RESEARCH PAPER

Comparative Study of the Flexural Strength and Impact Strength properties Between Two Types of the Ternary Polymer Blends

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A B S T R A C T:
Compatibility is one of the major problems which effect on the characteristics of polymer blends. Therefore, in the current search Polypropylene Grafted Maleic Anhydride (PP-g-MA) was used to improved compatibility between the components of the binary polymer blends. So, two sets of ternary polymeric blends were prepared by melt-mixing method using double-screw extruder. The first group is containing on (polypropylene (PP): 1% (PP-g-MA): X% polymethylmethacrylate (PMMA), the second group consists of (PP: 1%(PP-g-MA): ultra-high molecular weight polyethylene (UHMWPE)). The blends, containing between 5 to 20% ratios of a third material (PMMA or UHMWPE) and 1% of compatibilizer material (PP-g-MA). Investigation the bending strength and impact strength was done for the prepared specimens. Study shown that, the polymer blends (PP: 1 %(PP-g-MA): X% PMMA) gained the higher properties in flexural strength, whereas the polymer blends (PP: 1% (PP-g-MA): X% UHMWPE) have got the higher values in impact strength and fracture toughness.

KEY WORDS:Ternary polymer blends; (PP-G-MA); UHMWPE; PMMA

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1. INTRODUCTION :

Blending of polymers becomes very important way in production the products with an optimum property. Efficiency of polymeric blends depend on individual properties of each component in blend, molecular weight, their arranging in space, so, the binary polymer blend may be giving one phase or immiscible phases [1]. bulb extracts of both F. zagrica and T. kurdica medicinal plants grown in Kurdistan region- Iraq. Immiscible blends generally attain satisfactory performance, through reducing interfacial tension, and improving adhesion between two phases in the blend. Compatibility between two phases of immiscible blends, it can be improved by adding block or graft copolymers as a third component to the blend. Moreover, it can enhance the chemical interactions for these systems by adding the active polymers to the blend [2]. Weak characteristics of polymeric material, can be development by adding other polymeric materials to the blend [3]. Most a polymeric blend, show low mechanical properties with weak bonding strength. Studies shown that, such polymer blends, give a cooperative in mechanical characteristics when processes parameters of blend and chemical composition reach to optimum values [4].

Blending effect was study to overcome the viscosity problem, of UHMWPE with addition
HDPE via solid-state shear pulverization (SSSP) method instead of melt processing due to the poor dispersion. Results appeared that blending via SSSP leads to dramatic improvements in impact compared with other methods of preparation [5]. Other studies in the field of blend have been established by a group of researchers have been prepared three kinds of blends with matrix material is (PS), which was including from (PS+ %LDPE), (PS+ %PP) and (PS+ %PMMA) were prepared by double extruder. From results observed the impact strength of blends increases with increases (LDPE, PP and PMMA) ratios in the blends [6].

Recently, were studied improving the mechanical properties, through an attempt was made to manufacture binary polymers blends [(HDPE:PVC), (HDPE:PP) and (HDPE:SAN)] by using the friction stir processing (FSP) method on the surface of the matrix (HDPE) at depth 3 mm from the surface and with different percentages (10, 15, 20 and 25 %) for each of (PVC),(SAN), (PP) polymeric materials added to the matrix (HDPE). From the mechanical tests which included bending and impact tests it was obtained values indicating a marked increase in mechanical properties at percentages (85% and 34%) from the results achieved for the polymer blends (85%HDPE: 15%PP) and (85% HDPE: 15 % PVC) Respectively. Based on the results this demonstrate the success of the FSP method to preparation of different polymer blends and most of these polymers have high efficiency and without have any internal or external defects [7].

Another recent study effects the PVP ratio on the mechanical characteristics for two sets of polymer composites, (PP: x% (LLDPE: y% PVC) and (PP: x% (HDPE: y% PVC), with constant value (1%) of basalt particles as a reinforcement material, mechanical characteristic improvement when PVP ratio increase in composite samples. The optimal values for most mechanical properties were observed at 8% PVP ratio for first group samples, while the optimal values of mechanical properties for the second group samples were observed at 4% ratio of PVP material in the blend [8].

The aimed of present work investigate the effect of addition the (PP-g-MA) as compatibility material. As well as, the ratios of PMMA and UHMWPE materials content for two groups of ternary polymer blend, based on polypropylene and study some of mechanical properties.

