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The Effect of Various Minerals on Sound Transmission Loss and Mechanical Properties of Polypropylene

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The aim of this study is to investigate the effect of various filler materials such as talc, glass bead (GB), and bentonite on sound insulation efficiency of polypropylene (PP). In order to evaluate sound insulation properties of PP-based composites sound transmission loss (STL) was determined. Polypropylene based-composite granules were produced by using twin-screw extruder. Some test specimens were obtained by injection molding process. bentonite filled PP composite exhibited the highest STL values for 100, 200, 400, 500, and 800 Hz. While talc and bentonite loadings at 40 wt% into PP increased the flexural strength of PP, GB loading decreased the flexural strength of PP. Izod notched and unnotched impact strength of PP decreased by loading talc, bentonite, and GB into PP.

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1. Introduction

In the last ten years, polypropylene has been the plastic with the highest growth rate in automotive engineering [1]. The incorporation of fillers such as mica, talc, calcium carbonate into thermoplastics is a common practice in the plastics industry, leading used to reduce the production costs of molded products [2]. Applications of PP and the mineral filled thermoplastic compounds in exterior and interior parts of vehicles have been expanded successfully [1]. Fillers are also used to modify the properties of thermoplastics, such as the tensile modulus, tensile strength, strength, rigidity, durability, and hardness [2, 3]. High filler loadings, however, may adversely affect the processability, ductility, and strength of composites. Mineral filled polypropylene provides high mechanical stiffness, thermal stability, and good low temp properties and good dimensional stability over a wide temperature range. Human comfort requires an environment with low decibel levels free of unwanted noises occurring from a variety of sources such as manufacturing machines, vehicles, and, from daily activities [4]. For example, the sewage systems should be as silent as possible, especially in the course of discharge of kitchen appliances. Noise is also a danger for health, disrupting the sleep and other activities, and thus influences the cognitive and emotional responses [5]. The controlling of noise is a very important in modern structural design [6]. Engineers seek for new materials and arrangements to enhance the sound attenuation [7]. Materials such as glass wool, foam, mineral fibers and their composites are generally used in sound attenuation [8]. It is known that sound transmission capacity for composite materials depends on the proportion of filler material within the polymer matrix. However, higher filler ratios degrade the other properties of polymers, such as mechanical properties. In this study, three types of mineral fillers — talc, glass bead (GB), and bentonite (40 wt% filler loadings) — were compounded with polypropylene (PP) with a twin-screw extruder. The composite granules were injection molded, and the effects of the filler loading on the mechanical and sound transmission loss properties of PP were investigated. The aim of this article is to study the effects of the types of fillers on the tensile, flexural, impact and sound transmission loss properties of composites.

2. Materials and methods

2.1. Materials and manufacturing of composite materials

Copolymer grade Polypropylene (PP) resin with melt flow rate of 19.5 g/deg used in this study was supplied by IMSPolymers. Three types of fillers were incorporated into PP: talc (Omyatalc® Omya Madencilik, Turkey), GB (Microperl®223 solid glass beads, Sovitec, Belgium), and bentonite (Keepwater, Dolsan Madencilik). The compounding was performed with a co-rotating twin screw extruder (Leistritz Model ZSE 27 Extruder). The barrel temperatures of the zones were 195–215 °C, from the feeding zone to the die zone. The compounds

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were blended at a screw speed of 250 rpm. Test specimens were injection-molded with injection molding machine (Bole, model BL90EK).

2.2. Characterization methods

2.2.1. Mechanical analyses

Tensile tests of the samples were made by using a Hegewald&Peschke Inspect 20 universal testing machine equipped with a video extensometer system (Hegewald&Peschke Inspect 20 Non-contact Video Extensometer) at a crosshead speed of 50 mm/min according to ASTM D638-10 standard. Flexural properties of samples were obtained via three-point bending tests, which were conducted by using Hegewald&Peschke Inspect 20 universal testing machine with a 1 mm/min deformation rate. Izod notched and un-notched impact strengths of the samples were determined by using a pendulum-type tester according to ISO 179 standard. At least five tests were performed for each sample.

