

The FTIR spectra of polymers blends (PP: X%UHMWPE: 1 %(PP-g-MA)) with different ratios of UHMWPE (0, 5, 10 and 15%) are shown in Figure (3). From this figure, it is observed that all the characteristics vibration bands of polypropylene (figure 1) are presented in FTIR spectra of ternary polymer blend (PP: X%UHMWPE :1%(PP-g-MA)). Moreover, several peaks related to UHMWPE and (PP-g-MA) are observed in all samples of these polymer blends, on the other hand, no any other new peaks or the shifts in peaks locations are noted, but there is a clear decrease in the peak intensity with increasing UHMWPE content in the blend.

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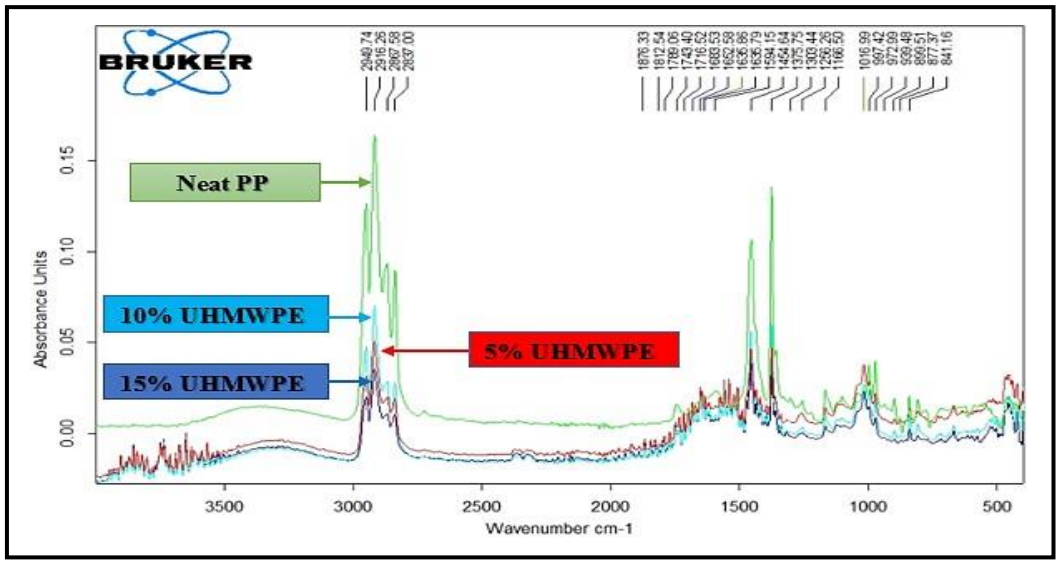

Figure 3. FTIR spectra of polymeric blends (PP:X% UHMWPE:1%(PP-g-MA)) as a function of UHMWPE content in blend

On the other hand, it can be seen from FTIR spectra for the two groups of ternary polymers blends (Figures 2 and 3) that the addition (PP-g-MA) to polymers blend leads to the appearance of absorbance bands at 1710 and 1780 cm^{-1} , assigned for cyclic anhydride groups [18], the intensity of peaks at (1456.88), (1375) and (1165.86 cm^{-1}) diminishes, showing that MA has been introduced as a graft onto PP [19].

Tensile Results

Tensile inspection was mainly achieved to investigate (stress-strain) curves behavior for polymer blends. Figures (4) and (5) demonstrates the (stress-strain) curves behavior for base material (neat polypropylene) and for two groups of ternary polymer blends (PP: X%PMMA: 1%(PP-g-MA)) and (PP: X%UHMWPE :1%(PP-g-MA)), respectively for different ratios (0, 5, 10, 15, and 20 wt.%) for each of PMMA and UHMWPE content in blends. The behavior of (stress-strain) curves of ternary polymer blends (PP: X%PMMA: 1%(PP-g-MA)) (Figure (4)) changes to hard and tough behavior when adding (PP-gMA) at constant ratio (1%) and PMMA at different ratios to the neat PP. This result is related to the nature of PMMA and its molecular chains. It is generally known that the PMMA is hardener, more brittle and stronger as compared to neat polypropylene, but these properties may be decreased something due to the addition of 1% (PP-g-MA) to the blend, where it was mentioned elsewhere that the addition of (PP-g-MA) material reduces the brittle behavior and increases the compatibility between blending components [16, 20]. Furthermore, the behavior of (stress-strain) curves of ternary polymer blends (PP: X%UHMWPE: 1%(PP-g-MA)) (Ffigure (5) changes from the hard behavior of neat polypropylene to the soft and tough behavior for ternary polymer blends due to the nature of the molecular chains of UHMWPE material and the behavior of (PP-g-MA) material in the blend, as mentioned earlier.

