

Wood and Quartz Substituted Composite Material Characteristics

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Many engineering designs focus on the production of durable, ergonomic, and economical new materials. In today's world where natural resources are rapidly decreasing, recycling waste materials is of great importance. As a result of the bending test, the sample's return to its original dimensions shows the plastic feature of the material. It was observed that the tensile strength can be increased if the speed of the injection machine is well adjusted in the production of tensile strength testing samples. There was an increase in the screw tensile strength of the samples and the joint hardness strength. Thermogravimetric analysis (TGA) showed that the reference samples were completely crumbled around 480 °C, and it was observed that only quartz remained from the input materials. Differential scanning calorimetry (DSC) showed that the peak point in the reference sample was at the heat flow rate of 29 m/W, while it was 18 to 19 m/W in the doped groups. Melting temperature was observed in the range of 125 to 135 °C in all groups. The mechanical properties of the quartz-substituted samples increased compared to the reference sample. It was observed that the quartz and wood powder contained in the mixture worked in harmony.

Keywords: Quartz; Wood powder; Composite material; Bending; Injection

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INTRODUCTION

Plastic composite products obtained from thermoplastic materials by various production methods in recent years have been used in many fields, such as the automotive industry, electronic home appliances, computer systems, white goods production, space technologies, and even artistic equipment. These materials can be formed easily; they are of low density compared to metals and their superior surface quality and resistance to corrosion have important effects on the tendency of interests towards plastic.

In a world where limited natural resources are gradually decreasing, it is important to recycle waste materials into production. Loss and waste material arise due to the unique working and production systems of each sector. Today, with the decrease of natural resources, it is of great significance to regain waste materials by using recycling systems.

A composite material contains phases that are separated from each other by their form and chemical composition and are basically insoluble in each other, such that there is a mixture or combination of two or more micro or macro components (Erol 2007). The composite material often consists of only two phases. The first phase, called the matrix, usually wraps the other phase and helps to increase the strength by providing continuity. Carbon fiber-reinforced composite materials, glass fiber-reinforced composite materials,

car tires, plastics, ceramics, and concrete can be given as examples of composite materials. Concrete is an example of a large-particle composite known as both a matrix and ceramic.

Many engineering designs appear because of the necessity of production of new materials. Strength, ease of use, lightness, and being economical are the main objectives of the new material. The purpose of the formation of nanocomposite materials is to enable the production of new materials that work on the nano-sized molecule-based materials. When the molecular structure it contains is considered, composite materials are divided into three classes: polymeric, ceramic, and metallic. Calcium carbonate is the most commonly used filling material with polyester resin systems. In nature, it is found in the form of chalk, limestone, marble, and travertine and may contain small amounts of other minerals (Feldman 1987). In terms of weight, it is the most important filling material added to ground calcium carbonate plastics. Its finely ground variety is also used especially in polyvinyl chloride (PVC). Calcium carbonate helps both to reduce costs and to increase physical and mechanical properties (Feldman 1987).

It is thought that there are three main ways to reduce costs by adding fillers to plastics: (1) using two different materials together, (2) strengthening with fiber materials, and (3) using polymers such as polyethylene and polypropylene with minerals such as calcium carbonate (marble powder).

The cheapest and most used strategy is to create new compounds with minerals. For example, although the increase in polymer usage has slowed down in the USA, the use of minerals in the polymer industry is increasing. In Western Europe, the use of minerals in the polymer sector also rose from 278,000 tons in 1972 to 650,000 tons in 1985, whereas the average annual polymer use increased 7% (DPT 1996).

As previously mentioned, the use of minerals, one of the most common ways to reduce costs, naturally has brought some problems. There is a difference in surface tension between polymers that are organic materials and minerals that are inorganic. For this reason, minerals are coated to obtain better physical values. Today, over 100 known types of surface coatings are made. The surface coating commonly used in CaCO_3 is made with stearic acid (DPT 1996). Nanocomposites are materials formed by the dispersion of nanometer (10^{-9} micron)-sized particles in a matrix (Bağcı 2006). In addition to polymer-based matrices, metal and ceramic-derived materials are also used as matrices in composite materials. Although other matrices are used, 90% of composite materials are produced with polymer-based matrices (Bağcı 2006). Because the usage areas of polymers has increased by diversifying, it has become important to develop polymers that provide the mechanical, thermal, and electrical properties required by their use or to bring the existing polymers to the desired properties with additives, and studies in this direction have increased (Tavman and Turgut 2006; Swoboda *et al.* 2008). Due to the nanometric dimensions of the filling particles, nanocomposites have high area/volume ratios and even at low clay densities, significant increases in physical and mechanical properties can be seen because the interaction area between phases is large (Yılmaz Bayhan 2006).

