Effect of Short Polyamide Fiber on Impact Property of Polypropylene Composite

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Abstract -*This work aimed at the investigation of the effects of the addition of a short polyamide fiber and carbon black powder on the impact strength and the surface hardness of polypropylene composite. The composite sheets were produced by using compression mould technique at different processing temperatures and times. The weight percentage of both polyamide fiber and carbon black in the composite were varied. The obtained results illustrated that processing temperature and time had insignificant effects on the surface hardness. The optimum fiber and carbon black contents under the experimental conditions were 9.22% and 0.245%, respectively. Processing temperature, fiber content and carbon black content had a reverse effect on the impact strength of the composite while the maximum value of the impact strength of 23.63 Kj.m^{-2} was recorded when the composite heated up to 7 min.* .

Key Words: Polypropylene composite, Polyamide fiber, Melt flow index, Impact strength, Hardness.

1. INTRODUCTION

There is extremely need to carry out more studies on the modification of polymer properties in order to extend their applications. Polypropylene is among thermoplastic polymers and has broad applications. Preference is given to propylene for its bulk, inert nature and low density. It has been used as a main matrix for fiber-reinforced polypropylene composites. Synthetic fiber-reinforced polypropylene composites have raised tremendous interest among materials scientists and engineers in last decades due to their desirable physical and mechanical properties. Lately, we can observe their applications in almost every industrial application; including constructions, aerospace, automotives, marine, furniture, carpet and blankets. Generally, synthetic fiber is known to exhibit good mechanical properties and blending the fiber with polymer matrix could lead to potential improvement of some composite mechanical properties. Quazi and his colleagues have reviewed the mechanical properties of polypropylene composites containing synthetic or natural fibers [1]. They have concluded that the mechanical properties of polypropylene composite vary according to fiber nature and content. In addition, synthetic polypropylene fiber composites have greater mechanical properties than that of natural polypropylene fibers composites.

Impact strength and hardness are some of the mechanical properties that are considered significant for fiber reinforced polymer composites. Previous studies have revealed how nature and type of fiber such as wood fiber [2] plant and animal based natural fibers [3], natural lingo-cellulose [4], jute fiber [5], flax fiber [6] affect the impact property of polypropylene composite. These properties also varied with processing temperature, processing time and chemical composition [5]. Introduction of fiber plays an important role in the impact resistance of the composite as it interacts with the crack formation and act as stress transferring medium [7]. Due to the fact that synthetic fibers have the ability to absorb high energy during impact than the natural fibers, Ruhul and his co-workers have revealed poor fiber matrix adhesion for jute-based composites when compared to that of the E-glass fiber composites [8] .

Disadvantages of reinforcement of the polymers by natural fibers resulted from biodegradation and UV-degradation of natural fibers in long-term composite applications, decomposition of natural fiber at relative high processing temperatures and duration of thermal exposure, in addition to high moisture absorption [5]. Biodegradability and moisture absorption characteristics of the natural fibers could eliminate their application in the polymer composites particularly in products intended for long term use.

Strong fiber with high failure strain imparts high work of fracture on the composite. The major drawback associated with the use of fibers as reinforcement in polypropylene matrix is mainly dependent on interfacial bonding between the fiber and the polymer. Previously published work showed that the addition of polyamide finer and carbon black to polypropylene matrix has affected the composite tensile properties. The degree of the enhancement was dependent on the weight percentage of polyamide fiber and carbon black and processing temperature and time [9]. The aim of the present work is to study the effect of addition of polyamide fiber to polypropylene matrix on impact strength of the composite. In general, there are several polymer processes used in blending and manufacturing of composites. A selection of polymer processing is dependent on several parameters such as mass production, product complexity, product specification and cost. The physical and the mechanical properties in addition to the performance efficiency of the composites are strongly dependent on manufacturing operational parameters of the process and the chemical composition of the blends. The effects of processing temperature and time and chemical composition of the composite, produced by hot press compression method, on the impact strength of the composite are evaluated. Carbon black is used in this work in very small weight percentage as ultraviolent radiation stabilizer.