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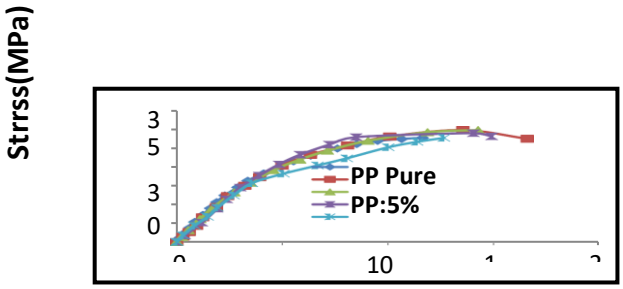

Figure 4. Stress-strain curve of ternary polymer blends (PP: X%PMMA: 1 %(PP-g-MA)) as a function of PMMA content in the blend.

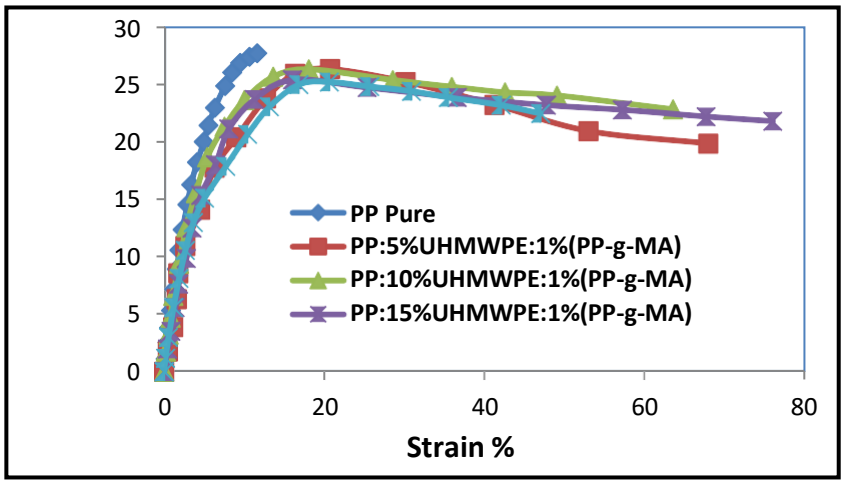

Figure 5. Stress-strain curve of ternary polymer blends (PP: X%UHMWPE: 1%(PP-g-MA)) as a function of UHMWPE content in the blend.

Figures (6 and 7) evince the tensile strength and Young's modulus, respectively for both groups of polymers blends (PP: X%PMMA: 1%(PP-g-MA)) and (PP: X%UHMWPE: 1%(PP-g-MA)) as a function of secondary material (PMMA or UHMWPE) content in polymer blends. From these figures, it is found that the tensile strength and elasticity modulus values increased with of addition PMMA material to polymer blend (PP: X%PMMA: 1%(PP-g-MA)), and tensile strength reached to maximum values at ratio 5% of PMMA in the blend, then the tensile strength value decreased with the increase of PMMA content to larger than 5% in blend but it remained higher than of the PP base material within the limits of addition ratios. Moreover, the elasticity modulus values for this group of blends reached their highest values at ratio 10% of PMMA in the blend and then decreased to less than that for the base PP material when increasing the addition ratio of PMMA to more than 10%. Whereas, the tensile strength and elasticity modulus values for second group samples of the polymer blend (PP: X%UHMWPE: 1%(PP-g MA)) decreased with the addition of UHMWPE material for all addition ratios to the polymer blends. Furthermore, the tensile strength and elasticity modulus values of the first group samples (PP: X%PMMA : 1%(PP-g-MA)) are larger than those of the second group samples (PP: X%UHMWPE: 1%(PP-g-MA)) of ternary polymer blend. These results may be related to the chemical structure of PMMA chains, where the presence of the methyl (CH_3) and methacrylate ($COOCH_3$) groups on every other carbon atom of the main carbon chain provides considerable steric hindrance and thus makes polymer blends tough and relatively strong [21]. But, the presence of another polymeric material having a high

