



Review Article

Study the Effect of Polystyrene on Ground Tire Rubber / High Density Polyethylene Compatibility

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Abstract: This paper deals with the study of properties for recycling tires toughening thermoplastic polymer. Large amounts of waste that arise daily as a result of scientific and technological progress with increasing humane consumer goods. This gave rise to the problem of the accumulation of the waste and its effect on the environment. So many researchers work to use this waste in useful products, and thus can achieve economic and environmental goals. The objectives of this study are to incorporate ground tire rubber (GTR) waste scrap into a thermoplastic matrix, recycled high density polyethylene (rHDPE) to improve the weakness of the mechanical properties due to the lack of compatibility between two polymers, a surface treatment was achieved by recycled polystyrene solution to increase the bonding between rHDPE and GTR and the properties of the blend were determined and compared. Several tests were conducted to determine the specifications of the resulting mixture with addition different ratios of GTR, such as tensile strength, bending strength, hardness, density, optical microscope examination and scanning electron microscope. The results show that the results showed improvement in tensile strength, bending strength and hardness, on the other hand, a decrease in elongation comparing with untreated samples.

Keywords: Recycled High Density Polyethylene, Ground Tire Rubber, Recycled Polystyrene Solution, Compatibility

1. Introduction

Plastics have been widely used because their advantages as lightness, hygiene, endurance, design adaptability and cheapness [1]. The accumulation of large amounts of plastic waste caused by increase in the use of plastic materials such as PS, PET, PE, PVC and PP and their derivative from these types of plastic, it is considered a major cause of pollution in the world [2, 3].

The large amount of waste produced worldwide is a growing environmental problem that has to be appropriately managed in order to achieve a more sustainable society. One way to reduce waste is to recycle materials, such as paper, glass, metals and polymers, in closed loop systems, where the same material is used several times. [4]

The generation of waste tire rubber has increased dramatically with the rapid development of vehicles [5, 6]. The disposal of worn tires and their economic recycling mean a great challenge nowadays. Material recycling is the

preferred way supported by legislative actions and economical / ecological arguments [7].

The reused of the tire rubber (TR) powder as an elastomeric phase dispersed in a thermoplastic matrix offers an opportunity to design second generation materials, which would be recyclable due to the thermoplastic matrix and which potentially could present thermoplastic elastomer-like mechanical behaviour [8].

It is generally believed that the interfacial adhesion between the dispersed rubber particles and the polymer matrix plays an important role in the toughening of polymer. In general, the addition of WRP to polymer causes considerable deterioration of the mechanical properties because of low compatibility and poor interfacial adhesion between the WRP and polymer [9]. Several attempts were made to improve the interfacial compatibility of plastic matrix and waste rubber powder disperse phase with compatibilizers, such as ethylene vinyl acetate copolymer [10].

In many cases when interfacial adhesion is not enough,

some pretreatments are applied in order to achieve better results.

- High-energy radiation, such as plasma, corona, and electron-beam radiation [11].
- Reactive gas treatment. Surface activation by a reactive gas treatment (e.g., a mixture of halogens and oxygen) [12].
- Chlorination. Chlorination with trichloroisocyanuric acid has been reported to be a very effective way of modifying the GTR surface and making it more polar [13].
- Surface grafting. The interfacial adhesion can also be improved by the grafting of different monomers onto the GTR surface [14].

2. Experimental Part

2.1. Materials

Recycled high density polyethylene (rHDPE) was obtained from Babylon fabric factory as granular materials, Iraq. Recycled polystyrene (rPS) was obtained from disposable polystyrene dishes. Ground tire rubber (GTR) was obtained by Babylon tires factory, Iraq

2.2. Recycled Polystyrene Solution Treatment

Recycled polystyrene used in research added as solution preparing by washing the dishes with water and then dried at room temperature. Chopping dishes by using cutting machine I and dissolves cutting polystyrene in toluene for (24 hours) at room temperature. The rPS solution treatment achieved by immersion GTR in rPS solution for (10 min) at room temperature and drying the powder at room temperature to evaporate the solvent. For removes all solvent the powder dried in air for (24 hour).