The combination of melt blending, extrusion, and compression molding methods is generally preferred by many researchers. The prerequisite for obtaining the desired polymer matrix nanocomposite sample is the regular distribution of the particles in the matrix (Tavman and Turgut 2006). Polymers' ease of processing, mechanical behavior, flexible structure, and low density are important advantages (Şahmetlioğlu *et al.* 2007).

In Toyota research laboratories, for the first time, clay-polymer nanocomposites combined with polymerization have shown far superior mechanical and thermal properties than organic and mineral materials (İşçi 2007). As a result of many studies, polymeric

nanocomposites have started to be used in automobiles today. Such materials are 10 times lighter and 10 times stronger than traditional talc filling composites in materials with low filler content. This important feature makes these materials suitable for automotive manufacturing (Yılmaz Bayhan 2006).

Polymer composite materials are engineering products formed by connecting many monomers to each other. This new material, which is formed when the fibers of woody and annual plants and flour (powders) of woody products are combined with polymer thermoplastics, is called a wood-plastic composite. Wood fiber or dust ratio should be more than 50%. The properties of wood-plastics are constituted by the used wood/fiber structure, molecular weight of thermoplastic polymer, additives, and adaptive substances (Mengeloğlu 2006).

In wood-plastic composites, the contents can include dust of wood materials or by-products such as compacted medium-density fiberboard (MDF) or chipboard. Wood powders, such as wood flour, increase the hardness of the composite material while decreasing its durability (Jeong 2005). Thermoplastic resins (low density and high-density polyethylene and polypropylene) and wood powders are used in the production of wood-plastic composite materials.

In the production of composite materials, cheapness, low density, high strength, low abrasion, and being degradable in nature provide motivations to use lignocellulose-based fibers (Chen 2009). The first wood-plastic composite was produced in 1907 by mixing wood flour and phenolics and was produced and used for commercial use as a gear lever in vehicles in 1916. The market share, which was 2% in 1997, increased to 18% by 2005, and a significant increase was observed in wood-plastic composite production. There are now manufacturers of these products in many parts of the world (Balma 1999; Mengeloğlu 2006; Rowel 2006).

In this study, test samples were produced using a molding method by extruding high-density polyethylene, wood powder (flour), and quartz mineral in certain amounts as thermoplastic materials with 100 bar pressure and 45 s injection loading, and the produced quartz-substituted wood-plastic composite material test samples were mechanically and thermally studied with experiments. The usability of quartz as a raw material was also investigated because the waste materials must be recycled in our world where the original raw materials are being consumed rapidly.

EXPERIMENTAL

Materials

Mineral aggregate quartz

Quartz as a filling material is preferred because it gives rigidity and high strength to the polymer concrete it is used in; this is due to its high hardness. The chemical and physical technical properties of the quartz aggregate used in the study are shown in Table 1.

Petilen YY I668 (high-density polyethylene) (HDPE)

The PETILEN YY I668 is a product produced in accordance with the injection molding technique, with high density and narrow molecular weight distribution as per ASTM D618-96 (1998). It is an ideal material for the production of rigid and flexible products in injection molding applications.

The injection molding method was used. Recommended processing conditions were in the range of 200 to 260 °C, and the technical features of the product used are given in Table 1.

Table 1. Technical Specifications of Thermoplastic Material and Quartz Mineral

Resin Properties	Petilen (HDPE)		Quartz Mineral Properties	
	Typical Value	Unit	Size of Product	0 to 75 micron
Melting flow rate (230 °C)	5.5	g/10 min	Hardness scale	7 mohs
Density	0.965	g/cm ³	Specific weight	2.65 g/cm ³
Melting point (differential scanning calorimetry)	134	°C		
Mechanical Properties			Quartz Chemical Analysis Report	
Tensile strength in flow	34	MPa	Compound	Compound Weight %
Tensile strength at break	17	MPa	SiO ₂	97.13
Elongation at break (MY)	1250	%	Al ₂ O ₃	1.72
Flexural modulus (23 °C)	1200	MPa	Fe ₂ O ₃	0.029
Izod impact resistance (23 °C)	2250	J/m	TiO ₂	0.031
Hardness (Shore-D)	66	R-scale	CaO	0.06
Rockwell hardness	----	R-scale	MgO	0.02
Environmental stress fracture strength	4	h	Na ₂ O	0.91
Thermal Properties			P ₂ O ₅	0.00
Deformation temperature (0.45 MPa)	-----	°C		
Vicat softening point (10 N)	124	°C		

Wood powder

Within the scope of the study, machine residual dust belonging to the remaining wood and wood products were used as waste material in the furniture sector. Mixing ratios of the powders were not fixed; sawdust and dust from pine, beech, poplar, MDF, chipboard, wood scraps, and some edge bands were collected. After this waste material was dried in the oven, it was ground and sieved through a sieve with a thickness of 200-mesh and a powder material was produced in the form of flour (Horta *et al.* 2017). When the values of the substances in this mixture were analyzed, the abundance of cellulose material were seen. The properties of the prepared wood powder (flour) are given in Table 2.

