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Charpy Impact Resistances of Carbon Nanotubes Reinforced High Density Polyethylene Nanocomposite Materials

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***Abstract*—In this study, Multiwall Carbon Nanotubes (MWCNT) reinforced High Density Polyethylene (HDPE) materials were used. Mechanical properties of the samples reinforced with Carbon Nanotubes at weight ratios of 1%, 3% and 5% were investigated. Reinforced samples were compared to samples produced with pure High density Polyethylene. Samples were produced by plastic injection method. The samples were then subjected to experiments and impact resistance values were measured in accordance with ASTM D6110 standards. Also Thermogravimetric Analyses (TGA) was performed for and Multi-Wall Carbon Nanotubes within the High Density Polyethylene. At the end of the study, it was observed that impact resistance decreased with increasing carbon nanotube reinforcement amount. Impact resistance of samples produced by means of plastic injection was decreased by 35% comparing with samples produced from pure HDPE. These results were explained with the fact that structures of composite materials were transformed to a tougher and fragile phase. In the TGA investigations, it was seen that mass loss breakdown temperature and melting point temperature increased by MCWNT ratio in the composite samples.**

***Index Terms*—Carbon nanotubes, high density polyethylene, nanocomposites, impact, TGA.**

I. INTRODUCTION

Since the documented discovery of CNTs in 1991 by Iijima [1] and the realization of their unique physical properties, including mechanical, thermal, and electrical, many investigators have endeavored to fabricate advanced CNT composite materials that exhibit one or more of these properties [2]-[4]. For example, as conductive filler in polymers, CNTs are quite effective compared to traditional carbon black microparticles, primarily due to their large aspect ratios [5]. Similarly, CNTs possess one of the highest thermal conductivities known [6], which suggests their use in composites for thermal management [2].

The main focus of this paper, however, will be on the use of CNTs as discontinuous reinforcement for polymer matrices. The CNT can be thought of as the ultimate carbon fiber with break strengths reported as high as 200 GPa, and elastic module in the 1TPa range [7], [8].

CNTs are graphitic sheets rolled into seamless tubes (i.e. arrangements of carbon hexagons into tube like fullerenes) having a diameter ranging from about a nanometer to tens of nanometers with lengths up to centimeters. Both theoretical and experimental studies have shown CNTs to have extremely high tensile module (>1 TPa for single walled carbon nanotubes, SWCNTs) and tensile strengths of the order of 500 GPa [9], [10]. Carbon nanotubes are thermally stable up to over 2400°C in vacuum, have a thermal conductivity along their principal axes about double than that of diamond and electric-current-carrying capacity up to 1000 times higher than copper wire. Due to their extraordinary mechanical, electrical and optical properties together with their low density (1.3-2.4 g/cm^3), CNTs have attracted great attention in recent years in the field of composites materials. As the structure and properties of the CNTs have been understood, there is a pressing need to transfer their outstanding properties from nano to micro/macro-scales. One essential step towards this goal is their processing, which often involves dispersing them in a polymeric matrix to form complex materials such as polymer-CNTs nanocomposites. These composites represent the first realized major commercial application of CNTs [11].

The addition of nanostructured materials, such as CNTs, to polymers offers a viable means of altering the mechanical [12], [13], thermal [3]-[14] and electrical [15], [16] properties of polymer-based composite materials. The resulting properties include tensile strengths of 100–600 GPa, a density of around 1.3 g/cm^3, elastic module of 200–5000 GPa and fracture strains of 10–30% [17], [18]. CNTs have desirable mechanical properties that make them particularly attractive for strengthening polymers [19].

II. MATERIALS AND METHODS

This section with High Density Polyethylene multiwalled carbon nanotube formed into a composite material which comprises the experiments. Properties of carbon nanotube are given at Table I, and properties of thermoplastic matrix are given at Table II.

The samples used in this study, is available from Fibermax Composites Multi-Walled Carbon Nanotubes with PETKİM Petrochemical Holding CO. is located in Izmir Aliaga. Quality Control and Technical Services Manager facilities are connected to the work done, again obtained from PETKİM F00556 combined with High Density Polyethylene was granulated.

