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RESEARCH ARTICLE

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Determination thermal and mechanical properties of Nano Carbon, Graphite and Graphene reinforced recycling Polypropylene composite sample

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Abstract

Polymer-based plastic materials occupy a major place in daily life. However, due to the nature of polymer materials, low thermal resistance and mechanical properties of these products, the need for new and sustainable materials in the industry has increased. With the rapid technological developments in advanced manufacturing industries such as aviation, marine, motor sports and defense industry, lightweight and high-strength composite products have become even more important. In this context, in this study, 1% nano carbon, graphene and graphite particle reinforced Polypropylene (PP) composite material mixed in a twin-screw extruder and MA/G series injection molding machine standard tensile test sample produced. Melt Flow Index (MFI), Heat Deformation Test (HDT), tensile test, Shore-D hardness measurement and density tests performed on these test samples. According to the results obtained from these tests, the mechanical and thermal properties of the test samples produced from different composite materials were determined. The best mechanical and thermal properties occurred in the graphene particle. It formed in graphite and nano carbon, respectively.

Keywords: Polypropylene, graphene, graphite, nano carbon, injection production, mechanical properties, thermal properties

1.Introduction

Today, due to the increasing need for materials in the industry and the increasing decrease in natural resources, and to meet the need for materials, the search for new materials compatible with the developing technology is becoming increasingly important.

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Polymer materials obtained using petroleum resources are among the most widely used materials in many sectors, such as bags, packaging, pet bottles and rigid plastic products, which are often used in many sectors. Polypropylene (PP) materials are known as polymers materials with the most widespread use from products for the automotive industry, textile products to food packaging [1]. The fact that the field of use of PP material and its mechanical and thermal properties are not particularly good has made it necessary to produce materials suitable for the progress in technology. Composite materials meet the needs of today's industry by combining various and varied materials with appropriate properties and Decently [1-2]. Rapid technological developments and increasing competitiveness and high-strength products in industries such as the aerospace and defense industry have made it mandatory to design and produce lightweight and high-strength materials in these products [3-4]. To meet this need of the industry, composite materials have started to enter the industrial industry since the past years and their usage areas have increased rapidly today [5].

Composite materials are materials created by combining the best properties of two or more materials of different structures to collect them into an original and single material [10-11]. Decoupled materials are materials that formed by combining the best properties of two or more materials of different structures into one original material. The most important criterion in the production of composite materials is the selection of the right matrix and reinforcement elements [12]. The most common composite materials with superior properties produced with polymer-matrices. These composite materials include thermoplastic or thermosetting polymers reinforced with glass, graphite, graphene, aramid, or nano carbon fibers [13]. These materials can produce with different production methods in different shapes and sizes. Composite materials have superior properties because they can use their superior properties such as high strength, hardness, and resistance to corrosion in many different areas [14].

Particles of dimensions, which defined as particles whose dimensions are 100 nm and below, constitute the main basis of nanotechnology. These particles show different and superior properties compared to their forms in micron and larger sizes [2-6]. The most important reasons for the increase in the research of nanoparticle materials are the size dependence of their electronic structure, quantum size effects, high surface-to-volume ratio and the unique characters of their atoms [2-7].

Nano carbon particle reinforced composite products are generally used in the aerospace sector, the automotive sector, and the marine sector [8]. Thanks to the new production techniques that are developing today, operating costs are decreasing and, accordingly, the areas of use are increasing. It has started to be used more widely, especially in the aviation and automotive sector, to reduce the flight costs of new generation aircraft and emission values in motor vehicles [8-9]. The field of use of nano carbon-reinforced composites, which have better mechanical properties than aluminum alloys used in the aerospace sector, has expanded [9]. It is widely preferred in the wings of wind turbines widely used in the renewable energy sector in our country due to its lightness, durability, and ease of production [4-7].

In this study, a homogeneous mixture of nanoparticles with PP made with a twin-screw extruder. Prototypes produced by injection method. Some thermal and mechanical properties of these new composite materials have studied experimentally.

2.Material and Methods

Injection molding method is one of the most important production methods applied in plastic production. In this study, graphene, graphite, nano carbon reinforced Polypropylene (PP) composite samples produced on the injection machine shown in Figure 1. Rectangular cross-sectional samples produced from a single screw sleeve with an injection speed of 45 mm/s and a production pressure of 50 bar.

Fig. 1. Injection Molding Machine.