Table 2. Technical Specifications for Wood Powder (Flour)

Elemental Analysis Weight	C %	H %	N %	S%	O %
	50.02	6.62	1.96	-	47.66
Analysis By Weight	Volatile Matter%	Ash%	Moisture%	Constant%	C Thermal Value (cal/g)
	75.68	1.01	4.10	19.21	5413.9
Chemical Analysis Weight	Extractable Substances %	Hemicellulose%	Cellulose%	Lignin%	
	9.8	11.1	56.1	23.0	

Methods

Preparation of test samples

High-density polyethylene material from thermoplastics, 200-mesh fine wood powder (flour), which is industrial waste, and quartz mineral with a fineness of less than $0.100\ \mu$ (micrometers), were prepared by the method of displacement at certain rates. Denomination and mixing ratios of the experimental groups prepared for quartz, wood, and polyethylene-added composite materials are given in Table 3.

Table 3. Mixing Ratios of Experimental Sample Groups

Reference C-0	High-density Polyethylene (100%)
PEWQ-1-	HDPE Polyethylene(30%) - Wood Powder(30%)-Quartz(20%)
PEWQ-2-	HDPE Polyethylene(50%) - Wood Powder(20%) – Quartz(30%)
PEWQ-3-	HDPE Polyethylene(50%) - Wood Powder(10%) – Quartz(40%)

The materials prepared separately with each recipe of thermoplastic, wood, and quartz materials were mixed in the mixer (KMIX200; Küçüköğlü Machine, Izmir, Turkey). All of the materials were brought together by blending them in the extruder machine (Fig. 1) (25/36D Extruder; Sarem Machine, Izmir, Turkey)



Fig. 1. Combining materials in the extruder machine

The extrusion process has played a major role in the development of the polymer processing industry. The most striking feature of the extrusion process is a cylindrical barrel and a screw rotating inside and this process is the most important polymer processing technique today. Approximately 60% of the polymers are processed by this method and become the final product (Bodur 2010). The samples that were brought together in the extruder machine were granulated in the crushing machine (Fig. 2) (SG-21EB; Hastek Machine, Aydin, Turkey).

The material, which became granular for the injection machine, was kept in the oven at a certain temperature and reduced in moisture content. To form test samples, for mechanical and thermal testing with the ready material, 100 bar pressure and 45 s injection loading were applied in the injection machine and the test samples were produced by molding method (Fig. 3). Four groups of material production happened under the same conditions.



Fig. 2. Breaking the material in the crushing machine



Fig. 3. Production of test samples with molding method

Experimental process

Quartz, 200-mesh fine wood flour (powder), and thermoplastic product (high-density polyethylene) were prepared by the replacement method in certain mixtures, and with the prepared material, the extruder and test bars used in the tests after the injection processes were produced (Figs. 4 and 5). Bending, tensile strength, screw pulling, and Janka hardness tests were applied to the test samples in accordance with the standards and the results and graphics of the tests are interpreted below according to ASTM D790 (2007), ASTM D638-99 (2007), ASTM D1037 (2012), and TS EN 323 (1999).

In addition, thermogravimetric analysis (TGA) (Pyris 6 Thermogravimetric Analyzer; Perkin Elmer, Mugla, Turkey), differential scanning calorimetry (DSC) (DSC 8500 is a double-furnace DSC; PerkinElmer, Mugla, Turkey), and scanning electron microscopy (SEM) (Model; Jeol Jsm-7600f SEM; JEOL LTD., Muğla, Turkey) analyses were performed on the composite elements produced as thermal tests.

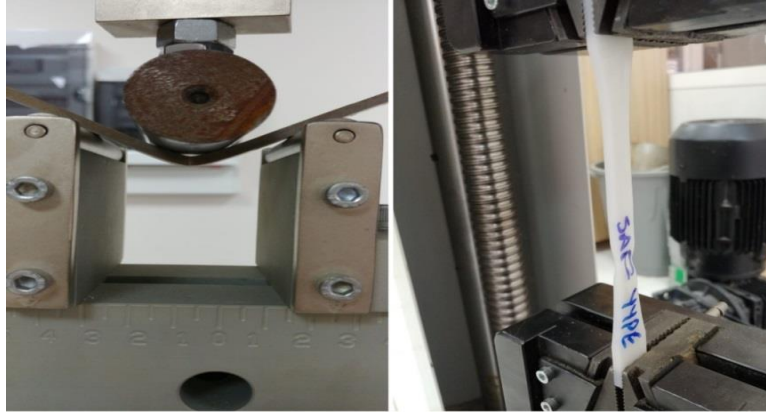


Fig. 4. Experimental process application images bending test and tensile strength test