2.Materials and Methods

I. Materials

Polymer materials used in this work are polypropylene (PP) grade (500P for extrusion), provided from Sabic Company, PP supplied in a pellet form. Virgin PMMA for extrusion supplied from china (Xlamen Keyuan Plastic co.,Ltd.) with density (1.18-1.19 Kg/m3) and melt flow rate (2-3 g/10min). Ultra-high molecular weight polyethylene (UHMWPE) supplied from china for extrusion in a pellet form, with specific gravity (0.9 g/m3) and melt flow rate (2 g/10min). Polypropylene- grafted maleic anhydride (PP-g-MA) from china in a powder form with melt temperature (150 °C).

II. Experimental Procedure

In this work, two groups of ternary polymeric blends were prepared as a plate by melt-mixing method using double-screw extruder. The first group is containing on ((PP): 1% (PP-g-MA): X% (PMMA)), the second group consists of (PP: 1% (PP-g-MA): X% Ultra high molecular weight polyethylene (UHMWPE)). The blends contain on 1% of the compatibilizer material (PP-g-MA) and different ratios between 5 to 20% of the second material (PMMA or UHMWPE). So that, the polymer blends were prepared based on the selected ratios in Table 1. The extrusion parameters shown in Table 2. In order to obtain plates with thickness 5mm, and then, the prepared plates were cutting according to the international specifications of each test.

III. Mechanical tests:

The flexural test and impact test were performed in order to evaluation Fracture toughness properties for all the prepared polymer blends samples.

Flexural test was done by using a three-point method; by a test machine, model (WDW 200 E),
this test was carried out with speed of cross-head 2mm/min all tests were carried out at a room temperature (23 ± 5 C°) and atmospheric pressure, and samples were extracted from the plates of each group of polymer blends according ASTM D790 standard [9]. The impact properties of materials represent its ability to absorb and dissipate energies to measure the strength of the material under impact or shock loading. Impact strength is an important property for polymeric materials which have different behavior depends on the type of polymeric material, manufacturing conditions, shape of the sample and test temperature. Impact test was enforced at room temperature according to (ISO-179) [10], by Impact test machine, model (XJU). In this test, the samples test were done without notches.

2. Results and Discussion

3-1 FTIR spectrum test results

This test is used for fully characterization of neat PP and for polymer blends specimens. Figure (1) gives the characteristics of FTIR spectrum of neat PP polymer, this infrared spectrum is quite similar to that reported by [11 and 13] the band observed at (2916.26 and 2837.48 cm-1) confirms the presence of C-H2 stretching band. The peak at (1454.64 cm-1) confirms the presence of asymmetric in plane CH3 bending and the peak at 1166.50 cm-1 attributed to CH3 wagging and peaks at 997.42, 972.99 and 84116 cm-1 are attributed to CH3 rockings, CH2 rockings and C-C stretching respectively [12 and13].

The FTIR spectra of polymers blends (PP:1% (PP-g-MA): x% PMMA) with different ratio of PMMA (0, 5 and 10%) are shown in Fig.2. From this figure it was observed that, all the characteristics as vibration bands of neat polypropylene Fig.1 are presented in (FTIR) spectrum of ternary polymer blend. On the other hand, no other new peak or peak shifts were observed, but there is a clear decrease in peak intensity with increasing PMMA ratio in blend. The FTIR spectra of polymers blends (PP:1% (PP-g-MA): x% UHMWPE) with different ratio of UHMWPE (0, 5, 10 and 15%) are shown in Fig.3. From this figure it was observed that, all the characteristics as vibration bands of neat polypropylene Fig.1 are presented in (FTIR) spectrum of ternary polymer blend (PP:1% (PP-g-MA): x% UHMWPE). moreover, several peaks related to UHMWPE and PP-g-MA are observed in all samples of these polymer blends, on the other hand, no other new peak or peak shifts were observed, but there is a clear decrease in peak intensity with increasing UHMWPE ratio in blend. On the other hand, it can be seen from FTIR spectra of polymers blends (Figures 2 and 3) that the addition (PP-g-MA) to polymers blend, the intensity of peaks at (1456.78, 1375.11 and 1166.8632 cm-1) diminishes, showing that MA has been introduced as a graft onto PP [15].