The dimensions of the tensile test samples made in accordance with the TS ISO 604 standard. The sample dimensions given in Figure 2. The original and recycled PP samples made by subjecting to tensile experiments at a tensile speed of 1 mm/min using Shimadzu brand universal tester Figure 3 with 250 kN capacity load cells. The tensile test repeated three times for each sample and the results averaged. All tests performed by the same operator in a laboratory environment under the same environmental conditions. Figure 4 gives notch throwing device and Figure 5 shows notching measurements.

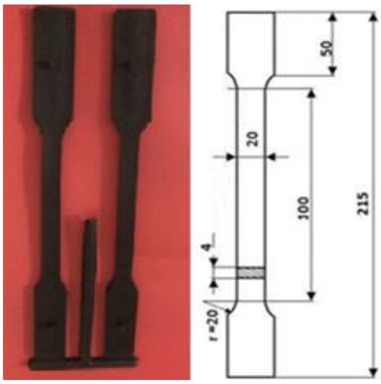

Fig.2. Composite Standard Test Sample.

Fig. 3. Tensile Testing Machine.

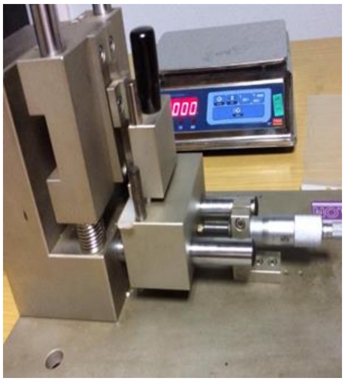

Fig. 4. Notch Throwing Device.

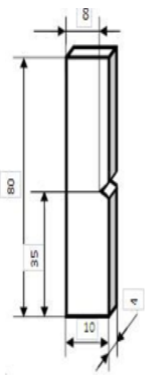

Fig. 5. Notching Measurements [15].

The Izod test device and Standard Izod test samples (100x10x4 mm) shown in Figure 6 and Figure 7. The tests were repeated three times for each sample and the average values were taken.

Fig. 6. Izod Test Device.

Fig. 7. Standard Izod test samples.

Shore-D test is a traditional hardness measurement method used to determine the hardness of plastic or flexible materials. It used to indicate the hardness values of polymers, elastomers, and rubber-based materials. Hardness tests of the test samples prepared by injection molding machine performed with the ZWICK brand Shore D durometer device shown in Figure 8. The tests repeated three times for each sample and the average values were taken.

Fig. 8. Shore-D Test Device.

The MFI test performed to determine the fluidity behavior of plastic materials during processing in an extruder and shaping by molding in an injection molding machine [16]. Thermal tests applied to plastics for changes in changes in the physical properties of materials by heating or cooling plastic materials in a controlled manner. Fluidity in polymer materials is of critical importance in the processing and molding of the product. Therefore, control is also an important parameter. The fluid index MFI (ISO 1133) test performed with the Melt Index test device shown in Figure 9.

Fig. 9. MFI Test Device.

Heat Deformation Test (HDT); Heat Deflection Temperature (HDT) used to determine the temperature limit up to which polymer, finished products and semi-finished products are exposed to feverish temperatures. HDT tests performed according to ISO 75 standard. The samples (100x10x4mm) assessed at 3 different stations and their temperatures were measured eight times at an average depth of 0.118 mm and the arithmetic mean of the results was taken. The starting temperature for PP polymer material is determined as 25°C and the starting temperature for composite material is determined as 25°C. The HDT device used in the experiments shown in Figure 10.

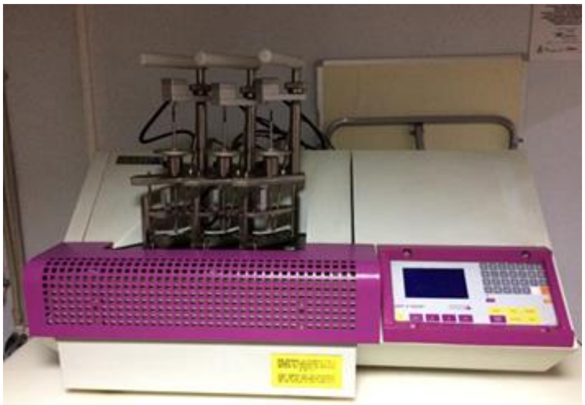

Fig. 10. Heat Deformation (HDT) Testing Machine.

The density test performed to determine the weight of the plastic materials in the unit volume and to determine the density. The tests conducted in accordance with the ISO 1183 test standard with the precision scale RADWAG WAS 220/X model density kit. The Density test device shown in Figure 11.

