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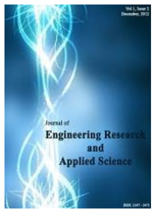

Investigating the Mechanical Performance of Nylon 66/Glass Bead Composites

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Abstract

In this study, the mechanical properties of glass bead-filled nylon 66 polymer composites were investigated. Composites with glass bead filler at rates of 10%, 30%, 40%, and 50% by weight were produced. Composite granules were produced using the compound production method while mechanical test specimens were molded using the injection molding method. The mechanical properties of the composites such as hardness, impact strength, tensile strength, % elongation at break and modulus of elasticity were investigated. The results showed that there were significant changes in the mechanical performance of the composites depending on the glass bead filler ratio. With the increase in glass bead filler, significant increases in tensile modulus and hardness were observed, while tensile strength, impact strength, and % elongation at break showed a decrease. The highest tensile modulus value, 5520 MPa, and the highest Shore D hardness value, 81.5, were obtained for the nylon 66 composite with 50% glass bead filler. The highest tensile strength value, 72.1 MPa, the highest un-notched Izod impact strength value, and the highest % elongation at break value were obtained for the pure nylon 66 polymer base matrix. From the scanning electron microscope images, it was determined that the glass beads were homogeneously distributed in the main matrix, but the matrix and the glass bead filler were partially bonded.

Keywords: *Glass bead, nylon 66, composite, mechanical properties*

1. Introduction

Plastic polymers are preferred in the manufacturing process of many materials in various industries due to their many advantageous properties such as lightness, corrosion resistance, resistance to chemicals, easy of production, good appearance, electrical insulation, and high toughness. However, plastic polymers also have disadvantages such as low strength and hardness, low-temperature resistance, low UV resistance, and deterioration. In order to improve their performance with regard to these disadvantageous properties, composite materials are produced by adding various additives to plastic polymer materials. In recent years, composite materials have begun to rapidly replace pure plastic materials in various industrial applications. The most important advantages of plastic polymer materials that result in such a wide range of usage are their high strength, high rigidity and hardness, lightness, ease of forming, and low cost. The most commonly used additives in polymer-based composites are strength enhancers such as glass fiber, carbon fiber, aramid fiber, glass beads, glass spheres, mica, talc, kaolin, and glass powder. While pure polymer materials without additives are generally ductile, their hardness and strength (but also brittleness) when made into composites allow their use in a wide range of industrial applications.

When glass bead fillers are added to the polymer material, they provide good flow properties and facilitate shaping. Also, since they are spherical, the small internal stresses in the composite material become homogeneously distributed within the polymer main matrix, which provides an advantage. They can even make the produced material look bright, hard, and beautiful due to their spherical properties. There are a number of publications in the literature on glass bead-added polymer-based composites [1-13]. A variety of polymers such as low-density polyethylene (LDPE) [1, 2, 8], polypropylene (PP) [3, 5], epoxy [7, 9], poly-ether-ether-ketone (PEEK) [6], glassy polymers like polystyrene (PS) and

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polycarbonate (PC) [10], and nylon (PA) [4, 11] were used as the base material for the composites in these studies. These studies investigated various properties such as mechanical properties [1-2, 5-8, 10-13], thermal properties [4, 6, 11-12], morphological properties [6, 8], and flow properties [3, 5] of the composites. However, only a limited number of studies have been found in the literature examining the mechanical properties of glass bead-added nylon-based polymer composites. The number of studies on glass bead-filled composites is limited in general. The following study was carried address the need for more studies in this area.

This study aimed to determine the mechanical properties of pure nylon 66 polymer and of nylon 66 composites containing 10%, 30%, 40%, and 50% glass bead fillers by weight. A laboratory twin screw extruder was used to mix the nylon 66 base polymer with the glass beads. Mechanical test specimens conforming to the standards were molded using the injection molding technique. Then, tensile and hardness tests were carried out and the results were reported using graphics.

2. Materials and Methods

2.1. Materials

The nylon 66 polymer main matrix used in the experiments was obtained from the LanXess and had the commercial code Durethan B40SK. The glass beads had an average particle size of 35 µm and were obtained from Kuhmichel.