2. MATERIALS AND METHODS

2.1 Materials

Polypropylene random copolymer used in this work is classified as RA130E-1498 grade imported from SK Corporation, Korea. Polyamide fiber with a code number of 614.70.90 and carbon black powder were obtained from Tires Manufacturing Plant-Libya, as gift. The polyamide fiber was grounded to small pieces with length range from 0.5 mm to 2 mm using Ball Miller equipment. Carbon black powder of specific gravity and surface area at 20^{o}C were 1.75 – 1.85 g/cm^3 and 38 – 48 m^2/g, respectively, has been used without any treatment.

2.2 Manufacturing of Composite Sheet

The composite sheets were manufactured according to the procedures described elsewhere [9]. The detail of the manufacturing process is described in this section. Due to the differences in the densities, shapes and sizes of the polypropylene pellets, carbon black powder and polyamide fiber, pre-treatment of the mixture was carried out. The mixture with specific weight ratio was physically mixed and heat at 100 ± 10^{o}C in thermostatic steel vessel for few minutes. This process was carried out to adhere both of the carbon black particles and the fiber on the surface of the polymer pellets. The obtained composite is used to produce a sheet using compression mould technique. Dimensions of mould were 150 mm x 100 mm x 2 mm. Pre-calculated weight of polypropylene, carbon black powder and polyamide fiber were added to the middle of the sheet mould which previously placed on the lower plate of a compression machine. The top and the bottom surfaces of the mould covered by polyamide film obtained from local market to avoid adhesion of the polymer composite on the surfaces of the mould. The composite sheet was produced by using Hydraulic Press HNO.500-7 heated to certain temperature for specific period of time and pressed to 100 bars. The mould was then cooled to room temperature by immersion in water. The sheet was extracted from the mould prior to characterization.

Sheets of different compositions were produced at different processing temperature and time. The weight percentage of polyamide fiber was varied from 3.07% to 15.38% at constant carbon black weight percentage of 0.06%. The weight percentage of carbon black in the composite was also varied from 0.061% to 0.298% at constant fiber percentage of 3.07%. These percentages were calculated based on the weights of the materials in grams amount. The processing temperature for the preparation of the composite sheets was changed from 170^{o}C to 200^{o}C by the interval of 10oC and the processing time also changed from 6 min to 9 min by the interval of 1 min. Three sheets were prepared for each composition.

2.3 Composite Characterization

I. Melt Flow Index

Selected samples were subjected to melt flow index analysis (MFI). The composition of the selected samples were 100% polypropylene, polypropylene–polyamide–carbon black (90.70%, 9.22% 0.061%), polypropylene–polyamide–carbon black (96.68%, 3.07%, 0.245%) and polypropylene–polyamide–carbon black (96.85%, 3.07%, 0.061%). Melt flow index analysis is carried out according to ISO 1133 using melt Flow Modular at 2.16 kg load and 230^{o}C. The results of the analysis were reported as g/10 min.

II. Surface Hardness Analysis

The samples are analyzed using Shore Hardness Tester and the analysis was carried out according to ASTM D-2240. The obtained results reported as R-scale.

III. Izod Impact

Izod impact analysis is very important for quality control to determine the material impact property. The specimens were punched from the produced sheet and three specimens from each sheet were analyzed. The analysis was carried out according to ISO 179. The specimens were subjected to izod impact analysis using Izod Impact instrument RESIL-R.I.18844. The impact property was determined using 3 replicates for each composition and the average values were recorded.

3. RESULTS AND DISCUSSION

The melt flow index of the polymer composite for different polypropylene, polyamide fiber and carbon black contents are presented in Table 1. It is very clear that the melt flow index value of polypropylene decreases when both carbon black powder and polyamide fiber are introduced to the polymer matrix. The MFI value of the composite also decreases when the weight percentage of fiber and carbon black powder is increased in the composite. The decrease in the values of MFI could be attributed to the presence of fiber and carbon black with molten polypropylene and high melting point of polyamide which may lead to the elimination of the mobility of the polypropylene chains.