Impact test samples were produced within the required

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measures to be implemented in accordance with the ASTM D6110 standard. Granules were produced in the sample by pressing the plastic injection molding machine. These samples were subjected to tests according to standard ASTM D6110. Thermogravimetric Analysis (TGA) was performed according to the ASTM E1131 standard.

TABLE I: THE PHYSICAL PROPERTIES OF MWCNT

Average Diameter	10-40 nm
Length	1-25μm
Purity	Min. 93%
Specific Surface Area	150-250 mm^2

TABLE II: THE PROPERTIES OF HDPE

Melt Flow Rate (g/10dk)	0,04
Density (g/cm^3)	0,956
Pour in the tensile strength (MPa)	22,555
Tensile Strength at Break (MPa)	29,420
Elongation at Break (%)	> 500
Melting Point (°C)	131

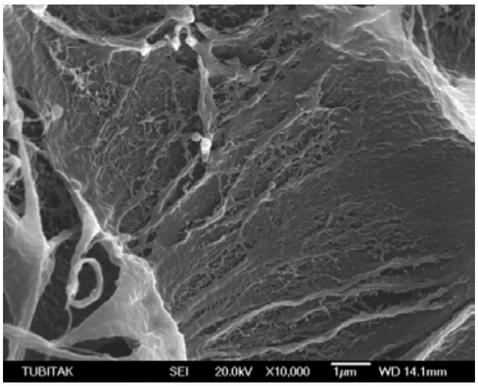

Fig. 1. 1% CNT-99% HDPE.

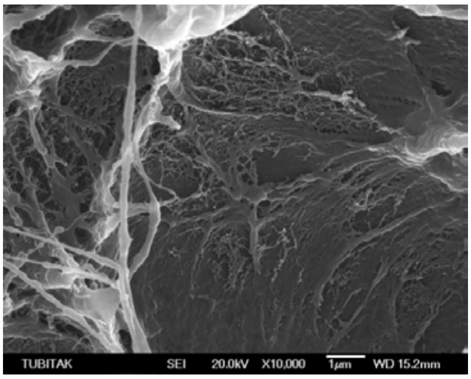

Fig. 2. 3% CNT-97% HDPE.

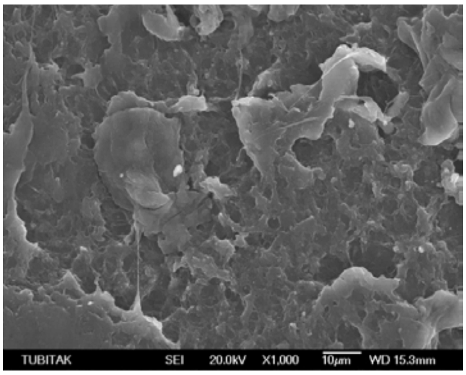

Fig. 3. 5% CNT-95% HDPE

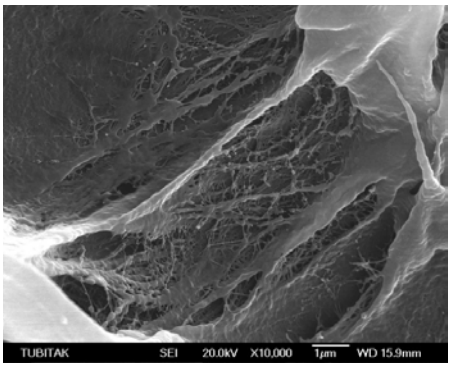

Fig. 4. 0% CNT-100% HDPE.