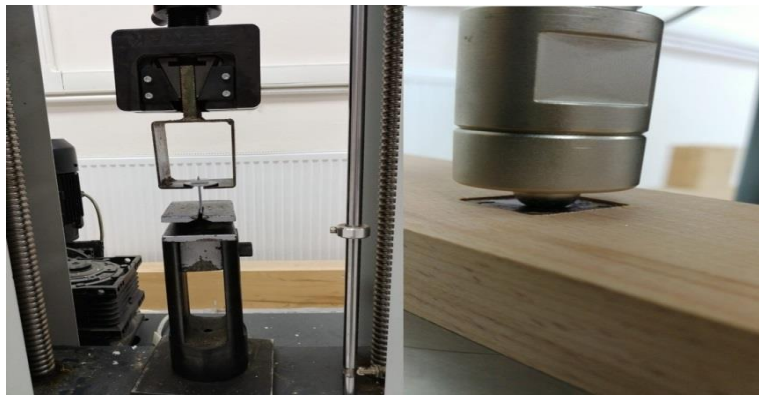


Fig. 5. Experimental process application images screw pull resistance test and Janka hardness resistance test

RESULTS AND DISCUSSION

Bending Test

It was observed that the bending resistance of the reference sample was 25.4 N/mm². In the sample PEWQ-1, there was an increase of 19.8% in the bending resistance compared to the reference sample. In the sample PEWQ-2, the bending resistance increased 3.6% compared to the PEWQ-1 group when the wood dust was less and the quartz mineral was high. In the sample PEWQ-3, the increase at the level of 3% continued in the maximum force and bending resistance compared to the group PEWQ-2 when the wood dust was low and the quartz mineral was high.

Tensile Strength Test

It was observed that the tensile strength of the reference sample was at the level of 19,700 N/mm². In the sample PEWQ-1, there was a decrease in the tensile strength compared to the reference sample, and accordingly, the tensile strength decreased at the level of 29.3%. In the sample PEWQ-2, there was a decrease in the tensile strength and accordingly an increase of 3.41% compared to the group PEWQ-1. In the sample PEWQ-3, there was a slight increase in the tensile strength compared to the sample PEWQ-2 and accordingly the tensile strength increased 1.12%.

Screw Pull Resistance Test

It was observed that the threading strength obtained by the reference sample was at the level of 109.8 N/mm². In the sample PEWQ-1, there was a decrease in the threading strength compared to the reference sample, and accordingly, the threading strength was at the level of 103.0 N/mm². In the sample PEWQ-2, there was an increase in the threading strength and accordingly, the threading strength increased 2.8% compared to the group PEWQ-1. In the sample PEWQ-3, there was an increase of 0.5% in the threading resistance compared to the sample PEWQ-2 and accordingly threading strength increased proportionally with the increase of quartz.

Janka Hardness Resistance Test

It was observed that the Janka hardness value taken by the reference sample was at the level of 34.4 N/mm². In the sample PEWQ-1, there was a decrease in the tensile strength compared to the reference sample, and accordingly, the rigidity resistance of the ring was at the level of 29.4 N/mm². In the sample PEWQ-2, there was an increase in the threading strength and accordingly, the rigidity resistance value of the ring increased 4% compared to the group PEWQ-1. In the sample PEWQ-3, there was an increase of 10.3% in the hardness strength of the Janka compared to the sample PEWQ-2, and accordingly the hardness strength of the Janka increased.

Resistance values against the maximum force in the bending, tensile strength, screw pulling, and Janka hardness tests of the test bars of high-density polyethylene are shown in Table 4, and the values are plotted in Fig. 6.

