

The Effects of Nanoclay on Mechanical Properties of High Density Polyethylene and Polypropylene Materials

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Polymeric materials find usage in most places in daily life. Expected features vary depending on the use of these materials. Composite material can be formed by combining one or more different materials. Physical and chemical properties of a new produced composite material can be improved with the addition of additives and fillers to polymer materials. The addition of additives and fillers improve one or more properties at the same time, despite that, it may lead to deteriorate another property. Therefore, it is necessary to investigate the mechanical and thermal properties of these produced composite structures. This study was carried out by nanoclay addition to high density polyethylene (HDPE) and polypropylene (PP) materials. Nanoclay additions were made to the polymer matrix at mass ratios of 5% and 10%. Tensile test, tear test and the Izod impact tests were performed. It has been observed that the tensile strengths of HDPE composites decreased whereas PP composites increased with respect to the pure products. Also, the tear strengths of composites decreased compared to pure products. In the Izod impact tests, all notched specimens were broken. The values of impact strength of the PP composites were not changed in the notched Izod impact tests, whereas the HDPE composites showed a decrease.

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1. Introduction

The diversity of product range, easy manufacturability, low cost and different features combined together of polymeric materials which make their usage areas has increased considerably in recent years. These materials which are often petroleum-based that called engineering plastics, their costs need to be reduced and some of their properties must be improved. The mechanical and thermal properties of the polymer matrix can be improved by adding organic and inorganic materials at different ratios in literature studies [1–3]. In addition, the cost of polymer materials can be reduced by adding fillers. The compatibility and particle size of these additives in the polymer matrix affect the properties of the polymer composite [4]. As the particle size increases, the mechanical properties of the polymer material decrease and therefore it is emphasized that the importance of using smaller particle sized nano-additives and fillers to nanomaterials. These materials which are called polymer nanocomposite, the particles are spread in more homogeneous form because of the nanoscale size of particles in the polymer matrix and better holding can be achieved as the surface area is increased [5, 6]. Several studies have been carried out to improve the mechanical and thermal properties of the polymer matrix adding nanoparticles with suitable compatibilizer [5–9]. It has been observed that the Izod impact resistance is reduced by nanosized particle reinforcement to polymeric materials [8, 10]. However, it is

seen that these properties can be improved with different compatibilizer [8, 11]. As can be seen clearly from the literature, tensile strengths and modulus of elasticity values can be increased with the addition of nanoclay to the polymer matrix [8].

In this study, HDPE and PP polymer matrices were produced by nanoclay addition at mass ratios of 5% and 10%. Mechanical properties of produced nanocomposites have been obtained to investigate the effects of nanoclay additions. The production of HDPE and PP polymers with and without nanoclay additives were always carried out under the same conditions.

2. Experimental

2.1. Materials

In this study, the polymer matrix with melt flow rate 5.5 g/10 min (190 °C/2.16 kg) of HDPE having density of 0.965 g/cm³ and melt flow rate 4.7 g/10 min (230 °C/2.16 kg) PP having density of 0.905 g/cm³ were used. Petilen YY I 668 and Petoplen MH 418 commercial products were suitable for injection molding with HDPE and PP, respectively. HDPE and PP materials in a granular form were supplied from Petkim Inc. (İzmir, Turkey). Nanoclay filler material was get from Nanokil Ltd. Co. (Erzurum, Turkey). The nanoclay has a grain size of 1–200 nm and contains mass of 6.13% Fe₂O₃, 20.67% Al₂O₃, 53.28% SiO₂, 2.82% MgO, 1.71% CaO, 0.02% Na₂O, 0.82% K₂O, 0.63% TiO₂. The granules were coated with polydimethylsiloxane (PDMS) to spread the nanoclay filler homogeneously. Siltech F-12500 was used for PDMS which is the product of Siltech Co. (Toronto, Canada).

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2.2. Specimen preparation

The surface of the granules was coated with PDMS by pre-mixing. The nanoclay additives were added to matrix in 5% and 10% mass proportions given in Table I and mixed for 5 min at 200 rpm with a mechanical stirrer. Then, the mixtures were dried at 100 °C for 2 h and ready for molding by injection. The blended mixtures products were transferred from the feeding zone to the nozzle zone by the injection molding at 160-170-180-190 °C temperatures. The mold temperature was set at 40 °C. The screw diameter of the injection machine is 35 mm and the L/D ratio is 30. From each mixture, 20 specimen groups were produced. There are tensile test specimens, notched and un-notched Izod impact test specimens, UL94 test specimens, tear test specimens and cone calorimeter test specimens in these specimen groups.