First, samples were weighed in a beaker using a BP 310 S precision balance with 0.001 g accuracy. About 2.500 grams of sample were considered for each sample. MWCNTs were mixed with HDPE in weight ratios of 0%, 1%, 3% and 5% using a mixer; a hot mix was created using an extruder and given the desired shape by cutting from the resulting sample using a cutting machine. A German made TYYSSEN HENSCHEL model HENSCHEL Mischer FM10C Type electric double mixer, which was present in Petkim plastic processing plant, was used to stir each sample using a blade mixer with a speed of 525 rpm at room temperature for 10 min. The initial mixture temperature of 27˚Chas reached 47˚Cafter 10 minutes. Mixed materials were then subjected to hot mixture using BRABENDER PLASTI-CORDER PL2000 model, L/D double screw extruder, situated in the R&D facilities, with the ratio of 18 and output speed of 50 rpm. The extruder with 4 heating zones was heated at 170˚C, 190˚C, 200˚Cand 190˚Cin that order and molten composite mixture leaving the extruder was cooled down by passing through a water tank connected to a thermostat unit using water cooling and crushed using a mechanical crusher to obtain small pieces of the granule. Experiment samples were obtained by the molding the samples prepared as granules in plastic injection molds prepared according to the ASTM D6110 standard under a pressure of 40 MPa and 20 sec at ironing temperature and 30 sec at refrigeration temperature under 200˚C, 180˚C, 180˚C, 180˚C in that order using a German made 1996 Arburg Spritzgie Bmaschine brand 270-E-50-210 type plastic injection machine. SEM images are given in the Fig. 1, Fig. 2, Fig. 3 and Fig. 4.

III. RESULTS AND DISCUSSION

ASTM D6110 standard samples prepared by the impact of the tests, KOMPEN CO. Ladik plants in the Quality Control Laboratory Ceast mark Resil Impactor model 6967 type impact tests were performed using a hammer 2J device. The experimental results in Table III and Fig. 5 are given.

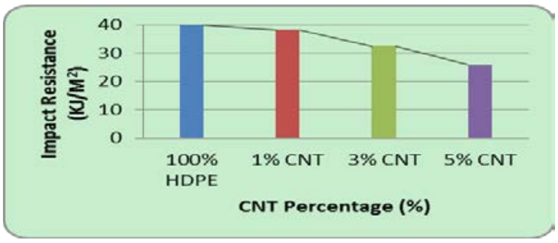

Fig. 5. Manufactured by plastic injection impact test results graph of samples.

TABLE III: PLASTIC INJECTION MOLDING TABLE COMPARISON OF THE RESULTS OF THE IMPACT TEST SAMPLES

SPECIMEN		0% CNT 100% HDPE	1%CNT 99% HDPE	3% CNT 97% HDPE	5% CNT 95% HDPE
INJECTION	Ingested energy (J)	1.994	1.908	1.616	1.291
	Area (mm^2)	49.875	49.875	49.875	49.875
	Impact resistance (KJ/m^2)	39.984	38.248	32.397	25.887
% Change compared to pure HDPE		0%	-4.34%	-18.98%	-35.26%

During TGA, a change in mass of the material heated with a controlled speed under a suitable atmosphere is measured using a very accurate electronic scale. The sample is heated with a suitable temperature program by selecting a gas suitable for the sample's properties, after weighing the sample on TGA device scale (5 - 20 mg). Usually, a speed of 10˚C/min speed and gas flow of 50 ml/min up to 1000˚C is programmed for polymer samples. Nitrogen atmosphere is replaced by air at 600˚C. The amount of change in the mass of the sample is recorded as a function of time or temperature. Weight loss within desired temperature range is calculated in mg on the thermogram drawn. Curves 1 and 2 can be differentiated; mathematical calculations can be made between curves. TGA/SDTA device is used in determining material type by analyzing, moisture, volatile matter, ash analysis and dissolved material, thermal decomposition, oxidation, all kinds of thermal behavior of polymers and various organic / inorganic based materials. The temperature range in which the polymer is pyrolyzed provides a means for identifying polymers or polymer mixtures, as different polymers have different decomposition kinetics. Monitoring exothermic and endothermic peaks with the SDTA signal also provides additional information on material melting and degradation. It has been raised to 1000˚C with 10˚C/min heating speed in PETKİM Petrochemicals CO R&D Laboratory using METTLER brand TGA/STGA 851 E according to the ASTM E1131 standard and nitrogen and atmosphere air were used as gas. As the crystallinity of the polymer composites is having influence on Young's modulus and toughness, it was decided to study thermal analysis of the composites, i.e. DSC and TGA. In the case of DSC curves, which are shown in Fig. 6, the addition of CNTs in HDPE increases the total enthalpy of crystallization. The melting point of composites occurred at about 137˚C indicating the degree of polymer crystallinity in all composites.