2.2. Preparation of Composites and Samples

Nylon 66 composites with 10%, 30%, 40%, and 50% glass bead additives by weight were produced in the form of granules in a Cooperion brand (ZSK 26 model) twin screw extruder. The produced granules were packed in polyethylene bags and stored before production. During production, extruder heater temperatures were set between 250-290ºC. Before injection molding, the granules were dried in a drying oven at 80ºC for 4 hours eliminating the possibility of moisture. Mechanical test samples were molded on a Haitian- brand injection machine. Injection heater temperatures were set between 245-285ºC and the test samples were pressed at an injection pressure of 130 bar. The temperature of the test sample mold was set to 80ºC using a mold heater. After the test samples were molded, they were conditioned for 24 hours at room temperature (23ºC) and 50% humidity.

2.3. Mechanical Test Samples and Standards

Hardness, tensile and impact tests were carried on the test samples. Hardness tests were measured in Shore D in accordance with the ASTM D2240 standard. During hardness tests, at least 10 measurements were taken for each test sample. Tensile tests are prepared in accordance with the ASTM D638 standard. The tests were carried out using a Zwick brand Z010 tensile testing machine. For each tensile test sample, at least 5 measurements were obtained and an average value was calculated. Tensile tests were carried out at a tensile speed of 5 mm/min. Impact test specimens were prepared in accordance with the ASTM D256 standard. For the impact tests, a Zwick brand impact tester was used. During the un-notched izod impact test measurements, for each test sample, at least 5 measurements were obtained and an average value was calculated.

3. Results and Discussion

In Figure 1, the tensile strength and tensile modulus of elasticity of the nylon 66-based composite materials with glass bead fillers are given.

As shown in the figure, the tensile strength of the composite materials decreased with the increase in the ratio of the glass bead additive in the composites. Compared to the pure nylon 66 polymer, there was an 18.3%, 18.7%, and 44.1% reduction in tensile strength for the 10%, 30%, and 50% glass bead composites, respectively. Similar results were obtained in the study by Unal et al. [13]. Huang et al. [11] found that for PA6-based composites, there was an approximately 36.5% decrease in tensile strength with the addition of 30% glass beads by volume. Similar results were also obtained in studies conducted by Liang et al.[8] with LDPE, as they found that, for composites with fillers of varying particle sizes, depending on particle size, there was a slight increase in tensile strength for filler rates up to 20%, and there were slight increases and decreases observed in tensile strength for filler rates above 20%.

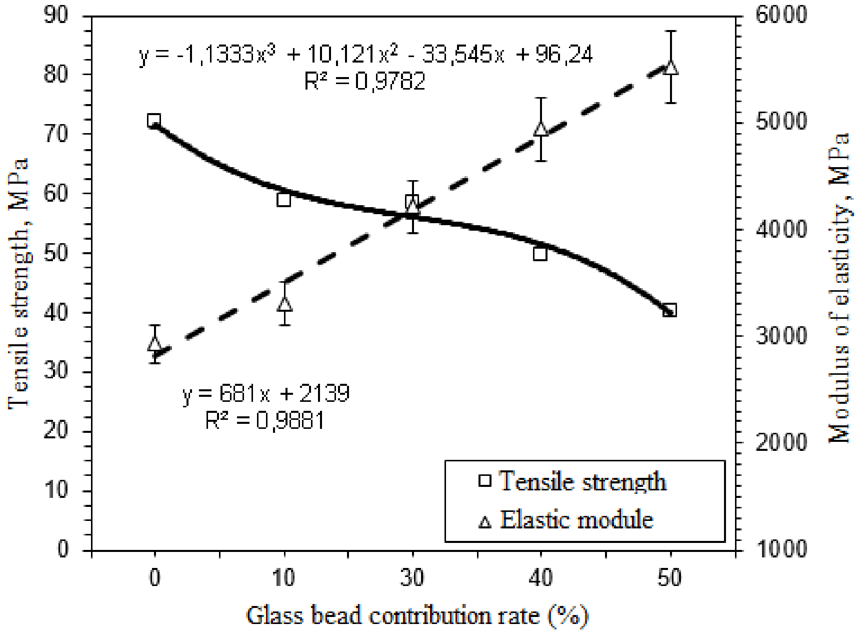


Figure 1. Variation of the tensile strength and modulus of elasticity of the glass bead added nylon 66 polymer composites depending on glass bead additive ratio