2.3. Preparation of Samples

rHDPE/GTR blends contain varying rubber ratio (10, 20, 30 and 40 wt%) then prepared from untreated and treated rubber. The mixing process was carried out in a two-roll mill heated at 150 °C. The sheets were prepared by hot pressing process using thermal hydraulic pressing, with controlled condition that the temperature (170°C) and the pressure (10 Mpa) for time (15 min). The cooling step was carried out under pressure for (5 min).

2.4. Apparatus

Mechanical properties

Tensile tests is performed on the sample were cut according to the ASTM D638 Type IV specimen dimensions, by machine used for the testing of tensile properties is micro computer controlled electronic universal testing machine model (WDW-5E), to determined tensile strength and the percentage of elongation. The bending strength is performed on the sample were cut according to the ASTM D790, tested using a three point test instrument, model (WDW-5E).

The Fourier transform infrared (FTIR) spectra were recorded on a FTIR 8400S-Perkin-Elmer spectrophotometer. The samples were pressed into tablets with KBr.

Density test is performed using (Matsu Haku, China, HIGH Precision DENSITY TESTER GP-120S with digital accuracy = 0.0001 g/cm³). Which contain water at room temperature and the measure based on Archimedes low.

Analytical Scanning Electron Microscope (SEM), model (JEOL 6400 F) used to examine the morphology of polymer blends composites.

Digital microscope is performed on the blended samples (model AM4815T Dino-Lite Edge) to show the morphology of the blend.

Hardness test is performed on the sample using Shore D with ASTM-D570 standard at room temperature in order to analyze the effect of ground tire rubber on the rHDPE hardness.

3. Result and Discussion

3.1. Mechanical Tests Results

The effect of the pre-treatments on the mechanical properties of treated and untreated reference samples are shown in fig. 1. The tensile strength values fig. 1 show a significant decrease when increase the tire contain, This decrease of mechanical performances could be ascribed to poor interfacial adhesion between the recycled high density polyethylene and ground tire rubber. Observed increase in tensile strength after pre-treatment the ground tire rubber GTR with recycled polystyrene rPS (GTR/rPS) when added to rHDPE, this due to the PS with as compatible agent covered the rubber particle lead to increase the bonding between the rubber and polymer.

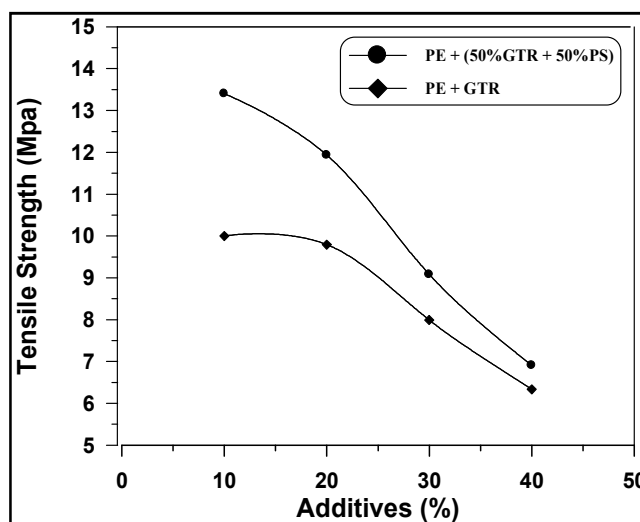


Fig. 1. Effect of ground tire rubber(GTR+rPS) percentage on the tensile strength of rHDPE blend.

The elongation decreases as the ground tire rubber ratio increased due to the polystyrene act as compatible materials which increasing the bonding between polymer and GTR

particles, as show in fig. 2. The bending strength also increases when added the GTR coated by PS to the rHDPE as compared with untreated (GTR+rHDPE) blend, as show in fig. 3.