3.2 Mechanical test results

Flexural behavior: Figures (4) and (5) were shown the effect of the addition PMMA and UHMWPE to (PP) on flexural properties of ternary polymer blends. From these figures it was observed that flexural properties reach to the highest values at 5% ratio of PMMA for polymer blend group (PP:1% (PP-g-MA): x% PMMA), while for polymer blend group (PP:1% (PP-g-MA): X%UHMWPE) flexure modulus values reach to highest values at 5% ratio of UHMWPE, whereas, the flexural strength increased with increase UHMWPE content to reach the highest values at 10% and 15% ratio of UHMWPE for the flexural strength. As well as the results showed the flexural properties of the first group (PP:1% (PP-g-MA): x% PMMA) have highest values as compared with the second group of polymer blend (PP:1% (PP-g-MA): x% UHMWPE). These results are related to the different in chain structures of PP, PMMA and UHMWPE materials, where the chemical structure of PMMA...
chain with the presence of two groups (ch3 and cooch3) on every second carbon atom of repeat units for the main carbon chain gave major hindrance of the movement of chains and thus makes polymer blends relatively strong [16], but presence another polymer having less flexible structure like PP, so the producer polymer blend has less strength compare to PMMA alone. Effect of addition 1% (PP-g-MA) as compatibilizer material with PMMA to the neat PP, increased in flexural properties of the samples as show in Figures (4 and 5) and that related to the nature of compatibilizer (PP-g-MA) which acts as an agent to increase the interfacial reaction and provides an effective compatibility between all constituent of polymer blends [8]. In addition, the maximum values of flexural strength and flexural modulus for the sample with an 5% ratio of PMMA in the first group may be related to the good interfacial reaction between the constituents of this blended material; the 5% ratio of PMMA with 1% compatibilizer (PP-g-MA) gave optimum compatibility to this blend. As well as, it can be observed from these figures that the effect of addition compatibilizer (PP-g-MA) at ratio (1%wt) with UHMWPE to the base polymer PP was slightly Increase in these properties of polymer blends [PP: PP-g-MA: %UHMWPE], this may be lead to the bad interfacial reaction in compatibility between all constituent of this polymer blends, so these ternary polymer blends got the lower values in these properties as compared with ternary polymer blends [PP: PP-g-MA: %PMMA].

Impact Results

Impact toughness is often considered the deciding factor in material selection because impact test measures the ability of polymer to withstand the load imposed upon being struck by an object at high velocity, thus it is a measure of energy required propagating the crack cross the specimen; therefore, the impact properties of the prepared samples are especially important. Figures 6 and 7 show the effect of blend ratios on the impact strength and fracture toughness respectively for two groups of ternary polymer blends (PP:1%(PP-g-MA): x% PMMA) and (PP:1%(PP-g-MA): x% UHMWPE). Results indicated the second group samples (PP: 1% (PP-g-MA):X% UHMWPE) has higher impact strength and fracture toughness as compared to the first group samples (PP: 1% (PP-g-MA): X% PMMA) due to molecular chain of the UHMWPE. As well as the results showed that impact property of neat PP improved with the blending strategy of UHMWPE especially with low weight ratios 5% and 10% reaching to 41.33 kJ/m2 and 41.53 kJ/m2 respectively as compared with neat PP value 26.36 kJ/m2, but goes down at 15 and 20wt.% but the values remained higher than in the basic material (neat PP). This result may be related to the natural of chain structure of Ultra-high-molecular-weight polyethylene (UHMWPE) is a linear polyethylene that has an extremely high molecular weight, has characteristics high energy absorption and extremely high impact resistance [17]. While fracture toughness for ternary blends (PP: 1% (PP-g-MA): X% PMMA) showed higher values at 5wt. % which reach to the value 28.46 kJ/m2 and goes down with increased the content ratios percentage of the third polymer material (PMMA) and this associated to chain structure of PMMA material which has chemical structure of PMMA chain with the presence of two groups (ch3 and cooch3) on every second carbon atom of repeat units for the main carbon chain gave major hindrance of the movement of chains and thus makes polymer blends relatively rigid behave and low fracture toughness [14 and 7].