On the other hand, a significant increase was detected in the tensile modulus. As shown in the figure, the modulus of elasticity, namely the stiffness, of the composites increased with the increase in the glass bead filler ratio. Compared to the pure nylon 66 polymer, there was a 12.9%, 43.6%, and 88.3% increase in the modulus of elasticity values were for the 10%, 30%, and 50% glass bead composites respectively. For the PA6-based composites in the study by Huang et al. [11], an increase of approximately 33.3% was observed in the modulus of elasticity with the addition of 30% glass beads by volume. In other words, the results obtained are in agreement with the work of Huang et al. [11], Liang et al.[8] and Unal et al.[13].

The variation of the un-notched izod impact strength and the % elongation at break values of glass bead filled nylon 66 composites is given in Figure 2. As seen in the figure, the un-notched izod impact strength of the composite materials decreased with increasing glass bead filler ratio. Compared to the pure nylon 66 polymer, there was an approximately 63.5%, 66.2%, and 86.4% reduction in un-notched iodide impact strength, respectively, for the 10%, 30% and 50% glass bead added composites. For the PA6-based composites by Huang et al., a decrease of approximately 51% was observed in notched impact strength with the addition of 30% glass beads by volume. This is consistent with the results obtained. Similarly, the % elongation at break values of the composites decreased significantly with the increase in the glass bead additive ratio. The addition of 10%, 30%, and 50% glass beads by weight caused a 71%, 72.9%, and 74.4% decrease in the % elongation at break values, respectively. Similar results were obtained for the PA6-based composites by Huang et al. [11]. They found that with the addition of 30% glass beads by volume, a decrease of approximately 84.6% was observed in the % elongation at break values. Similar results were also obtained in the study by Liang et al.[8] with LDPE, that is, the addition of 40% glass beads by weight to the LDPE polymer led to a decrease of approximately 50.6% in the elongation at break values. Similar results were obtained in a study by Unal et al. [13].

The variation of the hardness of the glass bead added nylon 66 composites is given in Figure 3.

As can be seen in the figure, the hardness values of the composite materials increased with increasing glass bead filler ratio. Compared to the pure nylon 66 polymer, there was an approximately 2.6%, 6.6%, and 8.6% increase in hardness for the 10%, 30%, and 50% glass bead filled composites, respectively.

