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ORIGINAL RESEARCH PAPER

Correlation Between the Acoustic and Cell Morphology of Polyurethane/Silica Nanocomposite Foams: Effect of Various Proportions of Silica at Low Frequency Region

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ABSTRACT

Introduction: Reducing noise pollution has become an essential issue due to the increase in public concern and also social demands for a better lifestyle. Using sound absorption materials is a preferred method to reduce the noise pollution. Undesirable properties of pure polyurethane such as poor absorption of mechanical energy in narrow frequency ranges can be improved by providing polymeric nanocomposites. The main purpose of this study is to synthesize the polyurethane nanocomposite foams in order to improve its acoustic properties.

Material and Methods: At the first steage, pure polyurethane foam was synthesized using the pre-polymer method. Afterwards, nanocomposite foams were synthesized with different mass fractions of Nano silica. The cellular morphology of prepared nanocomposite foams was investigated by scanning electron microscopy (SEM (.Utilizing a two-microphone impedance tube, sound absorption coefficient (α) was calculated in the frequency ranges of 100 Hz to 1600 Hz in order to investigate the acoustic properties of the new absorbant.

Results: According to the microscopic investigations, morphology of the cells changed after adding silica nanoparticles. Also, the cell sizes were observed to be decreased by increasing the amount of silica nanoparticles. Furthermore, the acoustic analysis of nanocomposite foams indicated that the sound absorption increased by enhancing the load of silica nanoparticles.

Conclusion: In the current study, the effect of silica nanoparticles additive amount on acoustic properties of the polyurethane-based nanocomposite was investigated. Our findings depicted that the polyurethane-based nanocomposites were able to promote the sound absorption coefficient.

Keywords: *Polyurethane, Nanoparticles, Sound absorption coefficient, Low frequency.*

1. INTRODUCTION

Nowadays, undesirable and potentially hazardous noises are considered as one of the important problems in human life with a severe harmful influence on people's health. Therefore, controlling noises becomes more and more important for countries all around the world [1]. Sound absorption and sound insulation are the most common ways to control the noises. Sound absorption for both mid and high frequencies can be easily obtained by porous absorbers due to the fact that thicker materials are needed for longer wavelengths. Hence, it is often impossible to absorb low frequencies[2]. Polymeric polyurethane (PU) foams have been widely used to absorb sounds and also to reduce noises, due to their attractive properties such as excellent viscoelasticity, relatively simple processing, cheapness, and lightness. However, the sound absorption of polyurethane (PU) foams is

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Table 1. Results derived from Sound absorption curves of PU pure reinforced with Nanoparticles

Content of Nano silica /%	Average absorption coefficient /%	Frequency range of absorption peak/Hz
0	37.5	1150 – 1300
0.5	40.1	1300 – 1400
1	56.5	1220 -1310
1.5	67.7	990-1100
2	42.5	1380 -1520

Table 2. Results from SEM test for pure PU and its nanocomposites at different content of Nano silica

Samples	Pure PU	Nanocomposite foams			
		0.5% SiO2	1% SiO2	1.5% SiO2	2% SiO2
Cell Size (µm)	410 ± 3	404 ± 3	390 ± 3	377 ± 3	368 ± 2
Cell Density ($\times 10^5 \frac{cell}{cm^3}$)	4.48 ± 0.5	5.2 ± 0.5	6.42 ± 0.4	7.68 ± 0.1	8 ± 0.1

strong in high-frequency regions but is relatively weak in low-frequency regions. This is due to the low capacity of sound energy attenuation[3]. Recently, polyurethane nanocomposite foams have considerably attracted the attention of researchers as new materials for the absorption of sounds. The aim of this study was, therefore, to use various amounts of silica nanoparticles to improve the acoustic properties of the polyurethane foams, especially at low frequencies.

2. MATERIAL AND METHODS

Poly (tetraethylene glycol) (PTMG ، Sigma Aldrich) with an average molecular weight of 2000 g/ mol, trimethylolpropane (TMP), and 1/4 butane diol (BD) were purchased from Merck and were used for polymerization. Azodicarbonamide (ADCA) as a chemical blowing agent was obtained from Chechen Co. Ltd. Nano silica particles with diameter of 20-30 nm and purity of 99%, were provided from Sigma-Aldrich. PU foams were synthesized using the pre-polymer method. First, PTMG was poured into a 100 ml three-necked reaction bottle, and was then placed under vacuum till its moisture was completely removed. Meanwhile, the temperature was kept fixed in the ranges of 70-75 °C. TDI was slowly added to the mixture in order to initiate the reaction between OH and NCO groups. The mixture was then heated for 55 min until the reaction was completed and NCO-terminated PU pre-polymer was obtained. BD/TMP mixture was then used as a chain-extending and a crosslinking agent. Finally, ADCA as a foaming agent was added to the mixture and was homogeneously mixed. After a few minutes, the mixture was poured into a Teflon mold and was then placed in an oven at a temoerature of 70 °C for 18-24 h. Afterward, different weight percentages of nano-silica (0/5 wt%, 1 %wt, 1/5 %wt, 2 %wt) were mixed with PTMG in order to synthesize PU nanocomposite foams. The sound absorption coefficient was measured using a two-microphone impedance tube of SW422 series according to ISO-10534-2.

3. RESULTS AND DISCUSSION

Table. 1 shows the sound absorption coefficient of PU nanocomposite foams with different wt% of silica nanoparticles. As can be implied from this table, the maximum sound absorption for pure PU foam is approximately in the frequency range of 37.5% at 1150 to 1300 Hz. Adding 0.5% wt of Nano silica has a negligible influence on the absorption coefficient while the addition of 1% wt of nano silica particles leads to a significant increase in the absorption coefficient than that of pure foam. Reduced cell size and increased cell density in the nanocomposite foams are the primary reasons for improving sound absorption (see also Table 2)[4-6].

Generally, for the porous absorber materials, sound propagation takes place in a network of interconnected pores and cells such that viscous and thermal interactions cause the sound and mechanical vibrational energy to be dissipated and then transformed into heat[4, 7]. In addition, the absorption coefficient improvement could be due to the increased energy dissipation as heat through the hysteresis phenomenon[4]. Moreover, when the nano silica content is 1.5% wt, the average sound absorption reaches its maximum value at the frequency range of 990 to 1100 HZ. The increase in the absorption coefficient for nanocomposite foam with 1.5 wt% nano silica compared to nanocomposites containing 0.5 wt% and 1wt% nano silica can be attributed to both increased open porosities and tortuous paths formed in the polymer foam [4, 7]. On the other hand, when the nano silica content increases to 2% wt, the sound absorption of the nanocomposite foam decreases and is even less than that of pure PU foam. It might be attributed to increased viscosity[8]. Overall, the results show that the sound absorption is significantly enhanced up to a certain load of nano silica and then is decreased, as the amount of silica nanoparticles increases.

4. CONCLUSIONS

Research shows that noise is one of the harmful factors in the workplaces, injuring people's health both physically and emotionally. Therefore, many studies have been carried out on the sound absorption and control. PU foams are widely used as absorbent materials. The acoustic characteristics of PU foams are not proper for a wide range of undesired properties. Therefore, they cannot be used practically. Numerous studies have been performed to improve the PU properties by modifying the chemical structure or adding various types of organic/inorganic fillers to the foams. In the current study, our findings demonstrated that the PU-based nanocomposites were able to improve the sound absorption coefficient. Adding silica nanoparticles to the pure foam enhanced the number of cells and increased the stiffness of the cell walls, followed by an increase in the absorption coefficient.

5. ACKNOWLEDGMENT

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