2.2.2. Sound Transmission Loss

Sound Transmission Loss (STL) values (dB) of samples were obtained according to ASTM E2611-09 Standard Test Method for measurement of normal incidence sound transmission of acoustical materials based on the transfer matrix method.

3. Results and discussions

3.1. Mechanical properties

Tensile and flexural properties of PP and its composites are given in Table I. Tensile strength values of PP, PP + talc, PP + bentonite, and PP + GB were obtained to be 23.0, 22.8, 21.7, and 13.9 MPa, respectively. 40 wt% loadings of talc and bentonite into PP have not led to considerable variation in tensile strength value of PP. It is known that bentonite, which is a natural mineral, has a high aspect ratio and plate-like structure [9]. Besides, talc has a high aspect ratio and a stacked layer structure [10]. GB loading into PP decreased the tensile strength of PP remarkably due to relatively low aspect ratio of GB compared to talc and bentonite. However, as expected, talc, bentonite and GB loadings into PP by weight fraction of 40% increased the tensile modulus of PP. The largest increase in tensile modulus of PP was observed by loading of talc. The high aspect ratio and high degree of orientation of talc along the tensile direction reveals the large increase in tensile modulus value of PP [10]. The lowest increase in tensile modulus was observed by loading of GB by 40 wt%. All the fillers used in this study decreased the elongation at break values of PP. The less decrease in elongation at break values was obtained by GB loading. While talc and bentonite loadings at 40 wt% into PP increased the flexural strength of PP, GB loading decreased the flexural strength of PP. This result may be attributed to relatively higher aspect ratio of bentonite and talc compared to GB. talc, bentonite, and GB loadings into PP by 40 wt% increased the flexural modulus of PP. In accordance with flexural modulus, the highest flexural modulus value was obtained by loading talc by 40 wt%.

TABLE I

Mechanical Properties of mineral filled PP composites.

Sample	Tensile strength [MPa]	Tensile modulus [MPa]	Elongation at break [%]	Flexural strength [MPa]	Flexural modulus [MPa]
PP	23.0 ± 0.4	893 ± 35	61.0 ± 5.2	31.0 ± 2.8	809 ± 27
PP + talc	22.8 ± 0.5	2541 ± 98	2.6 ± 0.1	39.1 ± 3.1	2669 ± 103
PP-GB	13.9 ± 0.5	1498 ± 85	44 ± 3.1	26.3 ± 2.7	1514 ± 94
PP-bentonite	21.7 ± 0.6	2010 ± 92	2.6 ± 0.2	37.3 ± 4.1	2132 ± 98

3.2. Impact test results

The effect of filler loading into PP on Izod impact strengths is shown in Fig. 1. Izod notched impact strength values of PP, PP + talc, PP + bentonite, and PP + GB were obtained to be 13.0, 4.9, 4.7, and 5.3 kJ/m^2, respectively. Izod un-notched impact strength values of PP, PP + talc, PP + bentonite, and PP + GB are 65.5, 20.1, 12.8, and 28.4 kJ/m^2, respectively. It can be noted that a considerable decrease in impact strength values were obtained. The less decrease in impact strength was obtained by loading GB rather than other fillers. In other words, GB is better than talc and bentonite in absorbing the impact energy [11].

3.3. Determination of STL Values

For characterization of sound insulation properties of materials, STL (or transmission loss) is commonly used [12]. The curves of the STL and the sound frequency for PP and its composites are presented in Fig. 2. When sound frequencies are 100, 200, 400, 500, and 800 Hz, the highest measured sound transmission losses belong