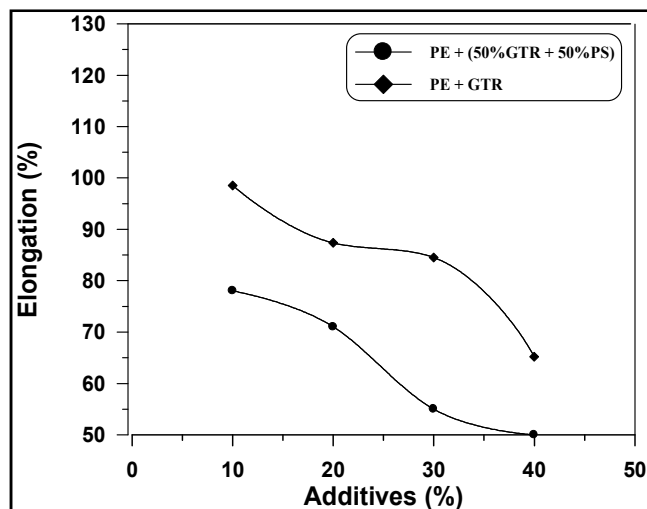


Fig. 2. Effect of ground tyre rubber(GTR+rPS) percentage on the elongation of rHDPE blend.

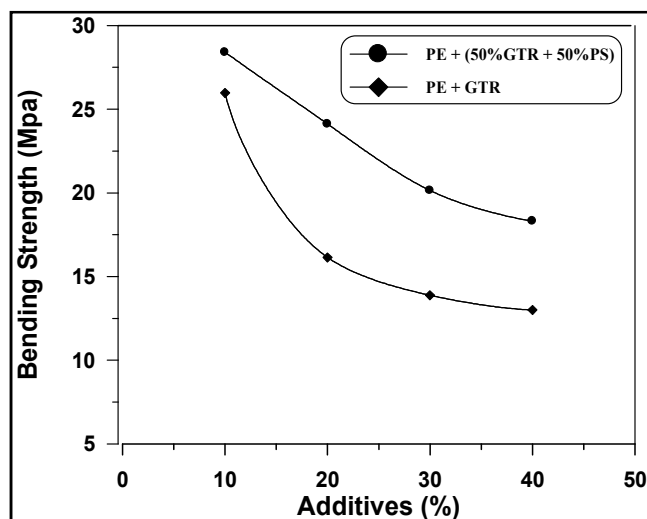


Fig. 3. Effect of ground tyre rubber(GTR+rPS) percentage on the strength of rHDPE blend.

Table 1. Bonds wave number of ground tire rubber.

Type of bond	Stander pure GTR peak [15]/cm ⁻¹	Exp. pure GTR peak/cm ⁻¹
CH ₂ ; CH ₃ stretching	2996–2855	2964
		2926
		2852.72
C=C stretching	1663	1647.21
C–H bending	1452	1454
C–H bending	1376	1369.46
C-S bond	1540	1538

Fig. 4, show the particle size distribution of ground tire rubber for weight, the total weight of the ground tires rubber (100g), The weight uses after sieving at particle size (425,

300, 212, 180) are (45.45g) and the residual (54.55g).

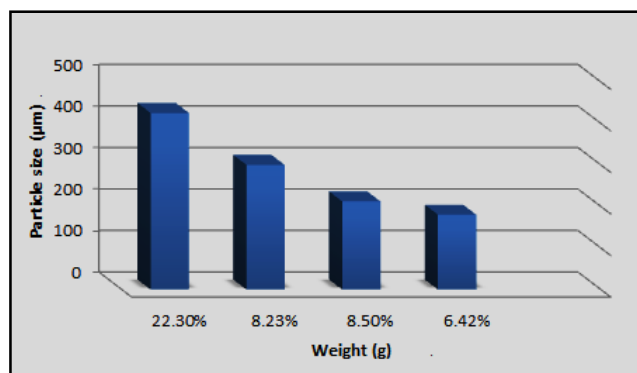


Fig. 4. The particle size distribution of ground tire rubber (GTR%).

