Special Issue of the 8th International Advances in Applied Physics and Materials Science Congress (APMAS 2018)

Mechanical Properties of Quartz-Added PP Based Composites Produced by High Speed Thermo-Kinetic Mixer

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Micronized quartz powders reinforced polypropylene (PP) composites were fabricated by using high speed thermo-kinetic mixer. The effect of micronized quartz on the mechanical properties of PP composites was investigated. Mechanical tests were carried out to determine tensile and flexural properties of composites. Dynamic Mechanical Analysis of composites was performed to determine their thermo-mechanical properties, such as storage modulus and loss modulus. The results indicate that the tensile strength of PP decreased with addition of micronized quartz. Flexural strength, tensile modulus and flexural modulus of PP increased with the addition of 10 wt% micronized quartz.

DOI: 10.12693/APhysPolA.135.1045

PACS/topics: polypropylene, quartz, composites, mechanical properties

1. Introduction

Thermoplastic based composites offer several advantages such as low density, high toughness, relative ease of manufacture and recyclability. Polypropylene PP is one of the most widely used polymer materials in the thermoplastic industry [1]. But polypropylene still need mechanical properties enhancement to enlarge its applications as engineering plastics [2].

Composite materials are the main substitute for the conventional engineering materials due to its good characteristics of strength to density, low-cost, eco-friendly manufacturing processes [3]. In the past decade, polymer matrix composites have replaced many conventional materials due to their better mechanical properties like corrosion resistance, wear resistance, better strength to weight ratio, better stiffness etc [4]. In general, the physical and mechanical properties of the composites depend on various factors such as the composition, their interactions and the operating conditions [5]. PP based composites have been already used in many industrial applications [6].

The objective of this study is to examine the influence of micronized quart and silanized quartz on the mechanical properties of quartz powders reinforced PP composites. In the study, quartz was used as a reinforcement material in PP composites. Quartz with various weight fractions was blended with PP using a high speed thermo-kinetic mixer.

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2. Materials and equipment

2.1. Materials

In this research, Petoplen MH 418 polypropylene that was supplied from Petkim with 25 kg polyethylene sacks was used. In this study, micronized quartz (MQ) powder obtained from quartz quarried at the mines of Pomza Export Mining Industry and Trade Co. in the region of Salihli Kaletepe and the silanized quartz (SQ) with surface modification agent obtained from Quarzwerke Group was applied. Also, MQ powder taken from Pomza was used as filling material in polymer matrix composite materials after it has been modified with four different surface agent. The result of particle size analysis of MQ powder is indicated in Table I.

TABLE I

Particle ratio of micronized quartz powders.

Size [μm]	Ratio [%]
> 75	max. 1
$75 \to 63$	0–4
$63 \to 45$	10–15
< 45	80–85

MQ powder is widely used as filling material for insulation applications in electricity sector because of its low electrical conductivity, high abrasion and corrosion resistance. The most important feature that should be considered when it is used as the epoxy filling material in respect of the insulating properties is the amount of iron and iron compounds impurities. Chemical composition of MQ powders used in this study is given in Table II.

TABLE II

Chemical analysis of micronized quartz powders [%].

SiO_2	Fe_2O_3	Al_2O_3	TiO_2	CaO	K_2O	others
99.410	0.040	0.200	0.002	0.160	0.020	0.080

2.2. Quartz surface modification process

Firstly, a liter of aqueous solution containing 5 wt% of alcohol was prepared in the plastic beaker. The plastic beaker was placed on a magnetic stirrer. pH value was measured. Acetic acid was slowly added to the beaker. Once pH value remained at the ideal level (3–3.5), 1.5 mL of the modification agent was added to the aqueous solution and stirred for 60 min at 500 rpm. At the end of this time, 150 g of MQ powder was added into the solution. The magnetic stirrer speed was then accelerated to 800 rpm and the quartz was mixed in the solution during 90 minutes. Next the magnetic stirrer was turned off and the solution was drained off with a paper filter to obtain surface modified quartz powder. This powder was dried at 110 °C during 4 h.

2.3 Production of quartz reinforced PP based composite materials

Composites were produced by high speed thermokinetic mixer at different particle/thermoplastic ratios (0–40 wt%). Prior to production, appropriate quantities of particles and thermoplastic granules were weighed separately to get the desired ratio. Mixtures were placed in the mixing chamber of the mixer and the chamber was safely sealed. Thereafter, the material production was carried out via operation of mixer. Composite mixing rates are given in Table III.

TABLE III

Composite mixing rates and short names.