Table-1: Melt Flow Index of polypropylene composite.

Sample No.	Chemical composition (Wt%)			MFI (g/10 min)
	PP	PA fiber	CB	
1	100	0.00	0.00	13.68
2	96.85	3.07	0.061	9.84
3	96.68	3.07	0.245	8.94
4	90.70	9.22	0.061	5.78

Polypropylene (PP), Polyamide (PA), Carbon black (CB), Melt Flow Index (MFI).

Processing temperature of 160°C was insufficient to complete the melting of the composite under the experimental conditions. To avoid the presence of any thermal degradation of the polypropylene, Temperatures higher than 200°C were not studied. Table 2 shows the effect of processing temperature and processing time on the surface hardness of the composite. For sheets fabricating, the polypropylene composite (96.85% polypropylene, 3.07% fiber and 0.061% carbon black) were processed at different temperatures for 7 min and for different periods of time at 180°C. It can be noticed that both parameters have insignificant effects. The changes in the value of shore A with temperature and time are very limited within the range of ±3 shore A.

Table-2: Hardness of the composite sheets as a function of processing temperature and time.

Processing Temperature (°C)	Hardness (Shore A)	Processing Time (min)	Hardness (Shore A)
170	95	6	95
180	89	7	89
190	90	8	92
200	95	9	90

The surface hardness of the polymer composite is affected by the chemical composition of the composite. Fig. 1 presents the relationship between the weight percentages of polyamide fiber and the shore hardness. The results revealed that the optimum fiber content to obtain the higher value of hardness of 92 Shore A was 9.22%. There is also small increase in the value of Shore A with the increase of carbon black powder content up to 0.245% which is recorded to be the optimum carbon powder content (see Fig. 2). The increase in the value of the surface hardness with the increase of the carbon content up to the optimum may be attributed to the restriction of the mobility and deformability of the matrix macromolecules caused by high content of carbon black powder [10]. The decrease in the hardness with further increase of the fiber and carbon black contents could be due to the discontinuity of the polypropylene matrix.

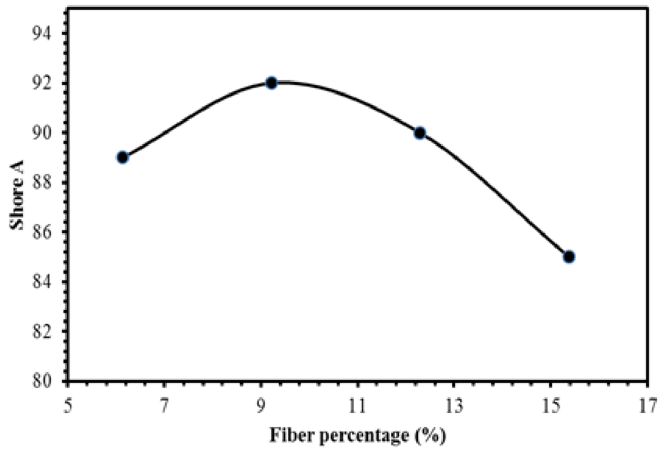

Fig-1: The effect of fiber content on surface hardness of the polymer composite [processing temperature 180°C: processing time 7 min: carbon content 0.061%].