3.2. FTIR Analysis

The attenuated total reflectance FTIR spectra of GTR, rHDPE, GTR/rHDPE are shown in fig. 5. In table 1 shows investigation of FTIR spectra of ground tire rubber in four main regions helps in successive interpretation and characterization of the key bands. The region were as follows: the region between 2964 and 2852.72 cm⁻¹ for CH₂, CH₃, and the band in the region 1647.21 cm⁻¹ represent the C=C stretching. The bands 1454 and 1369.46 cm⁻¹ for C-H bending, and the weak band at 1538.7 cm⁻¹ to zinc sterate an anti-adherent compound.

The FTIR spectrum of rHDPE It is clear from table 2 shows the peak at 2920 and 2854 cm⁻¹ corresponds to C–H stretching, the bands at 1467cm⁻¹ are assigned to CH₂ bending, the peaks at 1125 cm⁻¹ are attributed to C-C bending stretching. The band 723.31 cm⁻¹ for (CH₃ rocking),the band at 1088 cm⁻¹ was assigned to the (C-C stretching) and the band in region 1305 cm⁻¹ for(C-H bending),finally the band at 1363.67 cm⁻¹ which assigned to (CH₃ group of high density polyethylene).

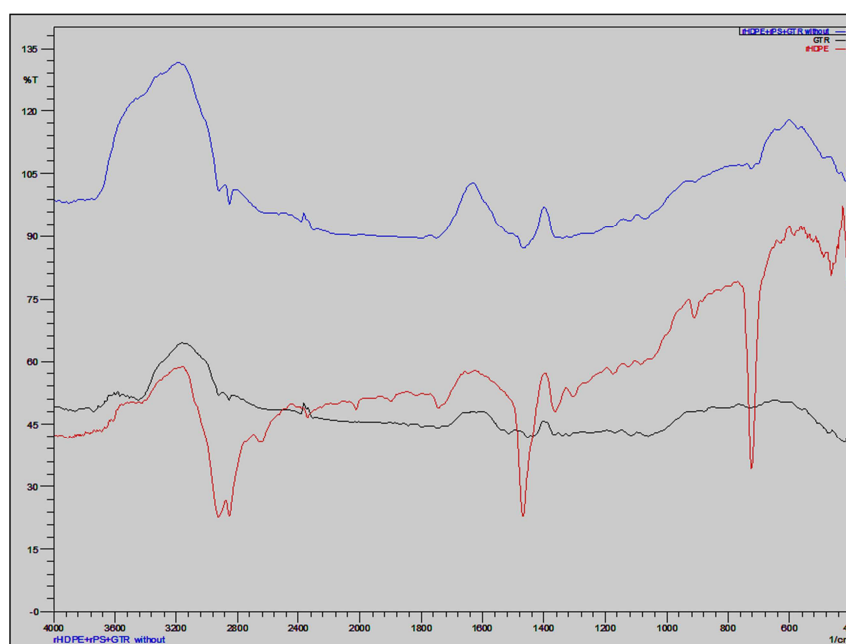
The FTIR spectrum of the blend of the GTR+PS with rHDPE observed the bands 2922.16 cm⁻¹ and 2848.86 cm⁻¹ shifted to 2920.23 cm⁻¹ and 2850.79 cm⁻¹ respectively, the band at 1467 cm⁻¹ shifted to 1467.83 cm⁻¹, the band at 721.38 cm⁻¹ shifted to 723.31 cm⁻¹, the band at 1124.5 cm⁻¹ shifted to 1118.71 cm⁻¹, the band at 1074.35 cm⁻¹ shifted to 1070.49 cm⁻¹, and the band at 1365.6 cm⁻¹ shifted to 1361.74 cm⁻¹, as shown in table 3.

Table 2. Bonds wave number of recycled high density polyethylene.

Type of bond	Stander rHDPE peak [15, 16]/cm ⁻¹	Exp. rHDPE peak/cm ⁻¹
CH ₂ stretching	2927	2920
	2852	2854
CH ₂ bending	1475-1463	1467
CH ₂ rocking	730-720	723.31
C-C bending-stretching	1130	1125
C-C stretching	1061	1088
C-H bending	1303	1305
CH ₃ Group	1368	1363.67

Table 3. Bonds wave number of GTR/rPS with rHDPE.