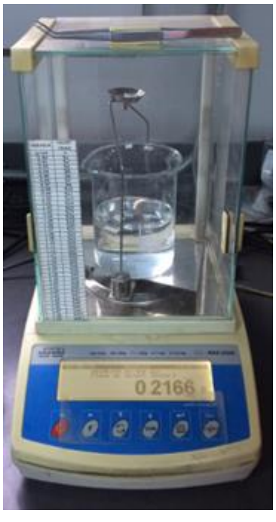

Figure 11. Density Measuring Device.

3.Results and Discussion

It is especially important to know and determine the mechanical and thermal properties of this material before choosing and using any material. In this study, a homogeneous mixture of the new composite material mixed homogeneously with a double-acting extruder, and the production of the prototype conducted by injection production method. For each test, experiments conducted on three distinct products and their average values taken. The Izod Impact Test results for determining the mechanical properties of unadulterated polypropylene and newly created composite material shown in Table 1 and Table 2.

Table 1. Pure PP Samples Izod Test Results.

Test	Material Measurements (mm)	Spent Energy of the Hammer (Joule)	Izod Result(kj/m²)
1	100x10x4	0.087	3.012
2	100x10x4	0,094	3.043
3	100x10x4	0.092	3.035
Average	-	*0.091*	*3.030*

Table 2. Izod Test Results of Composite Samples.

Samples	Material Measurements (mm)	Spent Energy of the Hammer (Joule)	Izod Result(kj/m²)
Recycled PP	100x10x4	0.091	3.030
PP+ Graphene	100x10x4	0.0156	5.136
PP+ Graphite	100x10x4	0.119	4.132
PP+ Nano carbon	100x10x4	0.108	3.750

Izod impact test used to determine the mechanical properties of materials operating under conditions that may cause brittle and fracture. In general. the purpose of the Izod Impact Test is to determine the amount of energy required for materials to break under dynamic stresses. as well as the ductility and brittle transition temperature [10].

In this study. three different Polypropylene composite samples used. The average of the test results taken. and according to the Izod test result of the new composite sample. there was an increase of approximately 70% in graphene-reinforced composite material. 42% in graphite-reinforced composite material. and 24% in nano carbon-reinforced composite material.

Tensile-Rupture test allows determining the shape change that will occur over time when determining the force that must applied to cause a certain shape to change in the material or when a certain force applied to the product [17]. This mechanical test is significant in engineering [13]. The results of the Tensile strength test shown in Table 3, and it shown in Table 4.

Table 3. Tensile Strength Test Results of the Pure PP Samples.

	Tensile Strength (MPa)	Yield Strength (MPa)	Modulus of Elasticity (MPa)	Elongation at Yield (mm)	Elongation at Break (mm)
Test 1	27.96	23.13	1410.9	3.85	17.27
Test 2	27.22	23.22	1965.8	3.33	14.84
Test 3	27.50	23.88	1639.5	3.57	15.93

Average	27.56	23.41	1672.06	3.58	16.01

Table 4. Tensile Strength Test Results in composite material test sample

Samples	Tensile Strength (MPa)	Yield Strength (MPa)	Modulus of Elasticity (MPa)	Elongation at Yield (mm)	Elongation at Break (mm)
Recycled PP	27.56	23.41	1672	3.58	16.01
PP+ Graphene	30.504	26.228	1510.9	3.33	7.93
PP+ Graphite	29.079	25.889	1900.6	3.36	8.97
PP+ Nano carbon	28.156	24.331	1909.8	3.63	9.85

In the tensile test. an increase in the elasticity modulus of the new composite material occurred. According to the tensile test results. in tensile strength values. there was an increase of 11% in graphene-reinforced composite material. 5% in graphite-reinforced composite material. and 2% nano carbon-reinforced composite material. According to these results. it shows the result that the strength values increase. but the shape change forced.

Shore-A test method used for soft polymers such as tires. and Shore-D test method used for other polymers [18]. Shore-D test results given in Table 5 and Table 6.

Table 5. Shore-D Test Result of Pure PP Test Samples.

Samples	Shore-D value
Test 1	69
Test 2	70
Test 3	67
Average	68.66

Table 6. Shore-D Test Results of Composite Test Samples.

Samples	Shore-D value
Recycled PP	68.66
PP+ Graphene	71.12
PP+ Graphite	70.42
PP+ Nano carbon	69.45

Shore-D testing has performed on three different samples s and there has been an increase of about 1.5% in the composite material. i.e., hardening. The density test results are shown in Table 7 and Table 8. According to the test results. there was not much change in the densities of unadulterated PP and composite material.