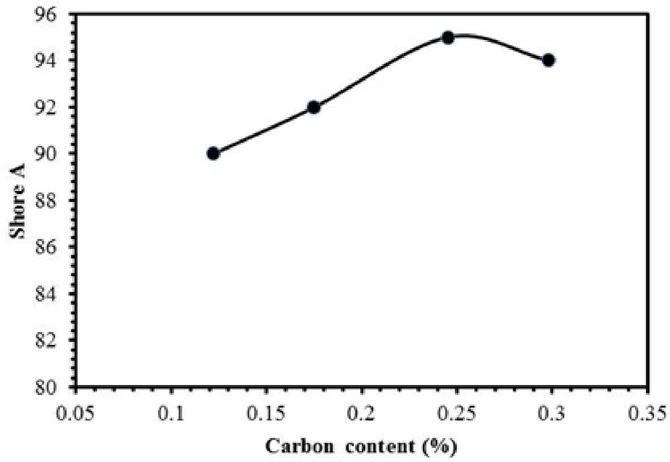

Fig-2: The effect of carbon black content on the surface hardness of the polymer composite [processing temperature 180°C: processing time 7 min: fiber content 3.07%].

The impact strength can be defined as the ability of a material to withstand fracture or the amount of energy required to propagate a crack. It depends on several factors such as fiber and polymer strength, load transfer efficiency, bonding strength, volume fraction, fiber distribution, and geometry [11]. It may also be affected by the processing parameters as the material subjected to heat for periods of time. Fig. 3 shows the effect of the processing temperature on the izod impact strength of the produced sheets. The recorded data is fit to a linear relationship with a regression factor of 0.993. The impact strength decreases when the processing temperature increased. The decrease in the impact could be attributed to the thermal history of the polypropylene chains during the processing which may have led to partially thermal degradation of the top and the bottom layers of the produced polypropylene sheets.

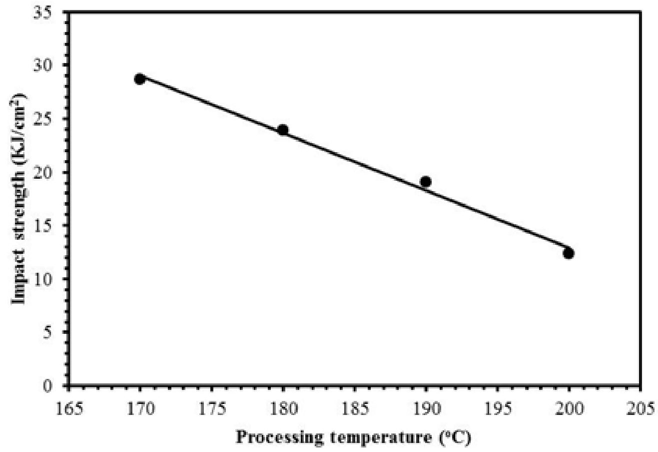

Fig-3: The relationship between processing temperature and impact strength [processing time 7 min: fiber content 3.07%: carbon content 0.061%].

The effect of the processing time on the impact property is also investigated and the result is presented in Fig. 4. The value of the impact strength increases with the increase of time up to 7 min then drops with further increase. The optimum value of the impact strength of 23.63 $Kj.m^{-2}$ was recorded when the composite was heated to 7 min. This led to the raise of the impact strength to about double the value of the sheet produced at 6 min heating time. This increase is due to the complete melting of polypropylene belts and achievement of a relative high adhesion between the composition and entanglement of polypropylene macromolecules. The decrease in the impact strength with further increase of time could be related to the movement of both carbon black particles and the fiber during the processing, particularly at higher time. That led to agglomerate both materials at certain sheet layers as a result of discontinuity in the polymer matrix and created weak areas in the sheet matrix.

Fig. 5 and Fig. 6 illustrate the effects of the percentages of fiber and carbon black powder contents on the impact strength, respectively. Similar trends in the obtained results for both effects are observed but with difference in the values of the impact strength. The impact strength decreases with the increase of the carbon black and polyamide fiber contents in the composite. The incorporation of carbon black powder has inverse effect on the impact strength of polypropylene but it is used as UV stabilizer. The reduction in the impact strength exhibited by the composite may be attributed to (1) the formation of agglomerates by the very fine fiber sizes, which made the dispersion of the fiber in polypropylene matrix difficult [12], (2) heterogeneous dispersion of the fiber resulting from the increasing fiber content and (3) a poor adhesion between the matrix and the fiber [11].