The reinforcement of CNTs in HDPE is not affected the melting point of the composites. In case of TGA curves which are shown in Fig. 7, thermal stabilization of CNTs–HDPE composites and the fraction of volatile components are observed with an atmosphere of air. It is observed that the onset temperatures of these composites are 405.76˚C, 417.50˚C, 420.05˚C and 430.32˚C for pure HDPE, 1%, 3% and 5% CNTs, respectively. It is observed that onset temperature decreases with an addition of chemically treated CNTs due to amorphous carbon present in the CNTs and other carbonaceous impurities that oxidize at temperature lower than that of CNTs. The oxidation temperature of composites, thermal stability of the composites, is found by differentiating the percentage of weight loss curve with temperature which is shown in Fig. 8.

The temperatures at which the maximum rate of oxidation is taking place are 492.28˚C, 493.02˚C, 488.78˚C and 481.56˚C for 5%, 3%, 1% and HDPE, respectively. It is observed that the oxidation temperature of the composite is not much affected by the addition of CNTs, which may be due to very low fraction of CNTs in the composites.

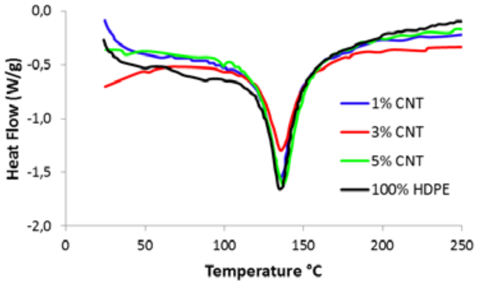

Fig.6. DSC curves of CNT-HDPE composites.

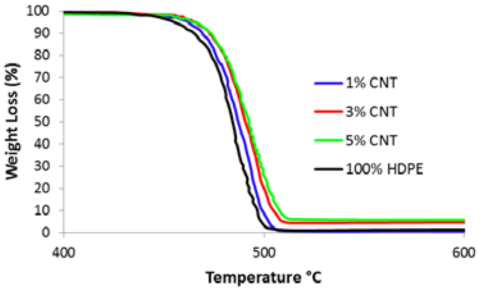

Fig.7.TGA curves of CNT–HDPE composites.

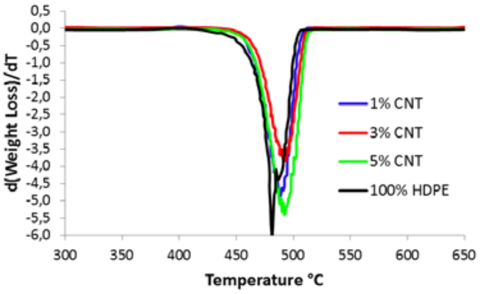

Fig.8. d (TGA)/dTcurves of CNT-HDPE composites.

IV. CONCLUSION

In this study, High Density Polyethylene (HDPE) into a 1 wt%, 3% and 5% participating multi-walled carbon nanotubes (MWCNT) granules, making itself after the plastic injection samples production methods impact resistance how to alter examined. However, the outcomes and recommendations are:

1) Multi-Walled Carbon Nanotubes with High Density Polyethylene in a mixture of primarily mechanical mixture directly without the use of any chemical substance mixed with granules were obtained in the extruder. We have tried to provide practicality and advantages for mass production.
2) The weight ratio of the composite increases impact strength decrease of MWCNT material was transformed into a fragile structure that is richer than us. Impact strength, the pure by High Density Polyethylene; 4.34% in 1% MWCNT contribute, to contribute 3% MWCNT

18.98%, 35.26% in 5% contribution MWCNT 'health has fallen. According to these results is the value of the good impact strength of pure HDPE (39.984 KJ/m²).

3) TGA analysis of the composite by weight ratio increases MWCNT distortion temperature increased mass loss. Depending on the temperature, the lowest value of the mass loss rate of 3% mass loss rate value in the MWCNT is additive. This increased ratio of the weight of the material MWCNT mass loss temperature and a melting point to reduce the rate of melting temperature was found to slightly increase.
4) High Density Polyethylene into a more homogeneous dispersion of MWCNT impact strength by working to reach a higher value.
5) Impact of the microstructure of the fracture surfaces of samples examined fracture properties of MWCNT may have an impact on how they will lead to fatigue and wear properties can be examined.

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