Composite mixing ratio	Short name
10% MQ + 90% PP	10MQ
20% MQ + 80% PP	20MQ
30% MQ + 70% PP	30MQ
10% SQ + 90% PP	10SQ
20% SQ + 80% PP	20SQ
30% SQ + 70% PP	30SQ
40% SQ + 60% PP	40SQ
Coatosil–2287 MQ 10% + 90% PP	2287
Coatosil–MP200 MQ 10% + 90% PP	MP200
Silquest A–187 MQ 10% + 90% PP	A187
Vemab A–110 MQ 10% + 90% PP	A110

3. Results and discussion

A universal tensile testing machine (Shimadzu AG-IC) with a load cell of 5 kN was used to determine the mechanical properties of the produced composites. Tensile tests and flexural tests were performed according to ASTM D638 and ASTM D790 standards respectively. The head speed is 50 mm/min in the tensile test and the head speed is 1 mm/min in the flexural test. Mechanical properties such as tensile strength, modulus of elasticity, flexural strength and flexural modulus of the composites were determined.

The tensile test results for each of the samples produced are given in 4 measurement averages and the flexural test results in 3 measurement averages. The tensile test results of the produced composite specimens are given in Table IV.

TABLE IV

Composites tensile test results.

Sample	PP	10MQ	20MQ	30MQ	10SQ	20SQ	30SQ	40SQ	2287	MP200	A187	A110
Tensile strength [Mpa]	34.2	29.3	29.0	26.3	32.4	30.1	28.5	24.3	32.4	32.1	31.8	32.4
Tensile modulus [MPa]	823	1240	1170	1337	1165	1268	1509	1397	960	986	974	1064

Tensile strength and tensile modulus results of MQ doped composite samples produced in high speed thermokinetic mixer are given in Table IV. According to it, quartz additive reduces the tensile strength of PP material. While tensile strength of PP is 34.20 MPa, tensile strength of 20MQ is 29.30 MPa, and of 30MQ is 26.28 MPa. As it is seen from the results, the tensile strength decreases as the MQ amount increases in the composite. The tensile strength of PP decreases approximately 14.33% for 10 wt% MQ additive.

When the results are examined, it is seen that the tensile strength decreases with the increase of SQ amount also. The tensile strength of the 10SQ sample is approximately 10% higher (32.70 MPa) when it is compared to the 10MQ composite sample with a tensile strength of 29.30 MPa. This is due to the fact that commercial SQ powders provide better matrix-filling interfacial alignment with PP matrix by comparision with MQ powders.

The decrease in tensile strength toward the PP matrix material is due to the fact that the additive material cannot be wetted sufficiently by the matrix material, the powders are not sufficiently dispersed and agglomerates. The adhesion between the matrix and the additive material is poor. The tensile strength of the filled PP decreases gradually due to aggregation of quartz powder and growing presence of micropores within the PP matrix with the increase of the filling rate.

TABLE V

Composites flexural test results.

Samples	PP	10MQ	20MQ	30MQ	10SQ	20SQ	30SQ	40SQ	2287	MP200	A187	A110
Flexural strength [Mpa]	48,3	53,5	50,0	43,8	51,1	47,6	44,0	39,8	48,1	49,5	49,1	50,1
Flexural modulus [Mpa]	1413	1840	2078	2173	1685	1897	2037	2470	1574	1796	1815	1619

Table IV gives tensile test results of composite specimens with quartz powders treated with 4 different surface modifying agents of forms are seen. It has been observed that the tensile strength of composite specimens using modified quartz powders increases compared to 10% micronized quartz composites. This is the promoted result of the surface modification process and the improvement of the filler-matrix interface compatibility.

The flexural test results of the produced composite specimens are given in Table V.

As shown in Table V, the flexural strength of the PP matrix material is about 48 MPa. Composite samples with 10% and 20% MQ additive have a higher flexural strength than PP. However, a dramatic decrease in the flexural strength of the composite sample with 30% contribution is observed. All composite specimens have higher flexural modulus than PP. With increase of the contribution rate the flexural modulus increases also. The flexural strength PP with 10% addition of SQ is higher than for the matrix material, however for bigger contribution rates it tend to decrease. The flexural modulus continues to increase with the growing amount of the additive. The flexural strength of the modified quartz-doped composite specimens shows very low increase with additive quantity. Nevertheless, this effect is more pronouncede for the flexural modulus.

The storage modulus and loss modulus of PP and quartz powder reinforced composites were evaluated using a dynamic mechanical analyzer (TA Instruments, DMA Q800). Single cantilever was used and multi frequency-strain modulus mode was selected to analyze all specimens between the temperatures of 25 and 130 °C in air atmosphere. DMA looks at the modulus of elasticity or the ratio of mechanical stress to relative deformation. The storage modulus (E') and the loss modulus (E'') were determined from the DMA tests. $E0$ represents the stiffness of a viscoelastic material, which is proportional to the elastic energy stored elastically and is reversible.