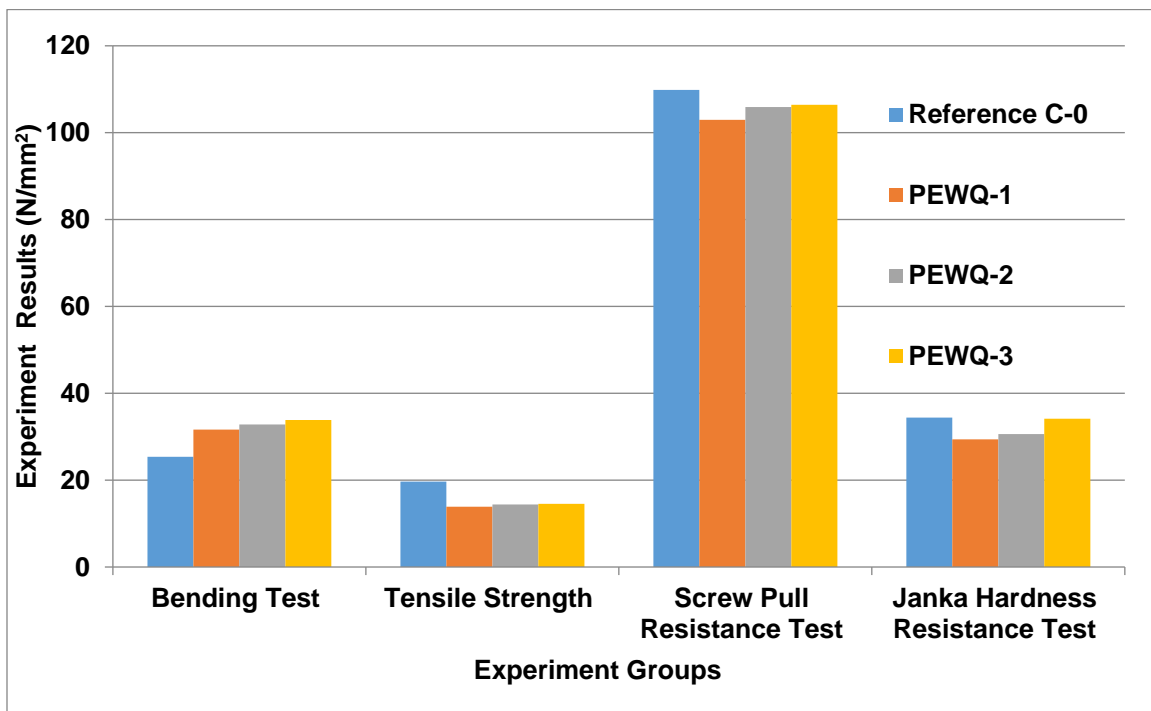


Fig. 6. The graph of bending, tensile strength, screw pulling, and Janka hardness test results on high-density polyethylene samples

Table 4. Results of Bending, Tensile Strength, Screw Pulling, and Janka Hardness Tests on High-density Polyethylene Samples

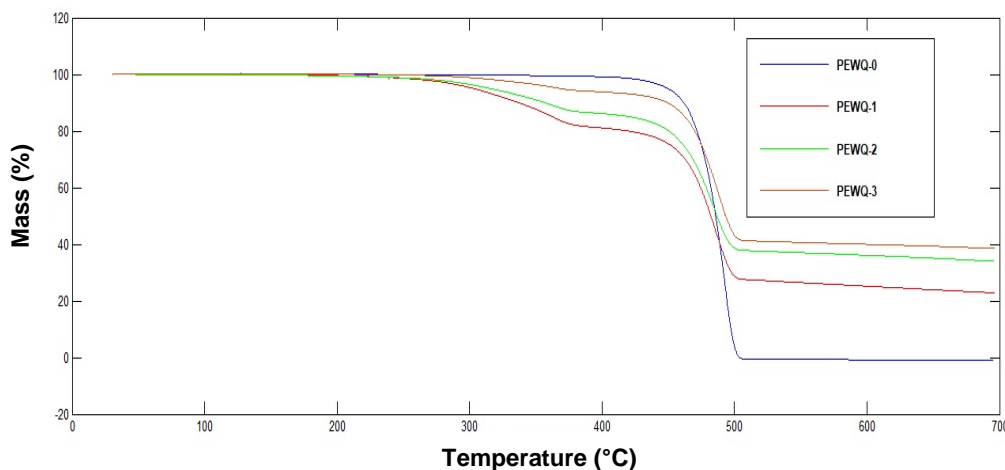
	Bending Test (N/mm ²)	Tensile Strength (N/mm ²)	Screw Pull Resistance Test (N/mm ²)	Janka Hardness Resistance Test (N/mm ²)
Reference C-0	25.3751	19.65422117	109.8348	34.38876
PEWQ-1	31.62693	13.89279667	102.9701	29.39389
PEWQ-2	32.82213	14.38313067	105.9121	30.62299
PEWQ-3	33.83346	14.54657533	106.4025	34.1534

Thermogravimetric Analysis (TGA) Results on HDPE, Wood Powder, and Quartz-substituted Composite Material

Thermogravimetric analysis on the composite samples used in this study was recorded by selecting the nitrogen flow rate of 20 mL/min, the heating rate of 30 °C/min, and measuring their behavior against heating of up to 700 °C.

In the study of Altuntaş *et al.* (2016), it was revealed that, according to the results obtained, the composite without boron (288 °C) lost weight earlier than the added composites (308 °C), and moreover, when the composites added with boron compounds were compared among themselves, the disintegration of the composites with zinc boron started at 319 °C and the boron components delayed the degradation of the material according to the results of the TGA curves of the composites with boron added (Altuntaş *et al.* 2016).

In another study, it was understood that added boric acid and borax compounds increased the decomposition temperatures of composites (Cavdar *et al.* 2015).

**Fig. 7.** TGA chart in HDPE, wood powder, and quartz-substituted composite materials

According to the results of TGA obtained, HDPE samples without additives completely dissolved around 480 °C and lost their weight. It was observed that in samples containing wood dust and quartz, the disintegration of the plastic material started after 300 °C and the polyethylene material and wood dust disappeared until it reached 480 to 500 °C, but only quartz remained.