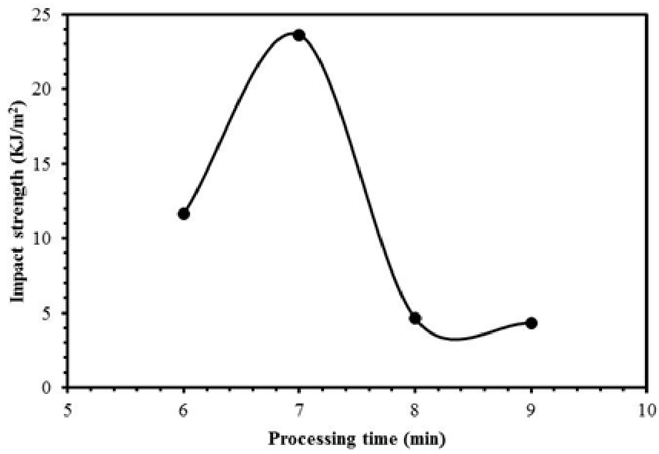

Fig-4: The effect of processing time on the impact property [processing temperature 180°C: fiber content 3.07%: carbon content 0.061%].

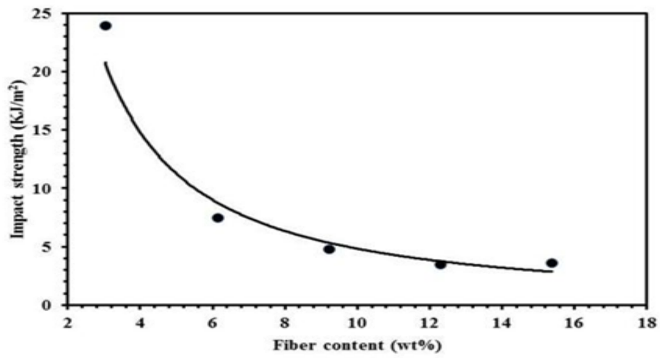

Fig-5: The effects of fiber content on the impact strength [processing temperature 180°C: processing time 7 min: carbon content 0.061%].

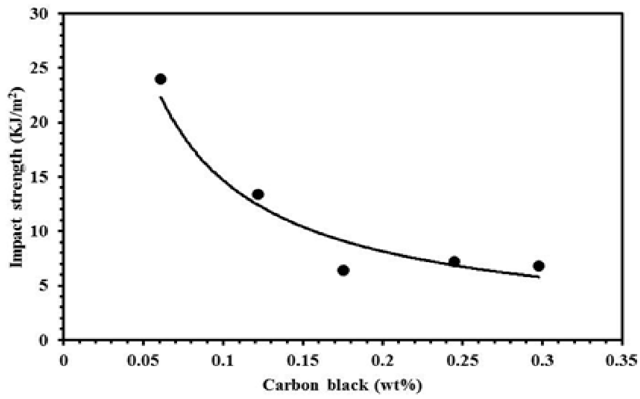

Fig-6: The effects of carbon black content on the impact strength [processing temperature 180°C: processing time 7 min: fiber content 3.07%].

4. CONCLUSIONS

The effects of short polyamide fiber and carbon black content on the impact strength, surface hardness and melt flow index properties of polyamide fiber-polypropylene composite are investigated in this study. Short polyamide fiber effectively affected the melt flow index, surface hardness and impact strength of the composite. The melt flow index of polypropylene decreased when both carbon black powder and polyamide fiber are introduced to the polymer matrix. Fiber and carbon black contents and processing temperature decreased the impact strength of the composite. Results showed that the surface hardness property of the composite was dependent on fiber and carbon black content. This composite can be used in automotive, home furnishing and construction applications.

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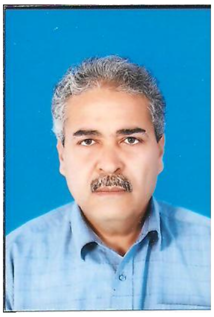
BIOGRAPHIES



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