Storage moduli of PP and quartz reinforced PP composites versus temperature as a function of quartz weight fractions are given in Fig. 1. The storage modulus decreases with increasing temperature due to an energy dissipation phenomenon involving cooperative motions of the polymer chain. Comparing the PP and the MQ reinforced PP composites with different MQ weight fractions at temperatures from 37 to 125 °C, it is easy to find that the modulus of the composites containing 30 wt% MQ was higher than the other specimens, although it decreased dramatically by increasing temperature.

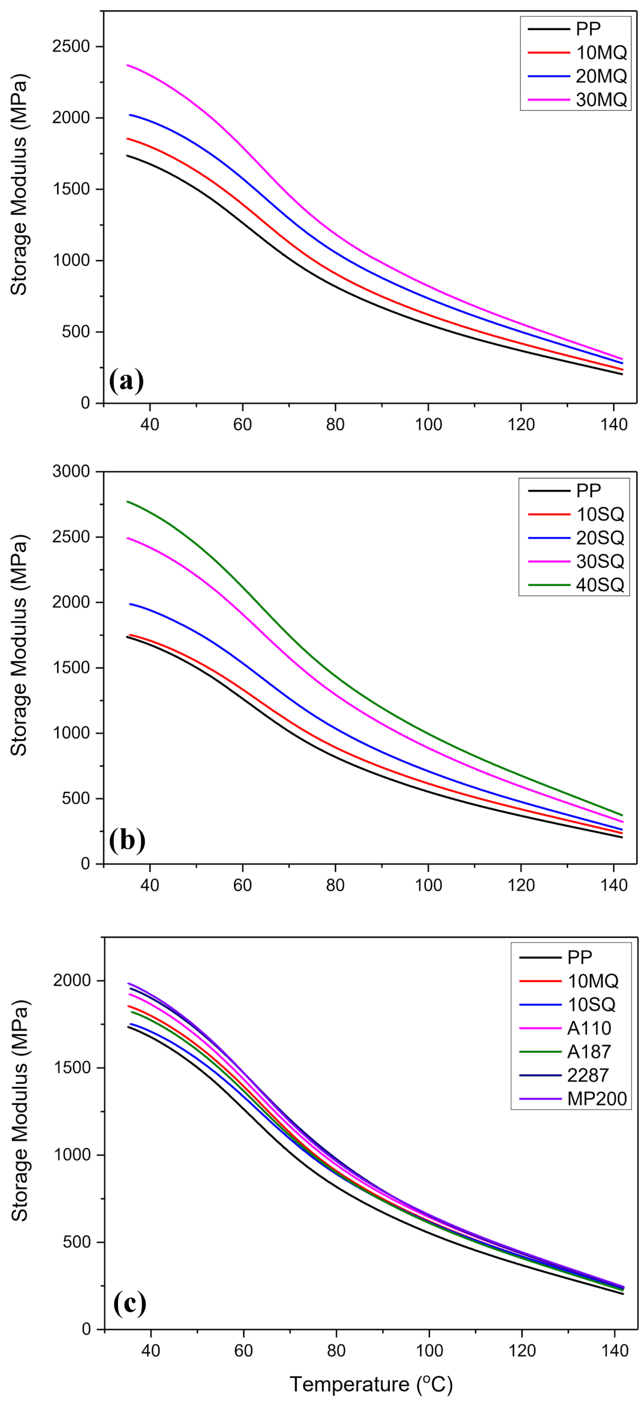

Fig. 1. Storage modulus (E') of PP and (a) micronized quartz, (b) silanized quartz, (c) surface modified quartz reinforced composites.

Comparing the PP and the SQ reinforced PP composites with different SQ weight fractions at temperatures from 37 to 125 °C, it is easy to find that the modulus of the composites containing 40 wt% SQ was higher than the other specimens.

Variations in storage modulus of PP, 10MQ, 10SQ and the surface treated filler loaded composites versus temperature were shown in Fig. 1c. MP200 composite has the highest storage modulus value among all samples at 35 °C. The storage modulus values of the all samples are decreased with increasing temperature because of an energy dissipation phenomenon [7].