Type of bond	Stander rHDPE peak [15, 16]/cm ⁻¹	Exp. rHDPE peak/cm ⁻¹	rHDPE+GTR without peak/cm ⁻¹	rHDPE+ GTR+rPS peak/cm ⁻¹
CH ₂ stretching	2927	2920	2922.16	2920.23
	2852	2854	2848.86	2850.79
CH ₂ bending	1475-1463	1467	1467	1467.83
CH ₂ rocking	730-720	723.31	721.38	723.31
C-H bend- stretch	1130	1125	1124.5	1118.71
C-C stretching	1061	1088	1074.35	1070.49
C-H bending	1303	1305	1309.67	1309.67
CH ₃ group	1368	1363.67	1365.6	1361.74

**Fig. 5.** FTIR spectra of GTR/rPS with rHDPE particle.

The effect of the treatment of ground tire rubber with polystyrene as a binder factor in order to enhance the compatibility between rHDPE and GTR, observed shifting spectra to lower wave number due to physical interaction between polymers and ground tyre rubber.

3.3. Density Test

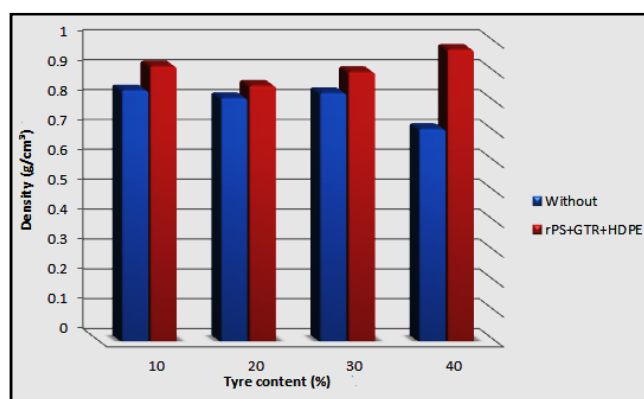
**Fig. 6.** Effect of GTR+rPS on rHDPE blend density.

Fig. 6 shows the density behavior of GTR/rHDPE blends as increasing ground tire rubber percentage, the density decreasing due to the presence of ground tire rubber between the polymer chains have low density.

In the case GTR/rPS with rHDPE blends as increasing ground tire rubber percentage, the density increasing as compared with untreated blend this is due to the high density of PS in the blend.

3.4. Scanning Electronic Microscopy

Microstructure of the blends was evaluated by SEM, fig 7 and 8. Untreated rHDPE+GTR blend appears smooth surface and the reinforcement material clearly show without any adherences with the matrix and can distinguished it clearly in fracture, so this particles unsuitable for mechanical adhesion this is the reason for a weak mechanical properties of the blend.

The treatment of GTR with rPS doing to encapsulates the particle of GTR and provides good dispersion of GTR in rPS. and also considered as a binder between GTR and rHDPE, thus lead to good adhesion between them and lead to good mechanical properties.

