International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Volume-2, Special Issue 1 (July-Aug 2014), PP. 15-18

ACOUSTIC ABSORPTION AND PHYSICOMECHANICAL PROPERTIES OF SBR/RR FOAM

Bashir Algaily, Sombat Puttajukr
Division of Applied Physics, Department of Science
Faculty of Science and Technology, Prince of Songkla University
Pattani Campus, 94000 Thailand

***Abstract*— This research focuses on the enhancement of acoustic absorption coefficient (α) with a broadband frequency response of a styrene butadiene rubber (SBR) blended with a reclaimed rubber (RR) (SBR/RR foam) composites by increasing the number of microstructure open cells using an inorganic chemical blowing agent (sodium bicarbonate). The effect of various compositions between RR and virgin SBR on the Physicomechanical properties was investigated as well. The results obtained clearly demonstrate that all samples provide superior sound absorption and the accession of the RR to the composition influenced the foam's ability and respectively the acoustic and the physical property of the blends. This new material can be utilized in different sound absorption applications and therefore helps to minimize hazards of the noise and air pollutions.**

Keywords—acoustic absorption coefficient, reclaimed rubber, sodium bicarbonate and styrene butadiene.

I. INTRODUCTION

Nowadays there are more concerning on the environmental pollution resulting from living and industrial waste materials. Particularly among the waste materials, waste tires were recorded as the most obvious hazard, because it need very long time for natural degradation due to cross-linked structure of rubbers and presence of stabilizers and other additives. This leading to serious environmental pollutions. Thus, it is necessary to find new methods for reclaiming tires and recycling it for other applications [1]. On the other hand, the acoustic noise from the traffic system and modern industries become more serious issue in our life. One way that used to reduce the acoustic noise by using sound insulation and sound absorption materials. Enhancement of acoustic absorber materials, particularly at low frequencies have been attracted enormous interest for building or transportation.

The audio frequencies are identified as frequency range for human hearing roughly from 20 Hz - 20,000 Hz, also can be affected by varying parameters such as physical condition and age. The sound frequencies range from 500 - 2048 Hz is most important for the oral communication [2]. Therefore, attenuated or absorbed sound materials in this frequency range are important tools to reduce the acoustic noise for human. Acoustic absorbent materials are applied extensively to manipulate the levels of the acoustic noise. Viscous losses, Helmholtz resonance effect and the thermal damping are the primary mechanisms for the acoustic absorption in the rubber foam. A major drawback of conventional porous absorbers is their performance in the low frequency range [3].

The terms rubber foam or sponge rubber refers to various types of cellular rubber products from either dry natural rubber or synthetic rubber. Open-cell sponge rubber has an interconnecting cell structure similar to that of latex foam. In contrast, closed-cell sponge rubber contains discrete non-inter connecting cells. Open-cell sponge rubber compounds contain blowing agents that are gas-producing chemicals. Sodium bicarbonate was used as a blowing agent in most open-cell sponge rubber compounds. Heat during the early stages of vulcanization, causes the release of gas from the blowing agent. The gas causes the rubber to expand. The cure system present in the compound must be capable, at this point of permitting the blown rubber to set up rapidly, so that its cellular structure does not collapse prior to vulcanization.

The reclaiming of tires in alternative applications is actually the use of base polymer in new formulations with simultaneous cost saving in raw material and preserving both natural resource and environment. The addition of reclaimed rubber into virgin rubber play important roles towards the market competition and production economy. By adding reclaimed rubber to the virgin SBR with blowing agent to obtain new polymer composites to behave as acoustic absorption material. There are a few interesting to develop a procedure for the design of material with high acoustic properties, broadband sound absorption and to assess the potential of used recycled tires as the main component of acoustic materials for ceiling and walls.

Enhancement of sound absorption refers to large amount of sound energy lose inside of the materials. Benkreira and his group developed material from elastomeric waste residue mixed with a foaming binder results in a new material with micro porosity which can enhance the acoustic absorption [4]. Najib and coworkers used an inorganic blowing agent (sodium bicarbonate) mixed with the natural rubber compounds. They found that it produces bubbles with an open cell structure [5], resulting in an improvement of sound absorption in the material.

In this research, SBR/RR foam added with blowing agent sodium bicarbonate was performed in this study. Sodium bicarbonate was used as an inorganic chemical blowing agent that can release carbon dioxide gas during decomposition. It decomposed at a relatively low temperature (145-150ºC) [5, 6] to enhance the acoustic absorption of the SBR/RR material.

II. MATERIALS AND METHODS

Table 2 shows the materials and compounds compositions used in this study. All materials were commercial grade and used as supplied.