Due to the high combustion temperature of quartz, it was observed that quartz preserved its weight without deterioration after 500 °C. It was understood that quartz,

which is used as a mineral filler, retards the disintegration in the composite material and also prolongs the decomposition temperatures.

Differential Scanning Calorimetry (DSC) Analysis Results on HDPE, Wood Powder, and Quartz-substituted Composite Material

Differential scanning calorimetry is a widely used instrumental method to investigate the thermal transients of polyurethane elastomers and their layout within the sample. Therefore, DSC curves are widely used for polyurethane morphology studies (Seymour and Cooper 1974; Zielinski and Rutkowska 1986).

Differential scanning calorimetry scans of Thermoplastic Elastomers (TPEs) showed a series of typical endothermic transitions grouped into three categories. Transitions below 60 °C were associated with the glass transition temperature of the soft part, endothermic transitions between 60 and 150 °C resulted in the rearrangement of the hard/soft part interface, and transitions greater than 150 °C were due to breakage of the inner-urethane hydrogen bonds (Seymour and Cooper 1971). These transitions depend on the characteristic information of the phase morphology of the polyurethane and the thermal history of the material. Thermal annealing results in increased order in the hard area and increased phase separation within the polymer. This low soft part may be associated with endothermic assembly at higher temperatures. The transitions associated with the rearrangement of the rigid segment were sharper and indicate more annotation within the increased regular area. Differential scanning calorimetry was also used to explain the hydrogen bonding effect on polyurethane structure.

Clough and Schneider in their work on this subject studied the hydrogen bonding effect of polyether and polyester-based polyurethane using DSC, XRD, and light scattering devices (Drobny 2007). In this study, they identified two endothermic transitions, indicating two sharp types of hydrogen bonding. The transition at 80 °C was interpreted as the soft part's ether oxygen or the result of hydrogen bonds between the ester carbonyl urethane hydrogen. It is thought that the transition occurring at temperatures above 140 °C is related to internal-urethane hydrogen bonds. They asserted that the higher temperature transitions were related to the type of hydrogen bond associated with the separation of urethane groups leading to the dominant structure (Crawford 1998).

Seymour and Cooper conducted annealing studies of a series of polyether and polyester-based polyurethanes in connection with infrared spectroscopy (IR) studies. They identified many endothermic transitions related to these polymers (Seymour and Cooper 1971, 1974; Seymour *et al.* 1975). Seymour and Cooper named these transitions T_1 , T_{11} , and T_{111} and observed these heat transitions as approximately 70 °C, 160 °C, and 185 °C, respectively. They attributed T_1 and T_{11} to the degradation of the short and long range order, respectively, and clarified that the peak of T_{111} was associated with the melting of the microcrystalline field (Seymour and Cooper 1973; Crawford 1998).

Samples were prepared in an aluminium pan by weighing 10 mg of polymeric materials. Starting from -50 °C, the system was heated up to 200 °C at a rate of 10 °C/min. The midpoint of the endothermic peak was taken as the T_g value. According to the DSC analysis chart on HDPE, wood powder, and quartz-added samples in Fig. 8, the reaction beginning temperature of the test samples started around 25 to 30 °C.

The peak point of HDPE was at a heat flow rate of 29 m/W compared to the doped ones, while it was at a heat flow rate of 18 to 19 m/W in the groups with wood dust and quartz additives. Melting temperature was observed in the range of 125 to 135 °C in all groups.

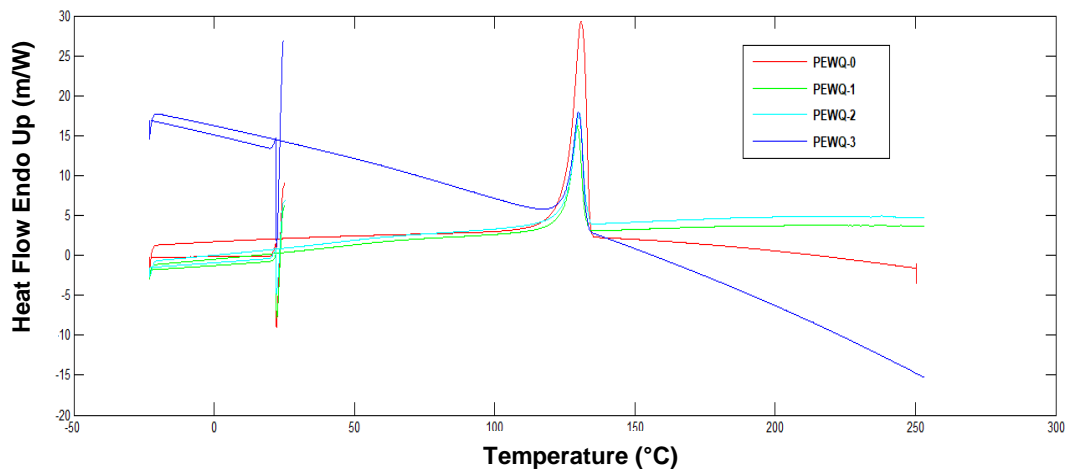


Fig. 8. DSC graph in HDPE, wood powder, and quartz-substituted composite materials

Scanning Electron Microscope (SEM) Analysis of HDPE, Wood Powder, and Quartz-substituted Composite Elements

According to scanning electron microscopy (SEM) of HDPE, wood powder, and quartz-substituted composite elements, the inorganic matter in the polymer was evenly distributed.

