Study of Some Properties for a Polypropylene with Short Polyamide Fiber and carbon black

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ABSTRACT - In the present work we investigated some properties of polypropylene composite material at processing temperature was varied from 170 °C to 200 °C for processing time ranged from 6 to 9 min, polyamide fiber and carbon black powder was blended with polypropylene with different weight ratios as a composite material model. The composite sheet of 150 mm length, 100 mm wide and 2 mm thickness are produce as a model using Hydraulic melt Press techniques. The obtained sheet was characterized by, melt flow index and water absorption, Thermogravimetric analysis was used to characterize the produced sheets interims of thermal stability and thermal degradation. The obtained results showed that the MFI decreased when both carbon black and polyamide fiber was introduced to polypropylene. percentage of water absorption increase with increase of the polyamide content. The thermal stability of polypropylene decreased when polyamide fiber and carbon black powder were added.

Key Words: Polypropylene composite, Polyamide fiber, melt flow index, water absorption, Thermogravimetric analysis.

1. Introduction

Polypropylene is the most produced polymer lately. It produces in different tacticities (atactic, isotactic, and syndiotactic polypropylene) and degree of crystallinity[1]. Generally, the isotactic and syndiotactic polypropylene have good rheological, mechanical and physical properties because of a high stereoregularity of its chains, which tend to increase the intermolecular forces and entanglements between the chains[2]. Polypropylene has been exploring importance in the last 20 years. The production of polypropylene continuous increasing nearly doubled quantity from 1.38 million tons in 1993 to 2.661 million tons in 2000 [3]. The increase in the production can be related to its advantages such as low price, easy production process with low energy consumption, good physical and mechanical properties, and excellent resistance against many chemicals. Polypropylene has been used in injection molding, extrusion, and film blowing processes due to the remarkable properties. However, polypropylene exhibits a poor impact resistance in specific applications particularly at relative low temperature. That is because of high degree of crystallinity and glass transition temperature (Tg), which eliminates its application in some fields[4]. For these reasons, polypropylene has blended with different polymers and impact modifiers to improve the impact strength [5].

Blending of incompatible polymer pairs are often prepared by extrusion mixing of two polymers having segments that may separately interact with each other [6]. Blending of

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polypropylene with polyamide fiber is a challenging task since combination of both polymers properties might be a promising way to generate a material with new characteristic. Both polymers are immiscible and form heterogeneous systems but may display good impact property. Several polymer processing are used to blend and manufacture of the plastic items[7]. Selection of polymer processing is dependent on many engineering parameter such as mass production, product complexity, materials specification, cost value and others. Injection, extrusion, calendaring and melt compression are among the polymer processing. The physical and the mechanical properties of the polymer blends depend strongly on the implemented polymer processing.

2. Material and Methods

Polypropylene random copolymer used in this work is classified as RA130E-1498 grade imported from SK Corporation, Korea. This grade complies with material requirements of DIN 8077, DIN 8078, and ISO 15874-1.2. Its melting temperature was 173°C and melt flow index was 10.25 g/10 min at 230°C and 2.16 kg. Its tensile stress at yield was 25mpa at 50mm/min. Its density at room temperature was 905 kg/m3. Polyamide fiber of a code number of 614.70.90 consists of very thin fiber with linear density (dtex) of 1400×2 and Twist yarn (T/M) of 390 ±152 obtained from Tires Manufacturing Plant. The polyamide fiber was grounded to small lengths ranged from 0.5 to 2 mm using Ball Miller equipment. Carbon black powder was also obtained from Tires Manufacturing Plant, Libya and used without any treatment or purification. Its specific gravity and its surface area at 20°C were 1.75 – 1.85 g/cm3. Its tensile strength was 5mpa, and 38 – 48 m2/g, respectively.

3. Results and Discussion

3.1 Melt flow index

The effect of the chemical composition of the produced sheets on the melt flow index (MFI) was studied. Experimental results of the melt flow index at different polypropylene, carbon black and polyamide contents are presented in Table.1 It is obviously that the MFI value of polypropylene decreases when both carbon black and polyamide fiber was introduced to polypropylene. Furthermore, when the polyamide fiber weight ratio was fixed at 0.061% and the carbon black was varied, the MFI was sharply drops. The value of MFI of reference polypropylene sheet was measured to be 13.68 g/10 min. This value decreases to 9.84 g/10 min when polyamide fiber and carbon black was mixed with polypropylene at weight percentages of 3.07% and 0.061%, respectively. MFI value continuous decreasing to 5.78 g/10 min when the polyamide fiber weight ratio was increased to 9.22% at constant carbon black percentage (0.061%). The melt flow index slightly decreases from 9.84 g/10 min to 8.94 g/10 min as the weight percentage of carbon black increase from 0.061% to 0.245% at a constant W% of polyamide fiber of 3.07%.