molecular weight structure and tough as UHMWPE produced polymer blend (PP: X%UHMWPE : 1%(PP-g-MA)) less strong compared to matrix material and polymer blend (PP: X%PMMA: 1%(PP-g-MA)). This result may be related to nature of chains structure for each of PP and UHMWPE materials, where it was reported elsewhere [22, 23] that the polymers of different molecular weights can produce an immiscible blend that

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results in a decrease in mechanical properties.

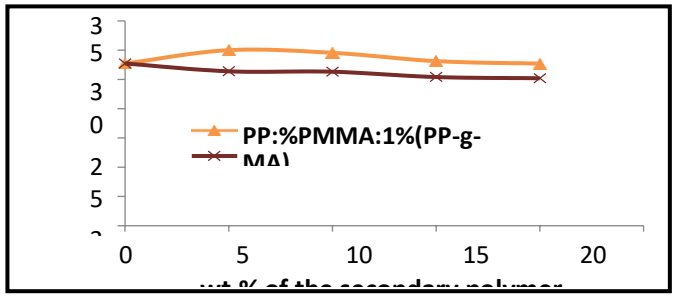

Figure 6. Tensile strength for both groups of ternary polymer blends as a function of PMMA or UHMWPE content in the blend.

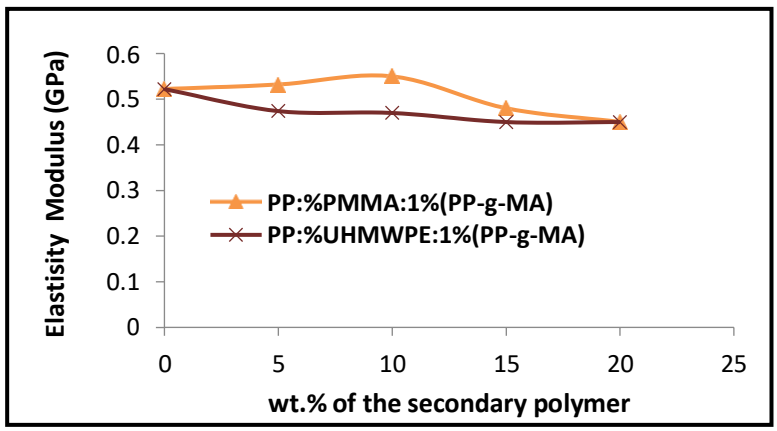

Figure 7. Elasticity modulus for both groups of ternary polymer blends as a function of PMMA or UHMWPE content in the blend.

The effecet of adding 1% (PP-g-MA) as the compatibilizer agent on the tensile strength is shown in Figure (8). Where, this figure exhibits the tensile strength values before and after adding 1% ratio of (PP-g-MA) to polymers blends, which have 5% ratio of the secondary materials [(PP: 5%PMMA) and (PP: 5%UHMWPE)]. From this figure, it was observed that adding 1% of (PP-g-MA) to blend (PP: 5%PMMA) increased the tensile strength value from 28.6 MPa to 30 MPa, and adding 1% of (PP-g-MA) to blend (PP: 5%UHMWPE) increased this value from 25 MPa to 26.4MPa. So, addition of (PP-g-MA) within limited proportion (1%) for both groups of the blend's sample will act as an agent to provide an effective compatibility among the constituents of polymer blend, this results agrees with that mentioned in literature [18, 22]. As well, it was found from this figure that the sample of ternary polymer blend (PP: 5%PMMA : 1%(PP-g-MA):) got the higher value in tensile strength as compared with the tensile strength value of neat PP material as control sample and the ternary polymer blend sample (PP: 5%UHMWPE : 1%(PP-g-MA)) and this may be related to the nature of chains structure for each of PP, PMMA and UHMWPE materials.