Table 7. Density Test Results of Pure PP Samples.

Material	Density gr/cm3
Test 1	0.89
Test 2	0.90
Test 3	0.89
Average	*0.89*

Table 8. Density Test Results of Composite Samples.

Samples	Density gr/cm3
Recycled PP	0.89
PP+ Graphene	0.92
PP+ Graphite	0.91
PP+ Nano carbon	*0.90*

Thermal tests are test methods used to determine the lowest and highest temperatures in which the product will be used and to determine properties such as melting temperature. thermal permeability. thermal expansion. decomposition temperature about the materials [22]. MFI test. which is one of the thermal properties. measures the mass or volumetric amount of polymer material flowing from a nozzle with a specified length and known cross-sectional area under certain temperature and loading conditions [12]. MFI test results are shown in Table 9 and Table 10.

Table 9. MFI Test Results of Unadulterated PP Samples.

Material	MFI Result (g/10min)
Test 1.	3.1
Test 2.	3.2
Test 3.	3.1
Average	3.13

Table 10. MFI Test Results of Composite Samples

Samples	MFI Result (g/10min)
Recycled PP	3.13
PP+ Graphene	3.51
PP+ Graphite	3.33

In the study, three different measurements made and the average of them taken. The viscosity of the new composite material has also been increasing. This also provides a disadvantage in the production of complex structured materials produced by injection molding. New composite materials provide more advantages in 3D printers and as a production method by extrusion. HDT is used to determine the temperature of plastic. durable rubber. nylon insulation materials. reinforced composite and high-strength thermosetting and thermoplastic softening point and temperature determination [11]. HDT test results indicated in Table 11 and Table 12.

Table 11. HDT Result of the Additive PP Samples.

	1. Station		2. Station		3. Station	
Test	Deep (mm)	Temperature (°C)	Deep (mm)	Temperature (°C)	Deep (mm)	Temperature (°C)
1	0.01	26.2	0.01	26.9	0.01	27.1
2	0.04	28.3	0.04	28.5	0.04	29.6

3	0.07	30.0	0.07	31.2	0.07	32.3
4	0.10	32.1	0.10	33.4	0.10	33.1
5	0.13	33.0	0.13	34.9	0.13	34.8
6	0.17	35.2	0.17	35.7	0.17	35.9
7	0.20	36.3	0.20	37.6	0.20	37.8
8	0.23	37.8	0.23	38.5	0.23	38.8
Average	*0.118*	*32.3*	*0.118*	*33.3*	*0.118*	*33.6*

Table 12. HDT Result of Composite Samples.

	1. Station		2. Station		3. Station	
Samples	Deep (mm)	Temperature (°C)	Deep (mm)	Temperature (°C)	Deep (mm)	Temperature (°C)
Recycled PP	0.11	32.3	0.11	33.3	0.11	33.6
PP+ Graphene	0.11	53.11	0.11	53.12	0.11	53.11
PP+ Graphite	0.11	38.71	0.11	38.53	0.11	38.91
PP+Nano carbon	0.11	34.92	0.11	34.13	0.11	35.12

In the study. eight different measurements were made at three stations and the average of the results of these measurements was calculated. Graphene-reinforced composite material increased by 64%. graphite-reinforced composite material increased by 19%. and nano carbon-reinforced composite material increased by 9%. The bending resistance of the new composite material against heat has increased.

In the literature studies [6], according to Izod impact test results, it was observed that the fracture energy increased by 5% in the polyester resin and 0.004% graphene composite material, and when 0.2% graphene was added, the mechanical properties of the new composite material increased by 86% compared to the resin polyester. These data were compatible with our composite material.

In another literature study [2], the deterioration temperature of 0.1% graphene reinforced Polystyrene composite material was observed to be 382 °C, the graphene ratio was observed to be directly proportional to the deterioration temperature and the mechanical properties of the material, and it was observed that the hardness values of the graphene reinforced Polystyrene composite material decreased with the graphene ratio. This led to the conclusion that our study is compatible with the literature.

4. Conclusions

In this study. a composite material formed by adding graphene. graphite and nano carbon material to PP material at a rate of 1-2%. Homogeneous mixture made with two screw extruders. Prototype standard plate tensile test rods have produced on the injection machine. According to the experimental test results, it has been observed that there is an increase in the mechanical properties of the composite material, and it has been observed that there is an increase in the thermal properties of the composite material. We can say that it is positive for test samples produced by extrusion method for 3D printers due to the increase in viscosity of new composite materials.

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