The decrease of MFI value with the increase of W% of polyamide fiber at constant carbon black could be attributed to: (1) adhesion of fibers with melted polypropylene, and (2) high melting point of the polyamide fiber compared with polypropylene which led to eliminate the mobility of the molten polypropylene chains, as a result, the melt flow index decreased. Generally, the melt flow index of the recycled polypropylene increased and the mechanical properties decreased when compared with virgin polypropylene, because of lower degree of chains entanglement caused by processing history. The obtained results showed that MFI decreased when polyamide fiber was introduced to polypropylene. That might encourage the application of fiber with recycling of polypropylene to improve certain properties. Mwaikambo and Ansell have reported similar results when linear low density polyethylene and high density polyethylene were mixed with fiber [8]. They showed that the MFI decreased with increasing the fiber content. They found such trend has substantial effects on molding operations such as extrusion process, the latter requires high flow ability of the polymer matrix.

Table.1 Melt flow index of polypropylene matrixes.

Sample No	Chemical composition (W%)			MFI (g/10 min)
	Polypropylene (W%)	Polyamide fiber (W%)	Carbon black powder (W%)	
1	100%	0.00%	0.000%	13.68
2	96.85%	3.07%	0.061%	9.84
3	90.70%	9.22%	0.061%	5.78
4	96.68%	3.07%	0.245%	8.94

3.2 Water absorption

polymers subjected to the water and high degree of humidity during summer . For this resin, it was of interest to measure the water absorbency as a function of the chemical composition. The water absorption of polypropylene composite was measured according to ASTM 570-98. The effect of the addition of carbon black powder and polyamide fiber to polypropylene on the water absorbency is investigated and the results are presented in Table.2 It is very clear that the percentage of polyamide in the polypropylene composite has dramatic effect on water absorption. The percentage of water absorption of 0.37% is measured when the polyamide ratio was 3.07%. This percentage increases to 2.93% when the polyamide ratio was increased to 12.29% at constant carbon black. Furthermore, insignificant effect of carbon black percentage on the percentage of water absorption was observed when the carbon black weight percentage was 0.061% and 0.298%. The value W% increases slightly to 0.46% with increasing the carbon black ratio to 0.298%.

Table.2 Percentage of water absorption of composition sheet

Sample No	Chemical composition (W%)			Percentage of water absorption%
	Polypropylene (%)	Polyamide fiber (%)	Carbon black powder (%)	
1	96.85%	3.07%	0.061%	0.37
2	87.63%	12.29%	0.061%	2.93
3	96.63%	3.07%	0.298%	0.46

The increase in the percentage of water absorption with increasing of the polyamide content could be attributed to: (1) presence of pores and gaps within the polypropylene-polyamide fiber-carbon black structure, and (2) polyamide contains nitrogen and oxygen in the chemical structure which may lead to from hydrogen bonding with water molecules. The slightly increase in the W% with increasing of carbon black ratio could be due to the presence of pores and gaps particularly at all the sample surfaces. Generally, polypropylene is classified as hydrophobic material with low water absorption of 0.13% and the measured water absorption is still very low which is below 3%.

Similar results were reported when water absorption of Jute fiber-reinforced polypropylene was studied and found that the W% increased with increased the Jute fiber content [9]. Other published work reported the effect of addition of Bamboo charcoal to polyolefin on the water absorption [10]. It showed that slightly increased in the water absorbency was achieved when charcoal content in the polymer matrix was increased.

