SOUNDPROOF EFFECT OF NANOCLAY REINFORCED POLYPROPYLENE COMPOSITES

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SUMMARY

The soundproof effect of nanocomposites of polypropylene (PP) was investigated at different filler loads of organically modified clay which was improved gradually with the concentration of clay and exhibited optimum value in the composites of 7% clay filled composites. The mechanical properties of this nanocomposite was also tested briefly.

Keywords: Polypropylene, Nanoclay, Soundproof, Transmission loss, Nanocaly reinforced polypropylene

1. INTRODUCTION

Noise means unwanted sound or sound pollution which can cause serious harmfulness to human body and environment. To reduce and remove noise from machinery and appliances has been developed widely in recent days[1-4]. An important and realizable way is to find and apply sound absorption and insulation materials in reducing noise surroundings[5-9]. In this study, sound insulation characteristics, properties, and sound insulation results of composites made by different percentage for nanoclay reinforced polypropylene were investigated.

1.1 Theory of sound insulation

The sound characteristics of space can be affected by the material, size and shape of the space wall. The acoustic energy that is incident on the wall is converted into reflected acoustic energy, energy loss, and transmission acoustic energy. Reflectivity is the ratio of reflected acoustic energy to incident energy and acoustic absorption is the ratio of the sum of energy loss and transmitted energy to incident energy. The ratio of transmitted energy to incident energy is defined as acoustic transmissibility.

The transmitted energy must become lower in order to increase soundproof efficiency. Therefore, energy loss and reflected energy must be maximized to minimize the transmitted energy, but energy loss by sound absorption becomes limited by the wall thickness of material[10]. So the most efficient and best way to increase soundproof efficiency is to reflect the incident energy in the incidence direction. In sound insulation, the efficiency would depend on the mass, stiffness, homogeneity, and uniformity of the wall material. The sound insulation ability of a wall is measured by sound transmission loss (TL). TL can be defined as the difference between the sound power level of the incident wave and the transmitted sound power[11,12].

1.2 Fabrication of nanoclay reinforced PP composites

Table. 1. Properties of clay and PP

Clay	
Specific Gravity	1.90 g/cc
Bulk Density	0.1636 g/cc
Particle Size	≤2.00μm
PP	
Density	1.145g/cc
Processing Temperature	200℃
Injection Pressure	54.5 Mpa

There has been a lot of interest in research on nanocomposites recently. Nanoclays are one of the important nanofiller materials to be reinforced in polymers composites which exhibit superior strength, modulus, thermal resistance and sound absorption. In this experiment, preparation of nanoclay reinforced PP (produced by Samsung company HJ400) composites using a solvent method has been developed and specimens made by injection molding machine using material of nanoclay reinforced PP were tested for their sound insulation properties. PP is a thermoplastic polymer used in a wide variety of applications including packaging, textiles, stationery, loudspeakers and automotive components. Melt processing of PP can be achieved via extrusion and molding by using injection molding machine to fabricate parts such as cups, cutlery, containers and housewares. Clay is a naturally occurring material composed primarily of fine-grained minerals, which show good plasticity through a variable range of water content, and which can be hardened when dried or fired. Nanocomposites are prepared by dispersing clay into host polymers generally at less than 15wt% levels which is also termed exfoliation. Xylene is a colorless and sweet smelling liquid which will be used here as a solvent to dissolve PP and nanoclay. Maleic anhydride is an organic compound showing a pure colourless state or white solid with an acrid odour which is used here to make clay and PP dissolved in xylene more quickly during heating process.

The main properties of clay and PP are shown in Table. 1. Nine kinds of specimens were prepared with 0, 1, 3, 5, 7, 9, 11, 13 and 15wt% of PP for quality of clay, respectively. The total mass of PP is 50 gram and 0.1wt% for maleic anhydride. Firstly, putting one magnetic stirring bar (40×20 mm) in flask and mixing PP and clay (0, 1, 3, 5, 7, 9, 11, 13 and 15wt%) together into it. The magnetic stirrer is used here to provide spin and make the mixture more homogenously. Then using hot plate to heat this mixture. In this experiment, setting heating temperature 135℃ for xylene and 550 rpm. After 2 hours, stopping heating and pouring this hot mixture liquid into beaker with 1000ml ethanol. After 10 minutes stirring this new mixture, using Buchner funnel to filter it in order to get lump powder. The last step is to use oven to heat this lump powder under 60℃ for 50h in order to get materials which can be put into injection molding machine to make final specimens.