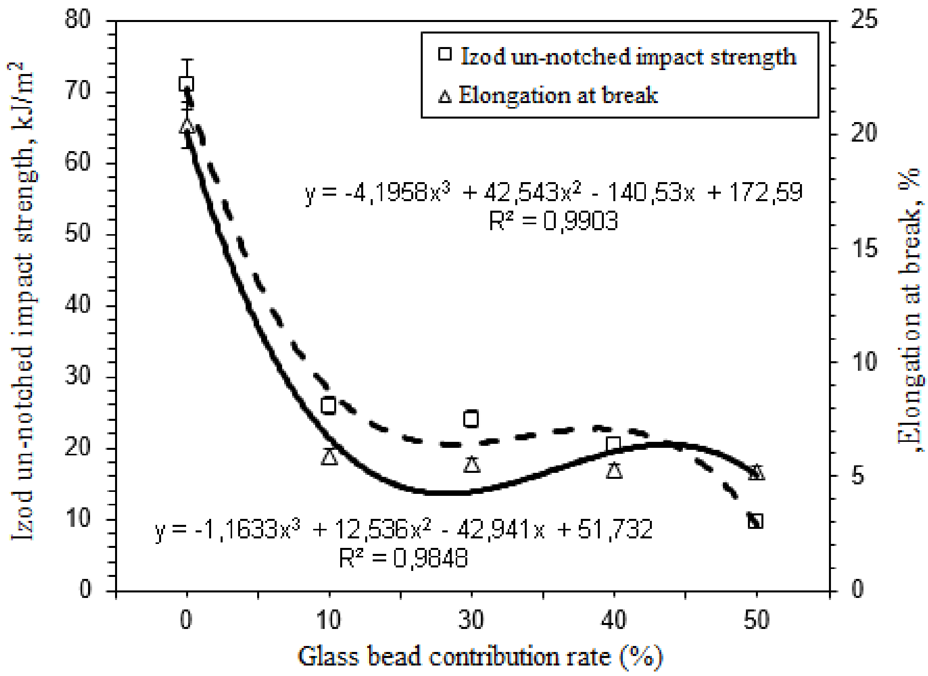


Figure 2. Variation of the un-notched izod impact strength and % elongation at break of the glass bead added nylon 66 polymer composites, depending on the glass bead additive ratio.

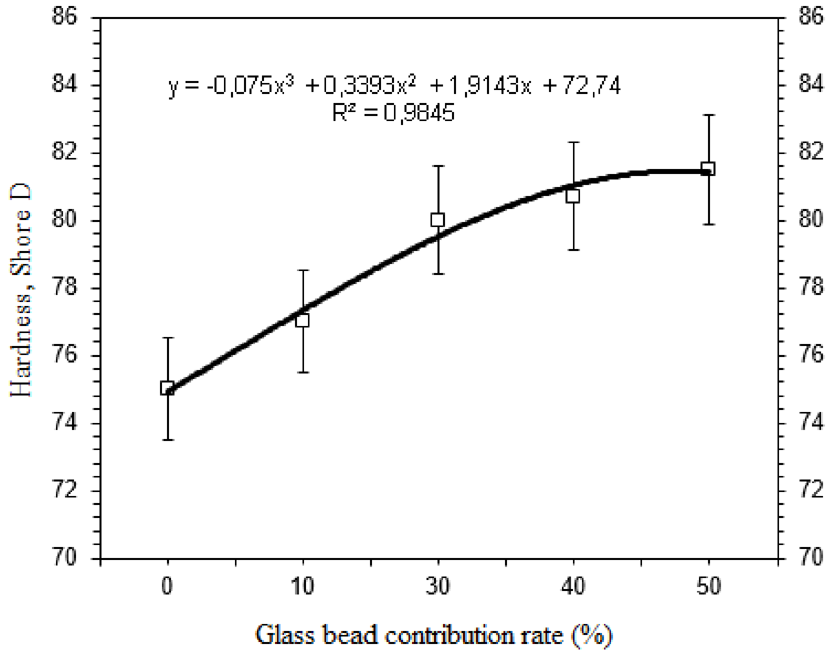
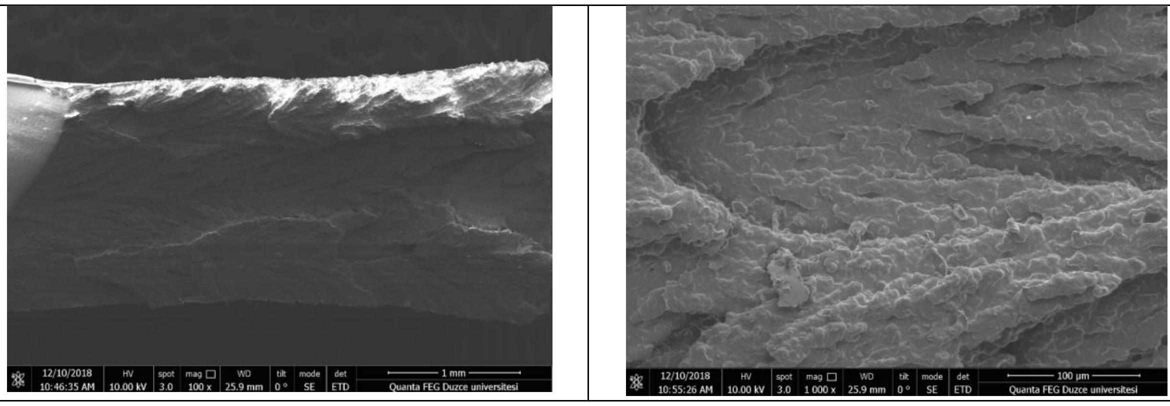
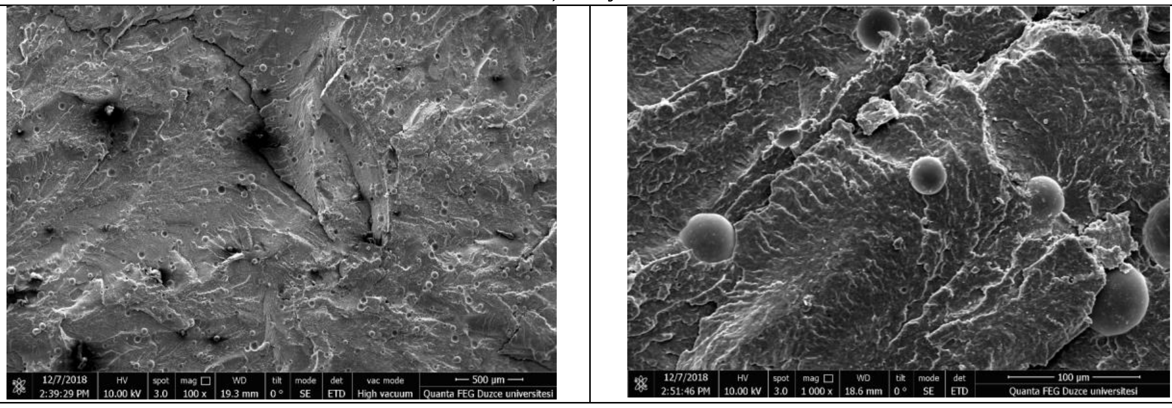