3.3 Thermogravimetric measurements

Thermogravimetric analysis (TGA) was carried out for selected samples based on weight percentage of carbon black and polyamide fiber. In addition, polypropylene sample was also selected for comparison. The thermal analysis of polypropylene sample is conducted and the thermal stability was examined on the basis of percentage weight loss at different temperature from (TGA) thermogravimetric and compared to other polypropylene composed. The thermogravimetric curve of polypropylene is shown in Figure 1. From the Figure, it can be seen that the sample decompose within 1.17% weight loss in the first stage at which the temperature increased from 0.0-120 °C implying a loss of moisture content. After the initial weight loss due to the evaporation of the moisture content in the analyzed sample. There is insignificant weight loss in the sample until a temperature of 290 °C is attained. From 290 °C, there is a sharp weight loss percentage and it is completed at the temperature about 445 °C. This weight loss is due to the thermal degradation of polypropylene chains to small molecular weight such as H_2O and CO_2. The residue weight percentage of about 1.5% of the total weight of the polypropylene sample is recorded at 600 °C.
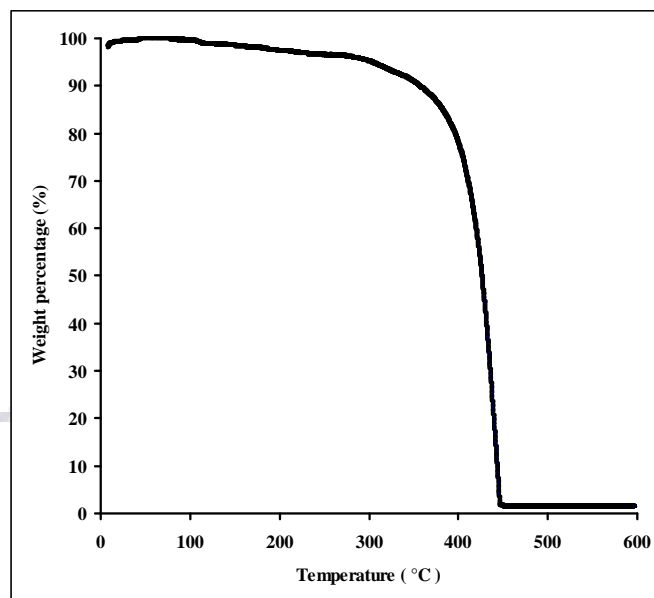
Figure .1: Thermogravimetric curve of polypropylene [heating rate = 10 ºC per min, under nitrogen gas atmosphere].

Thermogravimetric analysis of the sample consist of 84.54% Polypropylene, 15.38% polyamide fiber and 0.061% carbon black was carried out. Figure 2 shows the Thermogravimetric curve of the sample when heated from room temperature until 600 °C under N_2 gas atmosphere. The trend of the thermal degradation of this sample is different from the thermal degradation of polypropylene as the thermal degradation occurred in several stages. The polymer composite starts to degreed at relative lower temperature (about 190 °C) when compared with polypropylene sample. The percentage of weight loss of 21% was observed at about 260 °C. Furthermore, the percentage of weight loss of 65% at 340 °C is detected. At 450 °C and 600 °C the percentage of weight loss increases to 70.2% and 70.5%, respectively. In The stage were high weight loss percentage is measured was due to the degradation of the sample to small compound such as water vapor and other molecules. The residue at 600 °C (4%) represent the ash.

Thermogravimetric analysis of the sample consist of 96.63% Polypropylene, 3.07% polyamide fiber and 0.298% carbon black was carried out. Figure 3 shows the thermogravimetric curve of the sample when heated from room temperature until 600 °C under flow of N_2 gas atmosphere. The polymer composite starts to degrade at relative lower temperature (about 200 °C) when compared with polypropylene sample. The percentage of weight loss of 30.6% was observed at about 240 °C. Furthermore, the percentage of weight loss of 56.76% at 310 °C and 63.49% at 380 °C are detected. At 470 °C and 600 °C, the percentage of weight loss increases to 76.38% and 79.63%, respectively. The increase in the weight loss of the sample with the increase of the temperature from 200 °C to 310 °C is attributed to the thermal degradation of the polypropylene chains to small molecules such as H_2O. The slightly increase in the percentage of weight loss between 310 °C and 380 °C could be

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attributed to from thermal cross linking of the chain residue and the remained percentage of weight of about 20% at 600 °C can be characterized as an ash.
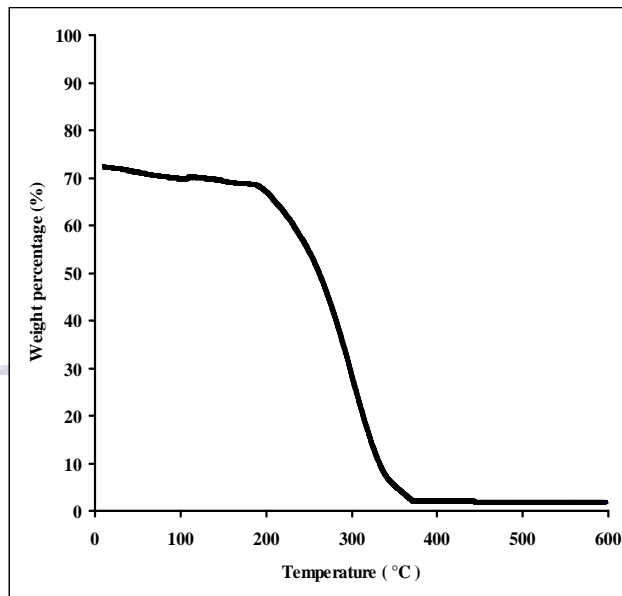