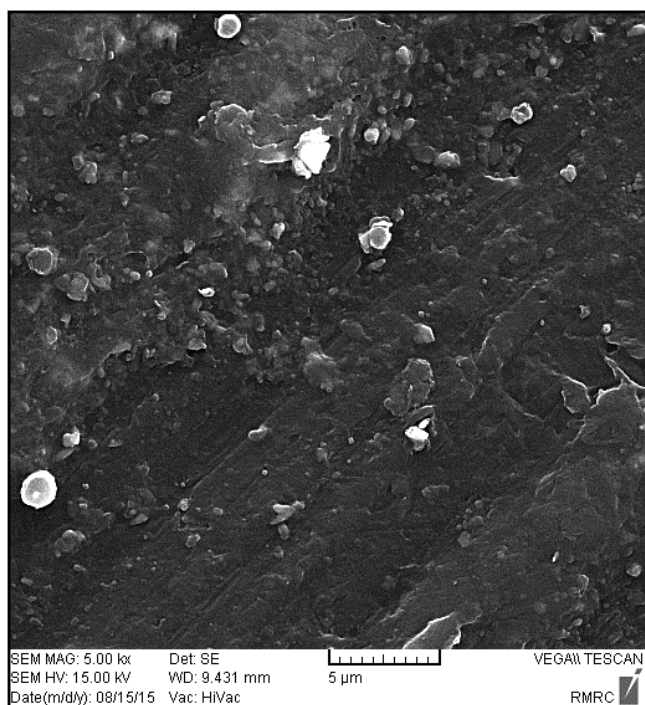


Fig. 7. SEM Image of untreated GTR/rHDPE blend.

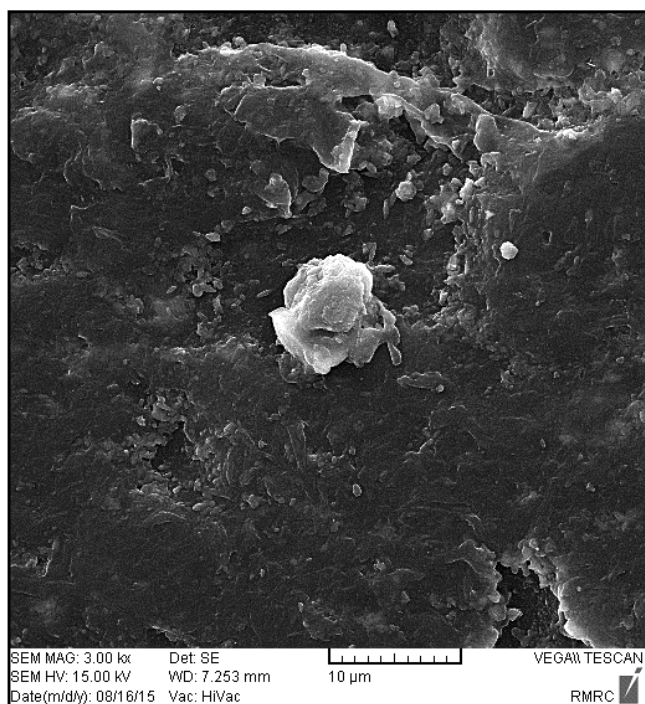


Fig. 8. SEM Images of GTR+rPS/rHDPE blend.

3.5. Morphology Result

The micrographs for blends containing 10 to 40 % GTR show a dispersed phase of GTR/rPS in the rHDPE matrix phase fig. 9. The results show that, good incorporating between polymers at percent 10 and 20% GTR, While show heterogeneity in surface morphology at percent 30 and 40% GTR due to weak interfacial adhesion between two polymers at increase the GTR.