Figure 3. Variation of the hardness values of the glass bead added nylon 66 polymer composites depending on the glass bead additive ratio

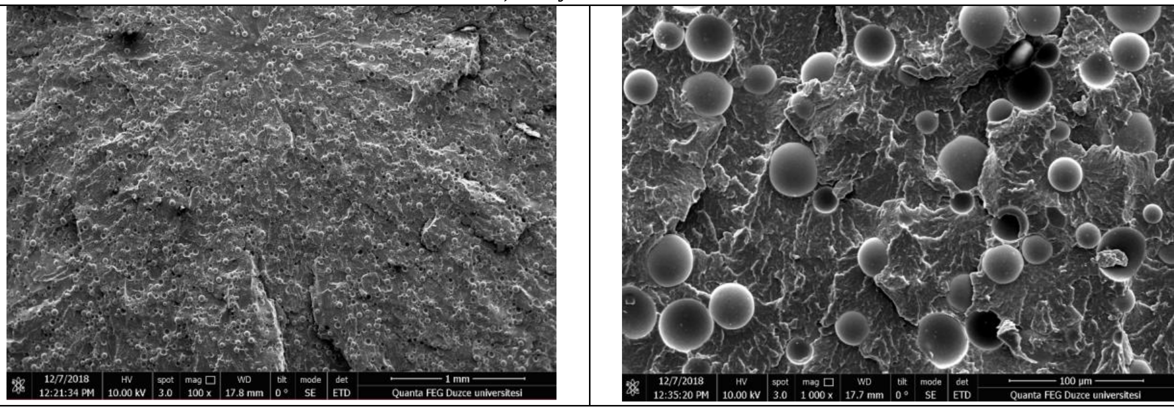
While the pure nylon 66 polymer is rather tough without any additives, the stiffness of the composites increased, along with their brittleness, with the addition of glass bead fillers at different ratios to the nylon 66 polymer matrix (see Figure 4). With the addition of the glass beads, the modulus of elasticity of the composites also increased, while the tensile strength, % elongation at break, and un-notched impact strength decreased (see Figures 1, 2 and 3).