Injection molding is a manufacturing technique for making parts from both thermoplastic and thermosetting plastic materials in production. Molten plastic is injected at high pressure into a mold, which is the inverse of the product's shape. The temperature of the barrel and nozzle of the injection molding machine were fixed at 200℃, 54.5 MPa, and the molten composites were injected into the mold to form disc specimens with 29 mm in diameter and 3 mm in thickness for this specimens fabrication process. The whole fabrication process is shown in Fig.1.

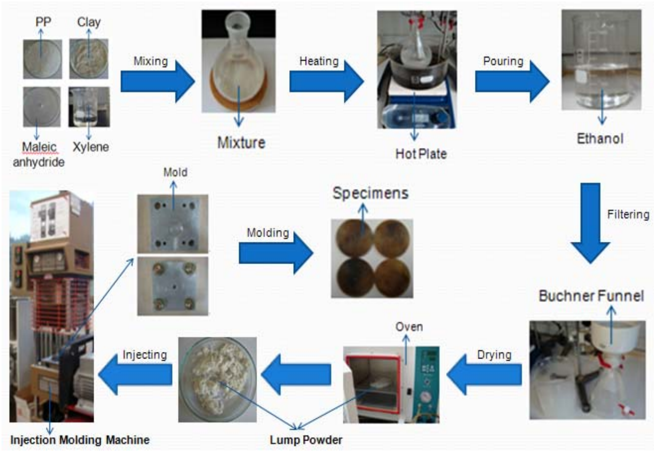

Fig.1. Specimens fabrication process

2. MEASUREMENT OF SOUND INSULATION

To measure sound TL of produced specimens, four microphone impedance tube method is used. Fig.2 shows the setup of this measurement process. The four 1/4 inch B&K microphones type 4196 for measuring incidence and transmitted wave are mounted on B&K impedance tube type 4206. The conditioning amplifier B&K NEXUS type 2690 is used to amplify low signal. Frequency analyzer, HP type 35670A, is used here as a sound source and a data acquisition device, and it is connected with a computer on GPIB interface. User interface program is programmed by LabView v7.0.

Fig.3 shows sound TL of all percentage nanoclay reinforced PP from 0wt% to 15wt%. Seen form Fig.3, the sound insulation efficiency of nanoclay reinforced PP composites was increased with an increase in the percentage amount of nanoclay from 0wt% until 7wt% but decreased from 9wt%. It means that there must be a most appropriate percentage between 7wt% and 9wt% which can show the best soundproof property of this nanoclay reinforced PP composites. In order to see clearly, Fig.4 shows the averaged value of the sound TL of nanoclay reinforced PP only from 0wt% to 7wt% and 15wt%. The measured results have an upward tendency with TL when the percentage of nanoclay reinforced PP is increased. For a more accurate comparison, the measured results at 3400 Hz are plotted in Fig.5. According to Fig.5, the TL results of 1% and 7% nanoclay reinforced PP composites are higher than pure PP by 24% and 78%, respectively.