Composition of blends and composites in wt%. TABLE I

| Abbreviation | HDPE [%] | PP [%] | PDMS [%] | NC [%] |
|--------------|----------|--------|----------|--------|
| PE | 100 | - | - | - |
| PE-Sil | 100 | - | 1 | - |
| PE-05NC | 95 | - | 1 | 5 |
| PE-10NC | 90 | - | 2 | 10 |
| PP | - | 100 | - | - |
| PP-Sil | - | 100 | 1 | - |
| PP-05NC | - | 95 | 1 | 5 |
| PP-10NC | - | 90 | 2 | 10 |

2.3. Tests and characterization

Tensile tests, tear tests and the Izod impact tests were carried out to determine the mechanical properties. The dimensions of the test specimens were arranged to standards of ASTM D-638 (Type IV) for the tensile test, ASTM D-624 (Type-T) for the tear test and ASTM D-256 for the Izod impact test. Tensile and tear tests were carried out on Tinius Olsen H10KT universal test equipment at a speed of 50 mm/min. The specimens were kept for 40 h at 23 °C and 50% relative humidity before the experiment. For the Izod impact tests, it was carried out at -40, -20, and 23 °C for 40 h, respectively. Impact resistance is measured with a 7.5 J hammer on the CEAST Resil Impactor device. Five specimens were used for each test.

3. Results and discussion

Tensile tests were performed to observe the effect of additives NC and PDMS on the mechanical properties. The effects of adding PDMS and NC to HDPE and PP polymers on tensile strength and modulus of elasticity are seen in Fig. 1a with comparing each composites. The average, maximum and minimum ranges of tensile strength, young modulus, tear strength and impact resistance values of composites are seen in Table II. Addition of PDMS to the polymer matrix resulted in a slight decrease in tensile strength and modulus of elasticity. It was determined

that tensile strength and modulus of elasticity values of PE-05NC specimens decreases by 14% and 12.6% respectively, whereas modulus of elasticity values of PE-10NC specimens increased by 5%. It is observed that the modulus of elasticity values of PE-10NC specimen is higher than that of the pure ones. Tensile strength and modulus of elasticity values increased regularly as NC ratio increased for PP composites. However, it is seen that PDMS addition to PP, tensile strength, and modulus of elasticity values decrease with respect to pure one.

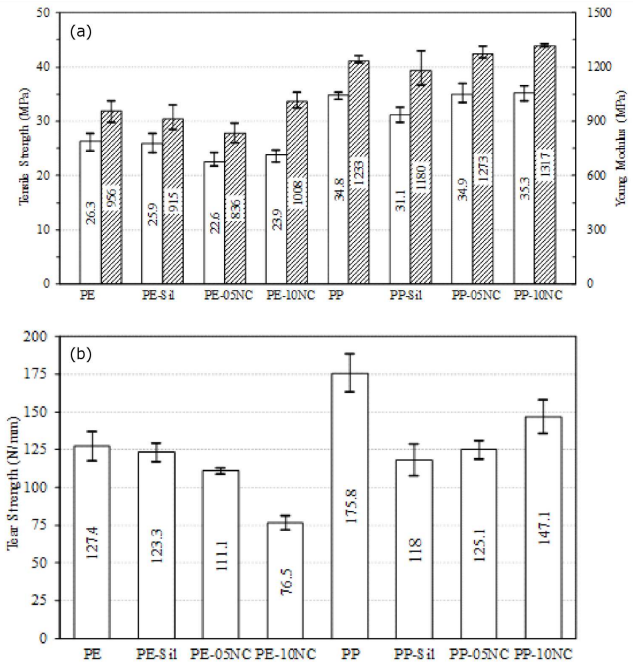


Fig. 1. Comparison of (a) tensile strength \square and the Young modulus \blacksquare and (b) tear strengths \square of HDPE/NC and PP/NC composites

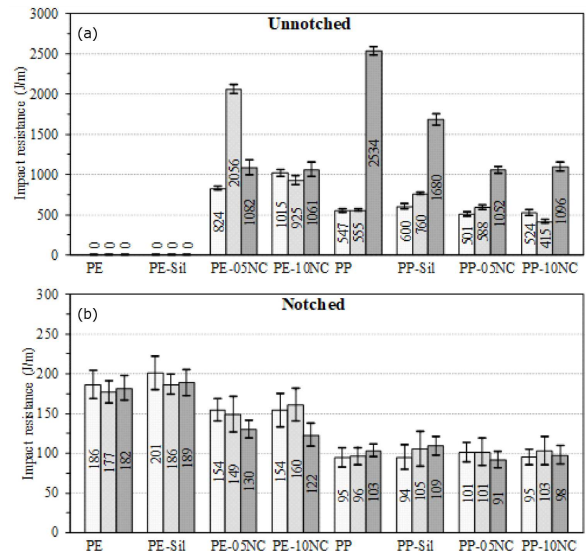


Fig. 2. Comparison of impact resistance of (a) unnotched and (b) notched HDPE/NC and PP/NC composites at -40(\square), -20(\blacksquare) and 23(\blacksquare) °C.