Figure. 2: Thermogravimetric curve of polypropylene composite [polypropylene = 84.54%, polyamide fiber = 15.38%, carbon black = 0.061%, heating rate = 10 ºC per min, under nitrogen gas atmosphere].
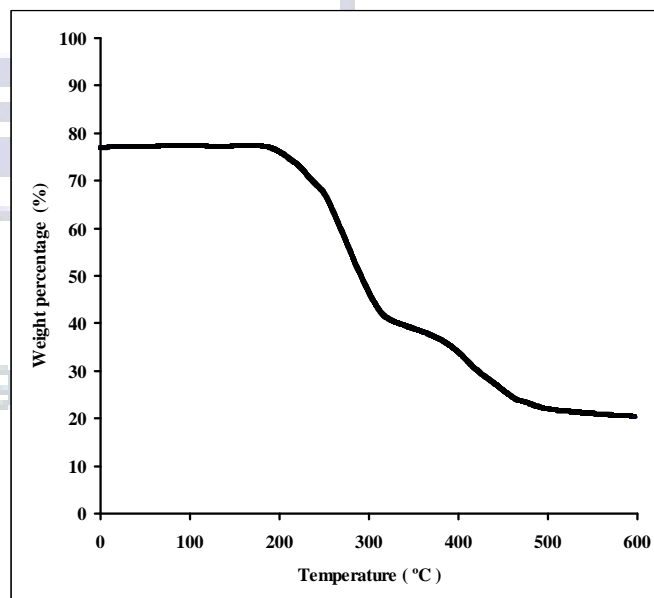

Figure .3: Thermogravimetric curve of polypropylene composite [polypropylene = 96.63%, polyamide fiber = 3.07%, carbon black = 0.298%, heating rate = 10 ºC per min, under nitrogen gas atmosphere].

The pyrolysis activation energy (E) of polypropylene, 96.63% Polypropylene-3.07% polyamide fiber-0.298% carbon black composite and 84.54 % Polypropylene-15.38% polyamide fiber-0.061% carbon black composite are calculated from TGA data accorded to the following mathematical equation [11].

$$-\ln\ln\left(\frac{1}{r}\right) = k - 0.457\,(\ln 10)\left(\frac{E}{RT}\right) \qquad (1)$$

Where r is the retained weight percentage, θ is the absolute temperature, E is the pyrolysis activation energy and R is the gas constant.

Plotting of - lnln (1/r) versus 1/θ calculation for the polypropylene data where thermal degradation was occurred is shown in Figure. 4. The obtained points were filled in to straight line with a regression factor of 0.79 (R^2 = 0.79). The pyrolysis activation energy of polypropylene was calculated from the slope of the filled straight line and found to be 8.95 KJ/mol.
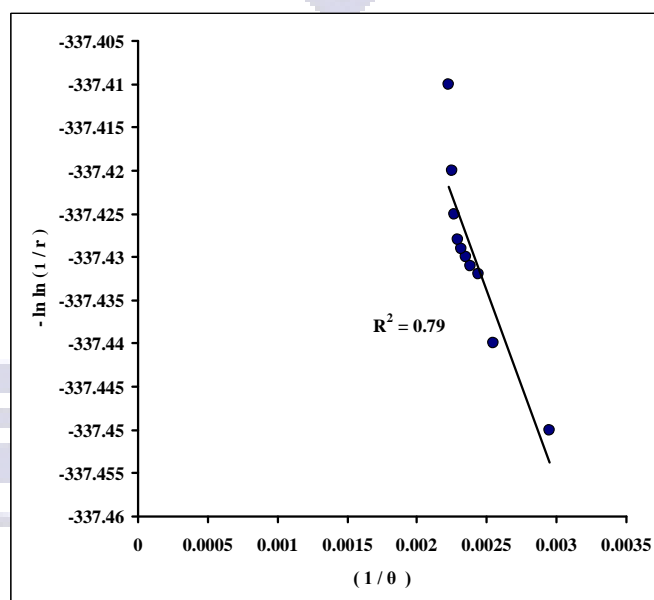

Figure .4: The relationship between - lnln (1/r) and 1/θ of polypropylene.