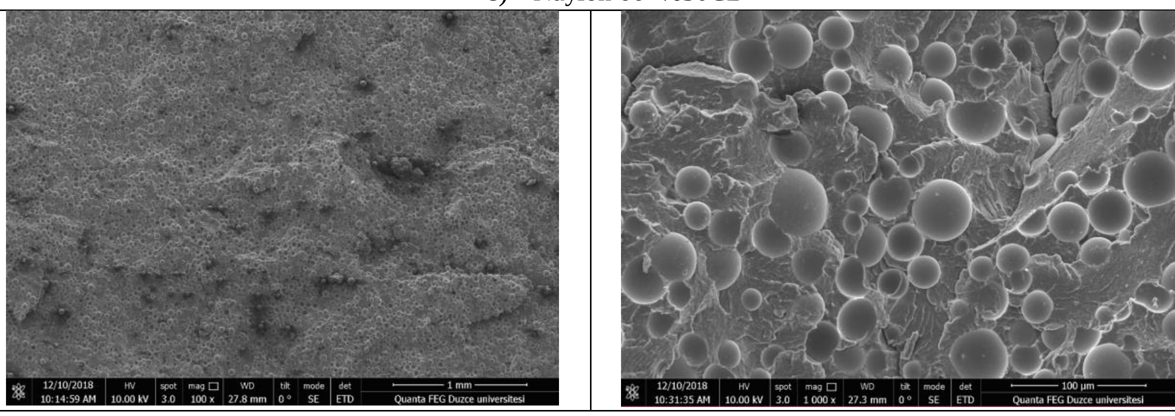
a) Nylon 66



b) Nylon 66+%10CB



c) Naylon 66+%30CB



d) Naylon 66+%50CB

Figure 4. Scanning electron microscopy (SEM) images taken from the fracture surface of the samples obtained following tensile tests on the pure Nylon 66 polymer and the 10%, 30%, and 50% glass bead added Nylon 66 composites

Scanning electron microscope (SEM) images taken from the fracture surface of the samples obtained following the tensile tests on the pure nylon 66 polymer and the 10%, 30%, and 50% glass bead filled nylon 66 composites are given in Figure 4 a-d. In Figure 4a, in the microstructure image of the pure Nylon 66 polymer, it can be seen that there is a ductile structure, that is, plastic deformation. In Figure 4 b, c, and d, fracture surface scanning electron microscope images of 10%, 30%, and 50% glass bead filled composites are given, respectively. It was observed that with the glass bead filler ratio, the composites became embrittled and the plastic deformation decreased. In the microstructure images, it was observed that the glass beads in the matrix were homogeneously distributed. It can be said that this homogeneous distribution is related to the use of twin screw extruders. As seen in Figures 4b, c, and d, the glass beads in the matrix are partially bonded with the matrix.

4. Conclusion and Recommendations

The following conclusions were drawn as a result of the experimental study.

- The hardness of Nylon 66 based composites increased with the increase in glass bead filler ratio. The increase in hardness for 10%, 30% and 50% glass bead ratio was 2.6%, 6.6% and 8.6% respectively.

- Similarly, the modulus of elasticity of the composites also increased with the increase in the glass bead filler ratio. The increase for 10%, 30% and 50% glass ball ratio was 12.9%, 43.6% and 88.3%, respectively.

- The glass bead filler addition to the nylon 66 polymer matrix decreased the tensile strength of the composites produced. The decrease in tensile strength for 10%, 30% and 50% glass bead ratio was 18.3%, 18.7% and 44.1%, respectively.

- With the addition of glass bead filler (10%, 30% and 50%), the un-notched izod impact strength of the composite decreased significantly. The reduction rate was approximately 63.5%, 66.2% and 86.4%, respectively.

- The % elongation at break decreased with increasing the glass bead fillers (10%, 30% and 50%). The rate of decrease was approximately 71%, 72.9% and 74.4%, respectively.

- The increase in the glass bead filler rate addition to the nylon 66 polymer caused the composite to become brittle.

- Scanning electron microscope images showed that the glass beads were homogeneously dispersed in the main matrix, but the matrix and the filler were partially bonded.

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