Tensile strength, the Young modulus, tear strength and impact resistance values of composites.

TABLE II

| Sample | Tensile strength [MPa] | Young modulus [MPa] | Tear strength [N/mm] | Impact resistance [J/m] | | | | | |
|---------|------------------------|---------------------|----------------------|-------------------------|---------|---------|---------|--------|--------|
| | | | | Unnotched | | | Notched | | |
| | | | | -40 °C | -20 °C | 23 °C | -40 °C | -20 °C | 23 °C |
| PE | 26.3±1.5 | 956±61 | 127.4±9 | - | - | - | 186±18 | 177±14 | 182±16 |
| PE-Sil | 25.9±1.7 | 915±68 | 123.3±6 | - | - | - | 201±21 | 186±13 | 189±17 |
| PE-05NC | 22.6±1.3 | 836±56 | 111.1±2 | 824±24 | 2056±55 | 1082±93 | 154±14 | 149±23 | 130±11 |
| PE-10NC | 23.9±1.1 | 1008±43 | 76.5±5 | 1015±38 | 925±53 | 1061±91 | 154±21 | 160±21 | 122±15 |
| PP | 34.8±0.7 | 1233±19 | 175.8±13 | 547±24 | 555±17 | 2534±52 | 95±13 | 96±11 | 103±8 |
| PP-Sil | 31.1±1.4 | 1180±93 | 118±11 | 600±31 | 760±15 | 1680±69 | 94±16 | 105±22 | 109±12 |
| PP-05NC | 34.9±1.8 | 1273±33 | 125.1±6 | 501±28 | 588±27 | 1052±46 | 101±12 | 101±18 | 91±11 |
| PP-10NC | 35.3±1.4 | 1317±8 | 147.1±11 | 524±34 | 415±24 | 1096±57 | 95±10 | 103±18 | 98±12 |

Tear strength tests were performed to observe the effects of addition PDMS and NC additives on tear resistance of polymer matrix which was shown in Fig. 2b. The average, maximum and minimum range of the tear strength values are given in Table II. With addition of PDMS to HDPE polymer, there was a slight decrease by 3.2% in the tear strength, whereas a significant decrease by 32.9% was observed with the addition of PDMS to PP polymer. With the increased addition of NC, a considerable decrease in tear strength on HDPE composites was observed, but the respectable increase was observed in PP composites compared to PP-Sil one.

The Izod impact test results were given in Table II. It was observed that the impact resistance of HDPE and PP composites were increased by PDMS addition at all temperatures (Fig. 2). The unnotched PE and PE-Sil specimens were not broken but the other samples were broken at temperatures of -40, -20 and 23 °C. The impact resistance increased at -40 °C while the NC ratio increased in unnotched HDPE composites. But it is decreased at -20 °C and decreased slightly at 23 °C. It has been found that impact resistance of notched HDPE composites increases slightly increasing amount of NC at -20 °C but impact resistance decreases compared to pure HDPE composites. A noticeable decrease was observed at 23 °C when the impact resistance of the notched PP samples was not changed much at low temperatures. Notched PP specimen's impact resistance values increased at low temperatures. It was observed a slight decrease at 23 °C.

4. Conclusion

The addition of PDMS to HDPE and PP polymers reduces the tensile strength and elasticity modulus values of those. As the NC ratio in HDPE/NC composites increases, the tensile strength and elasticity modulus values increase, but these values are lower than the pure product. As the NC ratio of PP NC composites increases, tensile strength and modulus of elasticity values increase with respect to pure product. With the addition of PDMS to both composites, the tear resistance of HDPE composites decreased slightly, while the PP composites showed a significant decrease. Compared to PP/Sil composites, a noticeable increase in tear resis-

tance was observed with increasing NC ratio in PP composites, whereas a remarkable decrease was observed in HDPE composites. All specimens were broken in the Izod impact tests except unnotched HDPE and HDPE/Sil specimens. With the addition of NC, the impact resistance of notched HDPE composites decreased while no significant change in PP composites was observed. The addition of PDMS to polymer composites increased the impact resistance at low temperatures, whereas it reduced only notched PP composites at 23 °C.

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