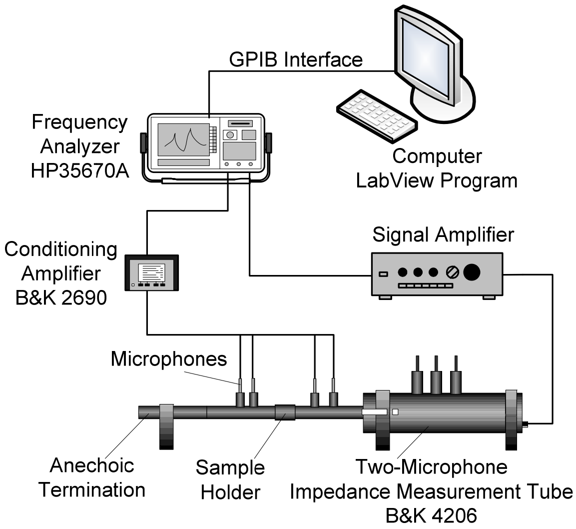

Fig.2. Setup of measurement device

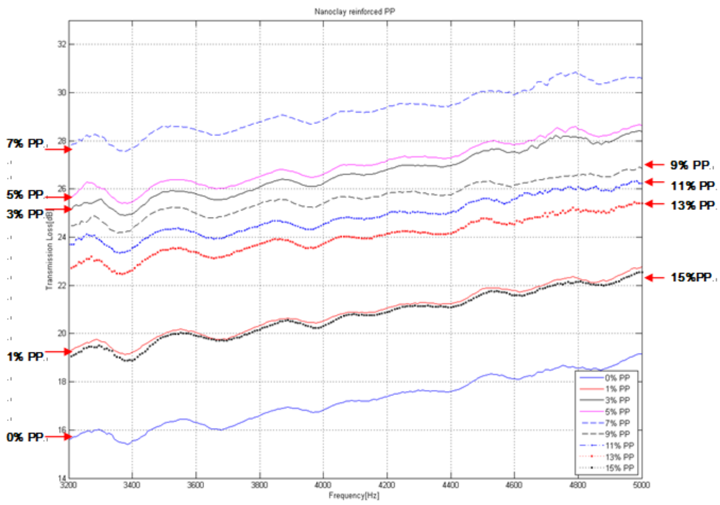

Fig.3. TL of nanoclay reinforced PP (0wt%~15wt%)

3. ANALYSIS OF DIFFERENT PARAMETERS

Generally, the performance and TL of sound insulation material is closely related with mass of material. However, the mass of this produced composites is not a main factor affecting TL tendency. In this chapter, which parameter for sound insulation property of nanoclay reinforced PP composite is a main factor will be discussed.

3.1 Measurement of density

The sound TL of the wall in low frequency is effected by the stiffness of the wall, but the damping of the wall is a main factor by the resonance frequency of the wall. After resonance frequency, the mass of the wall is a main parameter affecting TL of the wall. This region is a mass controlled region by mass law. This mass law predicts that doubling the mass per unit area or the frequency increases the TL by 6dB. One can use such equation to calculate TL.

$$TL = 20\log(mf) - 20\log\left(\frac{\rho_0 c}{\pi}\right)$$

where m, ρ_0, and c are the mass per unit area, air density, and the sound velocity in air.

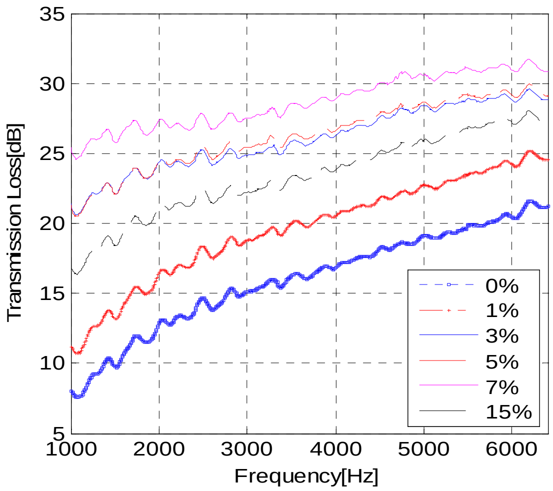

Fig. 4. TL of nanoclay reinforced PP (0wt%~7wt%,15wt%)

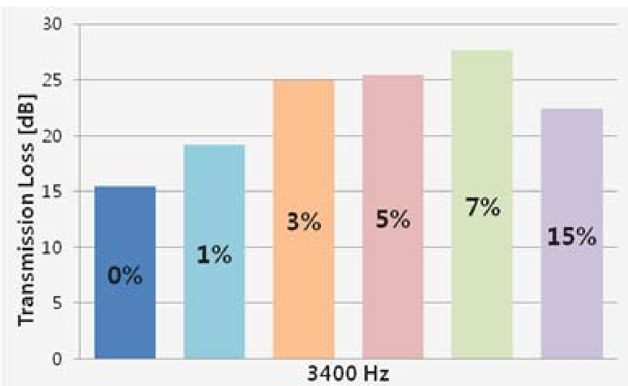

Fig. 5. TL of nanoclay reinforced PP at 3400 Hz

Fig.6 shows the normalized masses of nanoclay composites. The difference of the mass of pure PP and 7% nanoclay reinforeced PP is very small. The 7% nanoclay reinforced

PP corresponds to only 2.3% mass increase for this specimen. According to this reason, the mass of nanoclay composite can not be a main parameter affecting TL.