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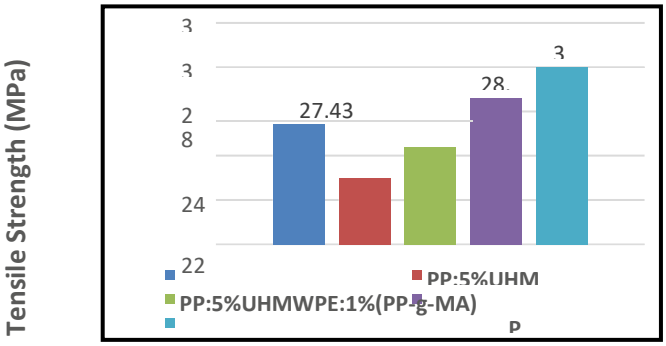


Figure 8. Comparation of the tensile strength values between neat PP material and two types of polymer blends [(PP: 5%PMMA) and (PP: 5%UHMWPE)] before and after adding 1% ratio of (PP-g-MA) to them.

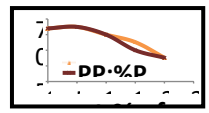
Hardness Results

It is noticed from Figure (9) that the hardness values of the two groups of polymeric blends [(PP: X%PMMA: 1%(PP-g-MA)) and (PP: X%UHMWPE: 1%(PP-g-MA))] decrease with increasing the ratios of each of the PMMA or UHMWPE content in blends to larger than 5% ratio. As well, the hardness values for the polymer blend samples (PP: X%PMMA: 1%(PP-g-MA)) are slightly higher than its counterparts of polymer blend samples (PP: X%UHMWPE: 1%(PP-g-MA)). This result may be related, as mentioned earlier, to the nature of polymeric chains structure for each of PP, PMMA and UHMWPE materials [21]. On the other hand, the nature of polmeric chains structure for each component in the blend perhaps leads to produce amorphous structure, especially at ratios higher than 5% and this will increase the free volume structure which eventually leads to a decrease in the hardness values for each sample of polymer blend.

Figure 9. Shore D hardness of ternary polymer blends as a function of PMMA or UHMWPE content in the blend.

Compression Results

It is noted from figure (10) that the compressive strength values of the two groups of polymer blends increase with the addition each of PMMA or UHMWPE to polymeric blends and reached to the higher values at 5% ratio. This may be related to the chemical structure of PMMA chain that having the methyl (CH_3) and methacrylate ($COOCH_3$) as two side groups on every other carbon atom of the main carbon chain and this provides considerable steric hindrance about the



volume, leading to lower the compressive strength for this polymer blend movement of polymeric chains. Thus, it leads to make the polymeric blends as a rigid material leading to the production of a polymeric blend possessed higher compressive strength as compared to neat PP material that has a flexible structure [24]. Increasing the percentage of PMMA to more than 10% in the blend may be led to the formation of a structure with higher free .

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On the other side, the addition of another polymeric material instead of PMMA material like UHMWPE material, which have a linear structure of polyethylene and has an extremely high molecular weight and highly aligned, has increased the compressive strength [21]. Therefore, this polymer has lower free volume structure as compared with PP and PMMA, so, blending this polymer with PP material will lead to produce a polymer blend having the microstructure possessed lower free volume as compared with PP. Therefore, the produced polymer blend has a high compressive strength compared to neat PP.

In addition to that, the samples of polymer blends (PP: %UHMWPE: 1%(PP-g-MA)) have higher values of compressive strength as compared with their counterparts of polymer blend samples (PP: %PMMA: 1%(PP-g-MA)). This may be due to the higher crystallinity and high molecular weight of UHMWPE material, therefore, this polymer blend produces the lower free volume structure as compared with the polymer blend have PMMA, where this blending material has a random molecular structure as a result of unsymmetry in the structures of side groups, so, it produced a completely amorphous structure with a high free volume, which was leading to produce polymer blends samples possessing lower compressive strength values.