The relationship between - lnln (1/r) and 1/θ from TGA date for the sample composite of 84.54% Polypropylene, 15.38% polyamide fiber and 0.061% carbon black is plotted in Figure .5 and the pyrolysis activation energy is calculated using mathematical equation .1. The regression factor for the fitted straight line is 0.823 (R^2 = 0.823). The calculated pyrolysis activation energy for this sample is 5.039 KJ/ mol.
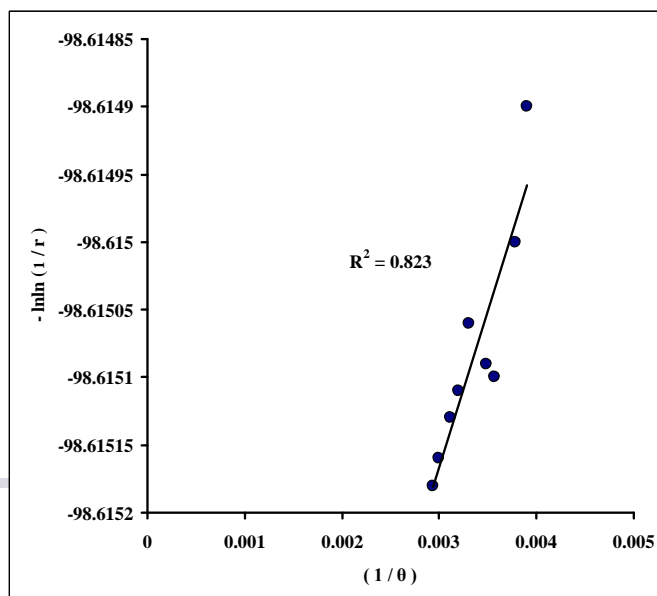
Figure .5: The relationship between - lnln (1/r) and 1/θ from TGA date for the sample composite of 84.54% Polypropylene, 15.38% polyamide fiber and 0.061% carbon black.

The relationship between the calculated - lnln (1/r) and 1/θ from TGA date for the sample composite of 96.63% Polypropylene, 3.07% polyamide fiber and 0.298% carbon black is plotted in Figure .6 the obtained data was also fitted to straight line and the pyrolysis activation energy is calculated using mathematical regression factor 0.987 ($R^2 = 0.987$). The calculated pyrolysis activation energy of the sample is 2.146 KJ/ mol.
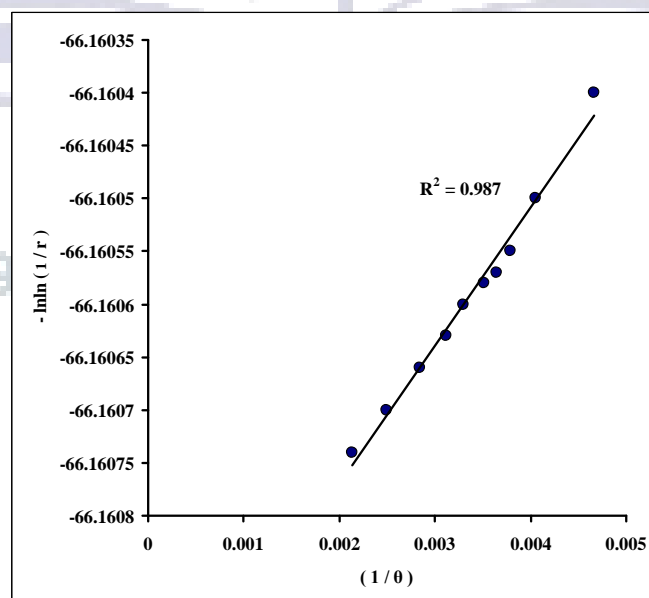

Figure .6: The relationship between - lnln (1/r) and 1/θ from TGA date for the sample composite of 96.63% Polypropylene, 3.07% polyamide fiber and 0.298% carbon black.

4. Conclusion

1. The Melt flow index decreased when both carbon black and polyamide fiber was introduced to polypropylene.

2. The Water absorption Increased with increasing of the polyamide content.

3. The thermal stability of polypropylene decreased when polyamide fiber and carbon black powder were added.

4. The pyrolysis activation energy of the polymer composite decreased when polyamide fiber content decreased.

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