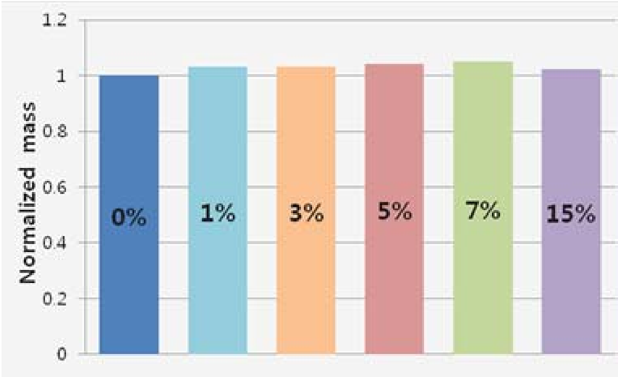

Fig. 6. Normalized mass of nanoclay composites

3.2 Mechanical properties test

Mechanical properties of one material should be considered much as they are so important for real engineering application. Nanoclay reinforced PP specimens were made by injection molding machine following ASTM standard (D638-03) for mechanical tensile test[13]. In this experiment, the specimen type is type Ⅰ with thickness 3.45mm and gauge length about 50.0mm. Fig.7 shows the 7wt% nanoclay reinforced PP specimens for mechanical tensile test. Among these five specimens, two are for strain guage test and there are for tensile test which is similar to other percent nanoclay reinforced PP specimens. Here, universal material testing machine (LLOYD Instruments LR50K) and strain indicator are used to do tensile test and strain gauge test each with test speed 5mm/min and preload 5.0*N* which can be seen from Fig.8.

Fig.7 7wt% nanoclay reinforced PP specimens for mechanical tensile test

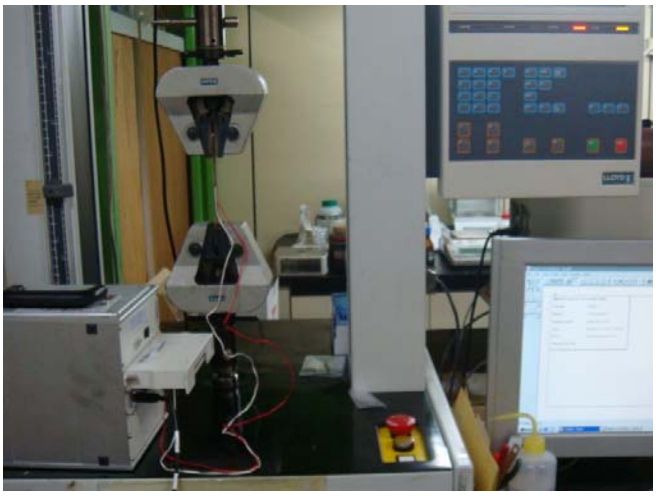

Fig.8 Tensile and strain gauge test

Table.2 shows the tensile test results. The mechanical properties of this nanoclay reinforced PP composites do not change so much as nanoclay percentage increasing from 0 to 15wt%. Therefore, mechanical properties are not main factor affecting TL.

Table. 2. Tensile test results

Nanoclay Percentage	Ultimate Stress (MPa)	Young's Modulus (E) (GPa)	Poisson ratio (ɣ)
0wt%	26.31	1.56	0.350
1wt%	25.35	1.70	0.336
3wt%	24.38	1.72	0.277
5wt%	22.68	1.81	0.281
7wt%	23.17	1.92	0.289
9wt%	22.21	1.96	0.313
11wt%	19.70	1.83	0.359
13wt%	21.54	2.26	0.357
15wt%	21.46	2.27	0.333

4. CONCLUSIONS

In this research, specimens made from nanoclay reinforced PP composites were fabricated and investigated to improve their soundproof property. The sound insulation efficiency of nanoclay reinforced PP composites was increased with an increase in the percentage amount of nanoclay until 7wt% but decreased at 15wt%. Such results prove that more percentage amount of clay inside matrix PP can form into agglomeration which decreases the soundproof efficiency much. The measured results show that there is an upward tendency in TL when the percentage of nanoclay reinforced PP is increased and the mass of nanoclay composites does not affect TL too much. As a future work, soundproof effect of more cheaper nanocomposites will be tested in order to reduce the cost of composite materials.

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13. ASTM standard D638-03

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