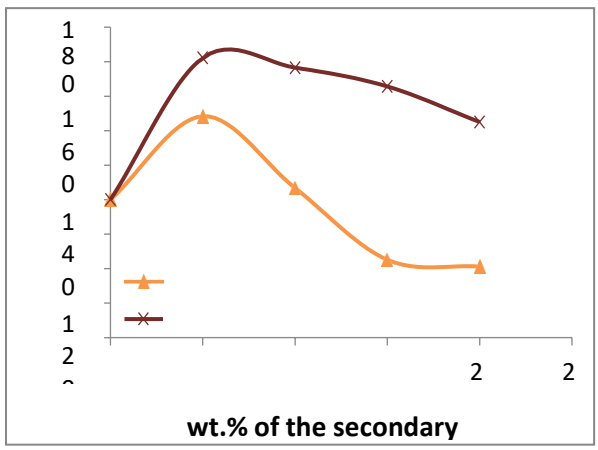

Figure 10. Compressive strength of the ternary polymer blends as a function of PMMA or UHMWPE content in the blend.

Morphology of Fracture Surface

The fracture surfaces of the tensile test specimens were examined by using a scanning electron microscope (SEM). The key point to phase morphology composed of the co-continuous phase and dispersed phase depends on the nature of components, ratio of components, component melt viscosities and processing conditions. Fracture surface morphology of the modified polymers blends [(PP: 5%PMMA: 1%(PP-g-MA)) and (PP: 10%UHMWPE: 1%(PP-g-MA))], was improved by adding (PP-g-MA) at 1% ratio to act as compatibilizer agent material. The blend structure morphology is presented in figure 11 (a- f) at two different magnifications (1000X) and (3000X). Where, figure 11 (a and b) illustrates that the fracture surface morphology of a neat PP material as control sample has a smoother structure morphology compared with a blend's morphology and it has some microscopic cracks which are indicated by arrows with a red color. This result is in a good agreement with the other workers' result [25]. Microscopic images in figure 11 (c and d) shows a good dispersion of PMMA material in the blend, and figure 11 (e and f) depiets that the UHMWPE material is dispersed in the morphology structure of polymer blend. As well, these microscopic images clearly reveal two different morphologies for polymeric blends depending on the constituents of blend and their ratios in the blend.Where from figure 11 (c and d)), it was noticed that there is co-continuous morphology in the structure of polymer blend (PP: 10% PMMA: 1%(PP-g-MA)) with a good dispersion of PMMA material in the blend and as a result, it was difficult to identify the individual polymers in this blend.

Whereas, microscopic images in figure 11 (e and f)) evincea heterogeneous morphology with a dis-continuous structure for the fracture surfaces morphology of polymer blend (PP: 10%UHMWPE: 1%(PP-g-MA)), this

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morphology show immiscibility of polymer blend with sharp interfaces and poor bond strength, with the appearance of some microscopic pores through this structure's morphology which are indicated by arrows with a red color. This result may be related to the nature of polymeric chains structure for each of PP and UHMWPE, as well as, they have high difference in the molecular weights, leading to produce an immiscible blend [26]. On the other hand, this can be attributed to poor compatibility at the interface of all constituents of polymer blends (PP: X%UHMWPE: 1%(PP-g-MA)) which led to a decrease in the mechanical properties, as previously mentioned. In addition, the microscopic morphology (figure 11 (f)) indicates to the formation of a dispersed phase of UHMWPE material in irregular shapes and sizes, which appear through the microscopic morphology of polymer blend, as indicated by arrows with blue color. It is widely accepted that a compatibilizer material has two main roles in the control of blend morphology, one of them is the prevention of the coalescence of secondary materials and the other is the reduction of interfacial tension [27-31].