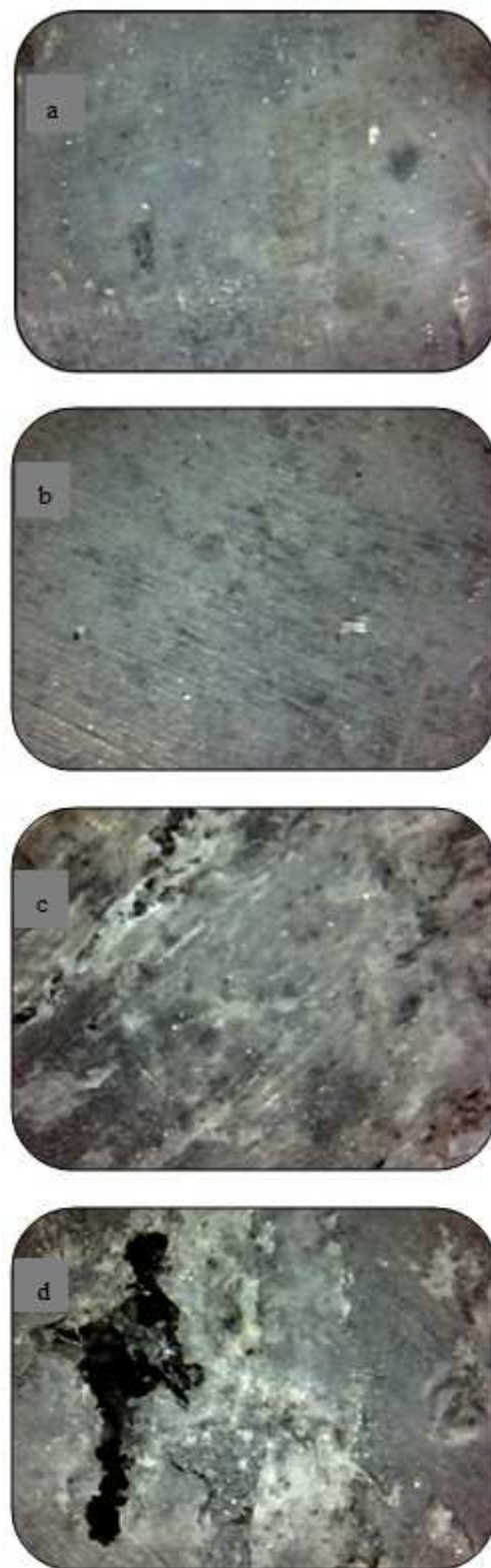


Fig. 9. Digital microscope ($\times 200$) (a) 10 GTR+rPS/90 rHDPE (b) 20 GTR+rPS/80 rHDPE (c) 30 GTR+rPS/ 70 rHDPE (d) 40 GTR+rPS/60 rHDPE.

3.6. Hardness Test

Results of hardness of the blends containing rHDPE/GTR are reported in fig. 10. Hardness of the blends was lower by

increase the ground tire rubber ratio as compared with pre-treatment of the ground tire rubber particle with recycled polystyrene (GTR/rPS) due to the polystyrene is a rigid material, and acts as a binder between rHDPE and GTR.

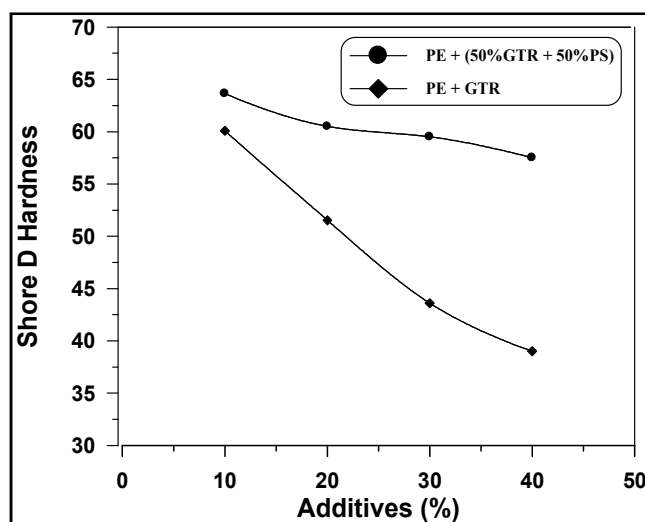


Fig. 10. Effect of ground tyre rubber(GTR+rPS) percentage on the hardness of rHDPE blend.

4. Conclusions

From this work we can summarize the following conclusions:

1. The pre-treatments GTR with rPS act improving the compatibility of the components resulting in better mechanical properties compared with untreated samples.
2. The tensile strength, bending strength and hardness increase while elongation decrease by treatment.
3. The mechanical properties increase by coating the tires particles with polystyrene.
4. FTIR spectrum of the blend shows lightly effect on the absorption band, which indicates that every treatment studied produces a specific physical modification on the ground tire rubber particles.
5. The density of the blend after pre-treatment has not seen a big change, while the density of the blend (GTR 50%+rPS 50%) with rHDPE increases.
6. Morphology test shows the homogenous of the blend after pre-treatment, in the case of the blend (GTR 50%+rPS 50%) with rHDPE the best morphology at percent at (10%, 20%).
7. SEM microphotographs show the better result after treatment.

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