If the distribution of inorganic matter in the polymer matrix is uneven, the inorganic material becomes lumpy in the polymer matrix and restrains the properties of the final product from enhancing (Sormana 2005). In the SEM images (Fig. 9), the wood powder and quartz added into the test samples showed homogeneous distribution in the polymeric composite element. It was clearly seen that the components entering the mixture were compatible with the segments inside and the bonding between them.

Bending resistance, tensile, screw pulling, and joint hardness tests were performed on high-density polyethylene, wood powder, and quartz-added composite material. When the bending test started, the samples resisted up to the maximum force, and the return of the sample to its original dimensions as a result of bending showed the plastic property of the material. No break or cracks were observed in the samples thanks to the compatibility of the components in the mixture with each other.

In the samples subjected to the tensile test, it was observed that there were gaps in some parts of the test sample, which was thought to be dependent on the machine speed during injection, but the tensile strength was around 20 N/mm² in the reference sample and 13 to 14.5 N/mm² in the doped samples. It was also understood that the tensile strength could be increased by paying attention to the injection machine speed setting to prevent gaps. In the screw pull resistance test and Janka hardness resistance test results, it was observed that there was an increase in the threading resistance and Janka hardness resistance of the samples. It can be mentioned that this was due to the technical properties of HDPE and quartz. The hardness of quartz showed its effect in the experiments. As the quartz amount increased, threading and Janka hardness values increased. The adherence of the components that make up the composite material was positive in terms of mechanical properties.