3.3 Morphology of Fracture Surface

The morphology of the fracture surface for neat pp and ternary polymeric blends is absorbed by
SEM. The main point to phase morphology depends on nature components, components ratio, component melt viscosities, and processing conditions. Morphology of fracture surface of the modified polymer blend (PP: 5% PMMA) and (PP: 10% UHMWPE), which were compatibilized with constant ratio (1%) of compatibilizer material ((PP-g-MA), Figure 8 shows the morphology of fracture surface for these blends at magnification (2000X) and (5000X). It can be seen a different morphology. Fig.8 (a and b) show that the fracture surface morphology for neat PP is smoother, featuring a brittle fracture this result is in a good agreement with other workers result [18]. Fig.8 (c and d) showed good disperse for PMMA material and UHMWPE material (Fig. 8 (e and f)) in the morphology of polymer blend, as well as, this figure clearly showed two different morphology for these polymeric blends which depend on natural of components and components ratios in these blends. A homogeneous co-continuous structural morphology has appeared. Furthermore, it does not observe any new phase emergence or phase separated dominants. As well as, it was observed from this morphology that, the most of the second materials are embedded inside the matrix material, which acts as an integral part of the polymer blend structure, indicating to the good adhesion between components of blend materials. And this indicated to a perfect compatibility between the constituents of polymer blend which enhances the mechanical properties [19]. The different in morphological compositions of the different components of the polymer blend is reflected in the different properties it provides. The addition of compatibilizer (1% (PP-g-MA)) produced regular shaped and relative uniformly sized of the dispersed phase. The consistency of the shape and size of the domains caused by the addition of compatibilizer is believed to be the result of reduced coherence between the components of the polymer blends due to the steric stabilizing role of the compatibilizer [21]. It is widely known that a compatibilizer has two main functions of control in the morphology of mixing, i.e., prevent coalescence and reduce surface tension [20].

4. Conclusion

1. All the characteristics vibration bands of neat polypropylene are presented in (FTIR) spectrum of ternary polymer blend (PP:1%PP-g-MA: %PMMA) and (PP:1%PP-g-MA: %UHMWPE), with several peaks related to PMMA and UHMWPE are observed in all samples of these polymer blends, on the other hand, no other new peak or peak shifts were observed, only decrease in peak intensity with increasing PMMA and UHMWPE ratios in the blends.

2. Flexural properties (flexural strength and flexural modulus) were high at low percentage of addition for the first group (PP:1%PP-g-MA: %PMMA) and second group (PP:1%PP-g-MA: %UHMWPE) of the ternary polymer blends.

3. Impact and fracture toughness characteristics of second group [PP: 1% (PP-g-MA): %UHMWPE] showed higher values compared with the first group [PP: 1% (PP-g-MA): %PMMA] due to structure between PMMA and UHMWPE.

4. The addition of compatibilizer (PP-g-MA) at 1% ratio produced regular morphology of a polymer blends and with uniformly dispersed of second phase in the blends. So, (PP-g-MA) compatibilizer has two main roles in the control of morphology of a blend and prevention coalescence reduction of interfacial tension.
Table (1): Components ratios for the prepared samples

| Samples | Weight Percentages |
|---------|--------------------|
| Neat PP | 100:0:0            |
| PP-g-MA): x% | 5 | 9:1:10 | 15 | 20 |
| PP-g-MA): x% PMMA | 5 | 9:1:10 | 15 | 20 |

Table (2): Extrusion parameters

| Polymer systems | Temperature (ºC) | d (rpm) |
|-----------------|------------------|---------|
| Zone1 | Zone 2 | Zone 3 |
| Neat PP | 190 | 200 | 210 | 45 |
| PP: 1% (PP-g-MA): x% UHMWPE | 190 | 200 | 210 | 45 |
| PP: 1% (PP-g-MA): x% PMMA | 195 | 205 | 210 | 45 |

Figure 1: FTIR spectrum for neat polypropylene material

Figure (2): FTIR spectrum of neat PP and polymeric blends (PP:1% (PP-g-MA): x% PMMA) as a function of PMMA content in blend
Figure (3): FTIR spectrum of neat PP and polymeric blends (PP:1% (PP-g-MA): x% UHMWPE) as a function of UHMWPE content in blend.

Figure 4: Flexural strength of ternary polymer blends as a function of PMMA or UHMWPE content in the blend.

Figure 5: Flexural modulus of ternary polymer blends as a function of PMMA or UHMWPE content in the blend.

Figure 6: Impact strength of ternary polymer blends as a function of PMMA or UHMWPE content in the blend.
Figure 7: Fracture toughness of ternary polymer blends as a function of PMMA or UHMWPE content in the blend.

Figure (8): SEM fracture surface morphology of (a) and (b): Neat PP, (c) and (d): ternary polymer blend [PP: 1% (PP-g-MA): 5%PMMA] and (e) and (f): ternary polymer blend [PP: 1% (PP-g-MA): 10%UHMWPE], where: (a), (c) and (e) magnification of (2000X), and (b), (d) and (f) magnification at (5000X).

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