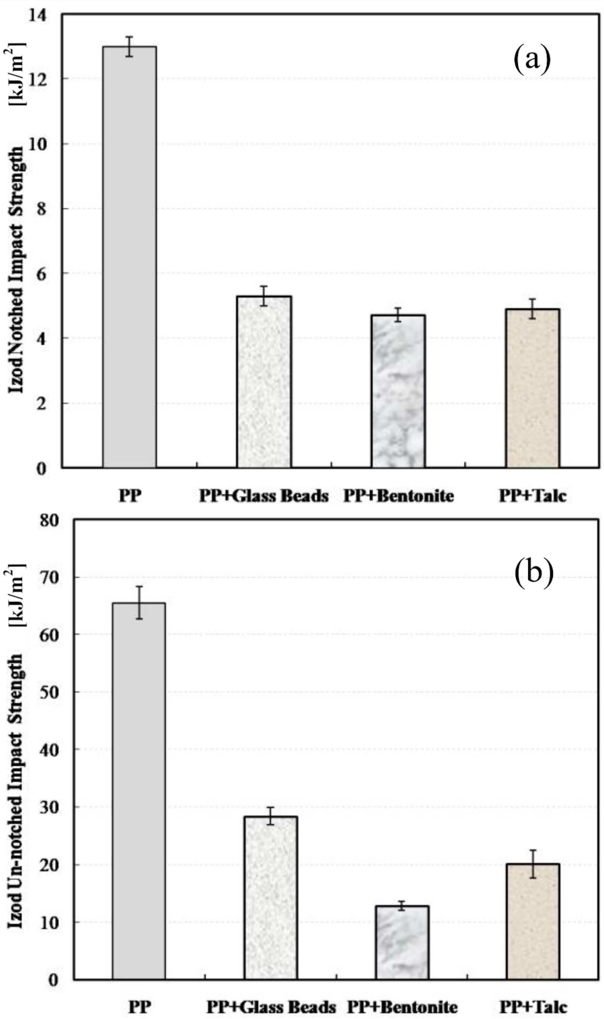

Fig. 1. Izod (a) notched and (b) un-notched impact strength values of composites.

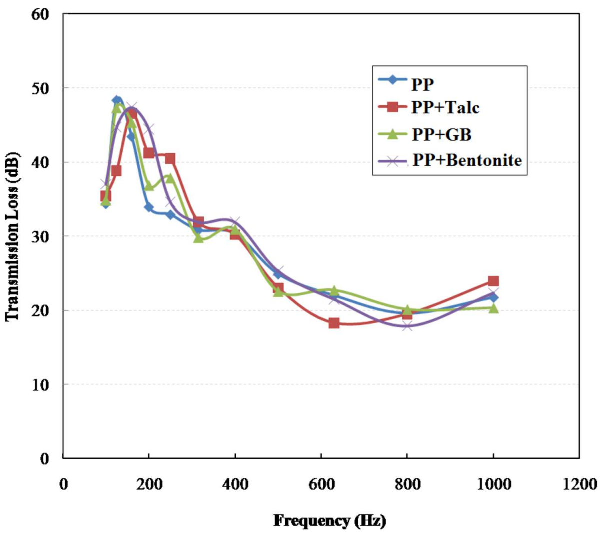

Fig. 2. STL values for PP and its composites.

to composites containing bentonite. At the highest frequency studied in this study, 1000 Hz, PP + talc exhibited the greatest transition loss value. It can be said that the extra sound wave energy consumption was generated in the composite containing bentonite which is a layered silicate. It is known that the sound transmission loss of polymer composites depends on, to great extent, the vibration way and transmission route of sound wave in the composites [13]. The increase in the sound insulation property of inorganic particulate filled PP composites might due to the behavior of reflection, scattering and refraction of the sound wave generated in the composites when the sound wave contacted with the filler particles [12].

4. Conclusion

Various tests have been performed on talc, bentonite, and GB filled PP composites to compare their mechanical properties and sound transmission loss values. 40 wt% loadings of talc and bentonite into PP have not led to considerable variation in tensile strength value of PP. Generally, talc and bentonite have been proved to be reinforcing fillers for PP on the basis of increases in the tensile and flexural strength with the filler loading. The highest measured sound transmission losses belong to composites containing bentonite for 100, 200, 400, 500, and 800 Hz, At the highest frequency studied in this study, 1000 Hz, PP + talc exhibited the greatest transition loss value at 1000 Hz in this study.

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