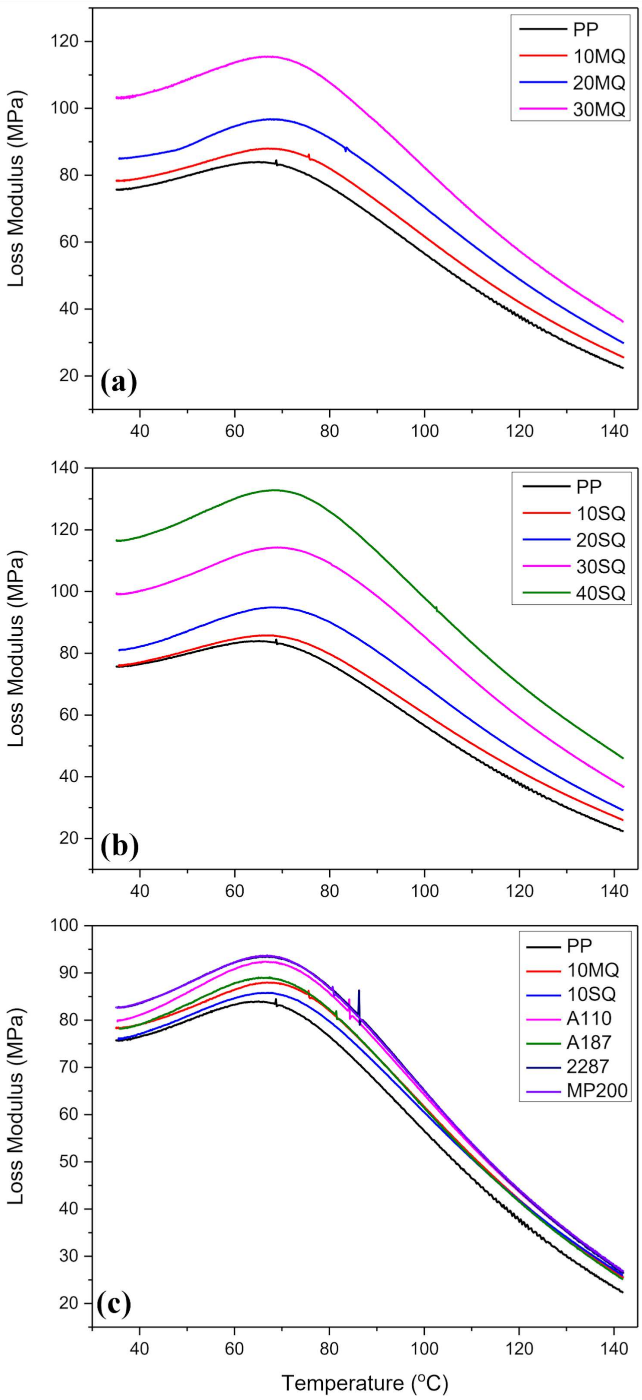

Fig. 2. Loss modulus (E'') of PP and (a) micronized quartz, (b) silanized quartz, (c) surface modified quartz reinforced composites.

Figure 2a shows the loss modulus values of PP and MQ-PP composites. Loss modulus (E'') is a measure of viscous response of a material. It evaluates the energy dissipated as heat. As it is seen in Fig. 2, the E'' of all composites is higher than that of PP in the whole temperature range. This may be related to decrease in the flexibility of polymer by decreasing the segmental mobility of polymer [4]. The loss modulus continues to increase as MQ weight fraction increases. Samples (PP, 10MQ, 20MQ, and 30MQ) show α-relaxation peaks at about 66.3, 69.3, 67.5, and 68.0 °C, respectively. The α-relaxation peak of PP increases after incorporation of MQ into PP. This may be attributed to higher viscous dissipation of the composites than that of polymer [8].

Figure 2b represents the variations in the loss modulus of PP and SQ-PP composites. As was seen in Fig. 2b, the E'' of all composites is higher than that of PP in the entire temperature range. This may be related by decreasing the segmental mobility of polymer. It can be seen that the loss modulus increases after loading of SQ fillers into PP. Samples (PP, 10SQ, 20SQ, 30SQ, and 40SQ) show α-relaxation peaks at about 66.3, 67.8, 68.4, 69.0 and 68.9 °C, respectively. The α-relaxation peak of PP increased after incorporation of SQ into PP due to higher viscous dissipation of the composites than that of polymer.

The variations in the loss modulus of PP, 10MQ, 10SQ and the surface treated filler loaded composites are shown in Fig. 2c. E'' of all composites is higher than that of PP in the all temperature range by decreasing the segmental mobility of polymer.

4. Conclusion

In this study, mechanical properties of micronized, silanized and surface modified quartz filled PP based composites were investigated. Elastic modulus of the composites increases as quartz weight fraction increases by 10 to 30%. Fluxural strength and flexural modulus of the composites increases when quartz added. The loss and storage moduli increases with increasing quartz powders weight fraction. The mechanical properties of the composites produced with surface modified quartz powders show better results compared to micronized quartz added composites.

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