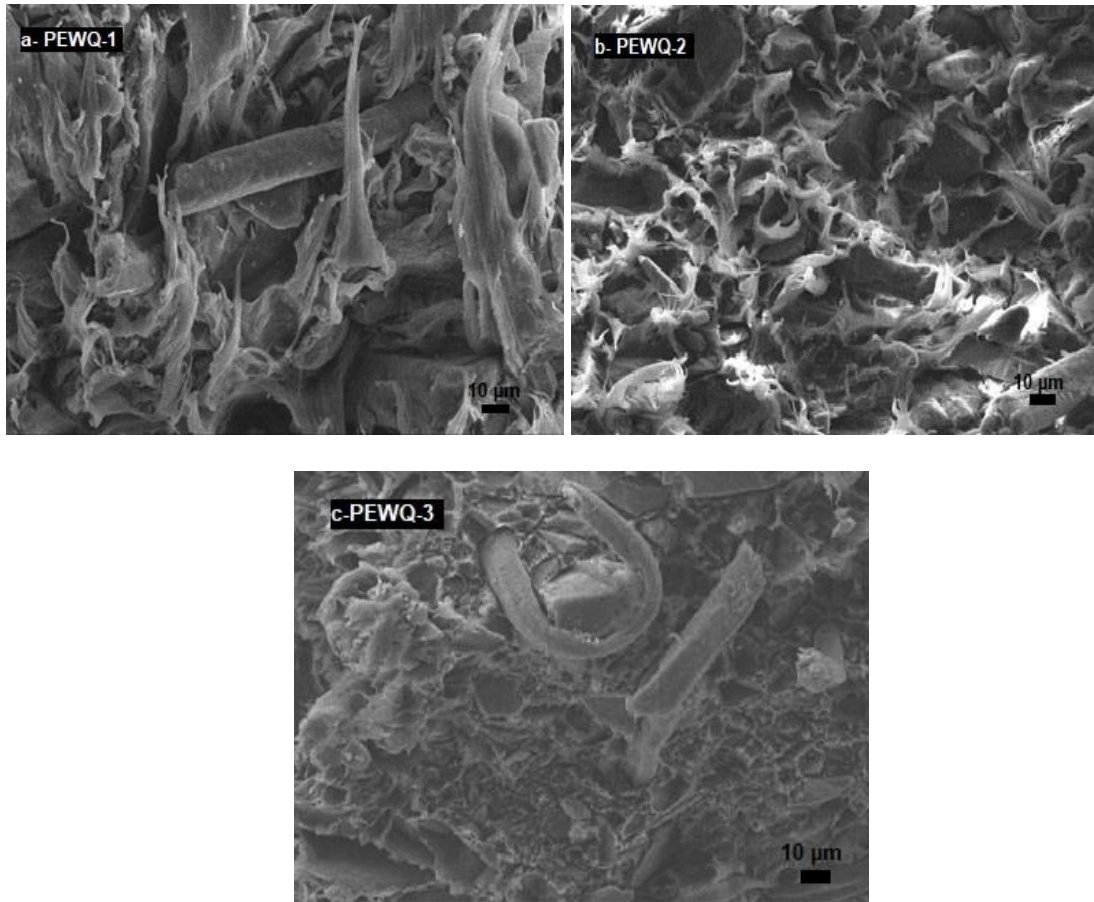


Fig. 9. SEM images of composite materials with HDPE (a), wood powder (b), and quartz substitution (c)

According to the results of the TGA obtained, HDPE samples without additives completely dissolved at approximately 480 °C and their weight was lost. In the samples containing wood dust and quartz, the degradation of the plastic material started after 300 °C and continued until the temperature reached 480 to 500 °C. At that point the polyethylene material and wood dust had disappeared and only quartz remained. Due to the high combustion temperature of quartz, it was observed that quartz preserved its weight after 500 °C without degradation.

It was found that quartz, which is used as a mineral, retarded the degradation in the composite material and also prolonged the decomposition temperatures. According to the DSC analysis chart on HDPE, wood powder, and quartz added samples, the reaction beginning temperature of the test samples started around 25 to 30 °C. The peak point of HDPE was at a heat flow rate of 29 m/W compared to the doped ones, while it was at a heat flow rate of 18 to 19 m/W in the groups with wood dust and quartz additives. Melting temperature was observed in the range of 125 to 135 °C in all groups. In the SEM Images, the wood powder and quartz added into the test samples showed homogeneous distribution in the polymeric composite element. It was clearly apparent that the components entering the mixture were compatible with the segments inside and the bonding between them.

In this study, the usability of quartz in plastic composite production was observed according to the results of the experiments performed on plastic HDPE, wood powder, and quartz mineral substituted test samples, and it was also seen as a result of the experiments

in this study that quartz, wood dust, and polyethylene increased the bending strength, tensile strength, threading, and joint hardness strength. The highest strength values were achieved in composites where quartz was used more.

In all groups with thermoplastic additives, it can be said that the samples with high quartz substitution increased relatively. Moreover, according to the results of the reference samples of the HDPE material due to the technical characteristics of the plastic additive, the quartz and wood powder in the mixture worked in harmony.

CONCLUSIONS

1. When the bending test started, the samples resisted up to the maximum force, and the return of the sample to its original dimensions as a result of bending showed the plastic property of the material. No breaks or cracks were observed in the samples due to the compatibility of the components in the mixture with each other.
2. In the samples subjected to the tensile test, it was observed that there were gaps in some parts of the test sample, which was thought to be dependent on the machine speed during injection, but the tensile strength was around 20 N/mm² in the reference sample and 13 to 14.5 N/mm² in the doped samples. It was also understood that the tensile strength could be increased by paying attention to the injection machine speed setting to prevent gaps.
3. In the screw pull resistance test and Janka hardness resistance test results, it was observed that there was an increase in the threading resistance and Janka hardness resistance of the samples. It can be mentioned that this was due to the technical properties of HDPE and quartz. The hardness of quartz showed its effect in the experiments. As the quartz amount increased, threading and Janka hardness values increased. The adherence of the components that make up the composite material was positive in terms of mechanical properties.
4. According to the results of the TGA obtained, HDPE samples without additives completely decomposed at approximately 480 °C and lost their weight. It was seen that in the samples containing wood dust and quartz, the degradation of the plastic material started after 300 °C and continued until the temperature reached 480 to 500 °C. At that point the polyethylene material and wood dust had disappeared, and only quartz remained. Due to the high combustion temperature of quartz, it was observed that quartz preserved its weight after 500 °C without degradation. It was found that quartz, which is used as a mineral, retarded the degradation in the composite material and also prolonged the decomposition temperatures.
5. According to the DSC analysis chart on HDPE, wood powder, and quartz added samples, the reaction beginning temperature of the test samples started around 25 to 30 °C. The peak point of HDPE was at a heat flow rate of 29 m/W compared to the doped ones, while it was at a heat flow rate of 18 to 19 m/W in the groups with wood dust and quartz additives. Melting temperature was observed in the range of 125 to 135 °C in all groups.
6. In the SEM images, the wood powder and quartz added into the test samples showed homogeneous distribution in the polymeric composite element. It was clearly apparent

that the components entering the mixture were compatible with the segments inside and the bonding between them.

7. In all groups with thermoplastic additives, the samples with high quartz substitution increased relatively. In addition, according to the results of the reference samples of the HDPE material due to the technical characteristics of the plastic additive, the quartz and wood powder in the mixture worked in harmony.

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