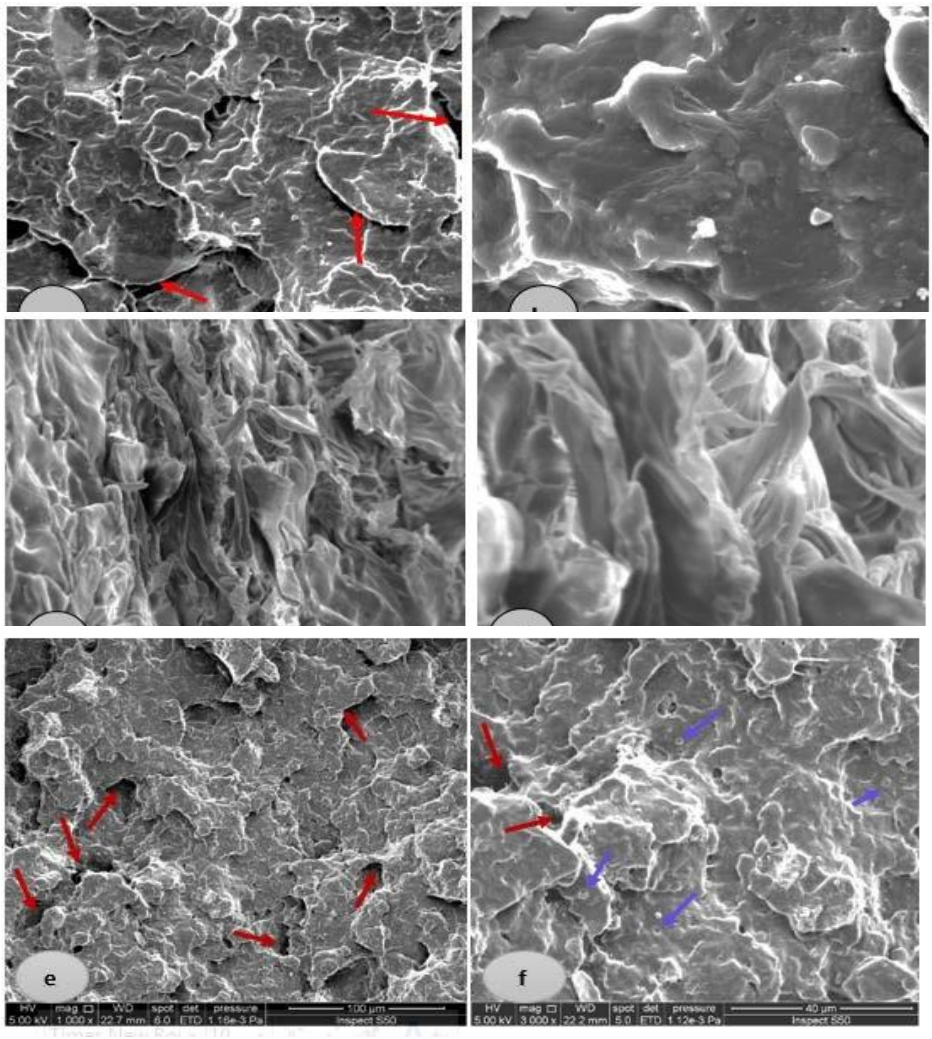

Figure 11. SEM fracture surface morphology of (a) and (b): Neat PP, (c) and (d): ternary polymer blend [PP: 5%PMMA: 1%(PP-g-MA)] and (e) and (f): ternary polymer blend [PP: 10%UHMWPE: 1%(PP-g-MA)] , where: (a), (c) and (e) at magnification (1000X), and (b), (d) and (f) at magnification (3000X).

CONCLUSIONS

Mechanical characteristics of polymer blend [PP: X%PMMA: 1%(PP-g-MA)] showed higher values compared with the polymer blend [PP: X%UHMWPE: 1%(PP-g-MA)]. The accepted compressive strength of the second

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blends group manifested higher values compared with the first blend.

The maximum values of mechanical properties (Young's modulus, compressive strength and shore D hardness) were obtained at low ratio of secondary material for both groups of polymer blend, except the tensile strength gives the maximum value of the second group at (10wt.%) ratio of UHMWPE.

In FTIR test observed no peak shifts but decrease in peak intensity with increasing PMMA and UHMWPE ratios in the blends.SEM pictures elucidated a good compatibility and a continuous blend of the first blends group, while the second blends group (PP: 10%UHMWPE: 1%(PP-g-MA)) exhibited the immiscibility of polymer blend having a bad compatibility with a heterogeneous morphology, and dis-continuous structure with sharp interfaces.

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