A. COMPOUNDING

Blending of virgin SBR, several compositions with RR and other chemical ingredients were carried out in two-roll milling machine, the entire time of mixing kept constant for all composites (30 min) at ambient temperature. Consequently, the blowing agent (sodium bicarbonate) and sulfur was added at the last stage of mixing respectively.

B. CURE CHARACTERISTICS

The cure characteristic of the mixing materials was observed by an oscillating disc rheometer (ODR 2000) in conformity with the ASTM D2084 at 160˚C. The optimum curing time (t_{90}) was determined from the rheometer chart. The final compounded rubber mixture was sent to compress in a molding machine to complete the curing (vulcanized rubber) at 160˚C, respective to optimum curing time obtained from the rheograph.

C. PHYSICOMECHANICAL PROPERTIES

Elongation at break and tensile strength were evaluated using a tensile test machine (Hounsfield, model H10KS) at ambient temperature (24ºC) with a constant speed of separation of 50 mm/minute. In this study, the measurements of the Crosslink density of SBR/RR blends were evaluated using the Mooney-Rilvin relationship, which identified the strain-strain behavior of the vulcanized rubber. The cross-link density can be determined using equations below. By plotting $\sigma/2\ (\lambda - \lambda^{-2})$ against $1/\lambda$, C_1 and C_2 are constants, which, C1 value obtained from the intercept of the graph on the $\sigma/2\ (\lambda - \lambda^{-2})$ and C2 is the slope. C_1 can be utilized to estimate them physical crosslink density (N_{phys}), which is merely given by Sombatsompop and Lertkamolsin [7]:

$$F = 2A_0 (\lambda - \lambda^{-2}) (C_1 + C_2 \lambda^{-1}) \quad (1)$$

$$\sigma_0 / (\lambda - \lambda^{-2}) = 2C_1 + 2C_2/\lambda \quad (2)$$

$$N_{phys} = C_1 / RT \quad (3)$$

F stands for the strength desired for extension the sample (Force), A_0 represents the unit area of the un-stretched sample, σ_0 was defined as the force over cross-sectional area, and λ is the elongation ratio. T is the absolute temperature, and R is the gas constant.

The densimeter (MD-300S) was used to measure the apparent rubber density of samples. The determination of the exact density of samples was recurrent at sundry times to hold the mean values. The density of the samples was determined from the average from at least three measurements.

D. SOUND ABSORPTION COEFFICIENT MEASUREMENT

The sound absorption coefficient (α) was carried out using a standing wave tube (Kundt's tube). The standing wave tube composed of an impedance tube, microphone, speaker and digital analyzer. A sample with 3.0 mm of thickness was placed at one end of the tube and a plane acoustic wave propagates parallel to the axis of the tube, for different frequencies in the range from 125 to 2000 Hz were generated by a function generator. This method presents several advantages with regard to other methods (i) needing only small test specimens (ii) very fast and (iii) the values are reproducible.

Sound absorption coefficient (α) can be determined as the ratio of energy absorbed by a material to the total incident energy at the surface. When the tube is forced out with acoustic absorbing material, some of the incident sound energy is taken up by the material presents a phase shift upon reflection. The amplitude at a pressure, maximum pressure (antinode) is A+B, and the amplitude at minimum pressure (node) is A-B. Because it is not possible to measure A or B directly. Nevertheless, the amplitude at a pressure node and anti-node can be assessed utilizing a microphone probe, which is put in a standing wave tube. The standing wave ratio (SWR) defined as the ratio of pressure maximum to a pressure minimum [8].

$$SWR = (A + B) / (A - B) \quad (4)$$

And

$$R = B/A = (SWR - 1) / (SWR + 1) \quad (5)$$

Where R is the reflection coefficient. Then the sound absorption coefficient defined by:

$$\alpha = 1 - R^2 = 1 - (SWR - 1)^2 / (SWR + 1)^2 \quad (6)$$

CHEMICAL ANALYTICAL DATA	%
ACETONE EXTRACT	14
ASH CONTENT	10
MOISTURE CONTENT	1
RUBBER HYDROCARBON CONTENT	50
CARBON BLACK CONTENT	25

TABLE 1. CHEMICAL ANALYTICAL DATA FOR RECLAIMED RUBBER

III. RESULTS AND ANALYSES

A. CURE CHARACTERISTICS

Curing characteristics of different SBR/RR blended systems with sodium bicarbonate loading can be determined by the cure time (t_{90}) and were summarized in Table 2. The results indicate that the t_{90} increase with increasing of RR, probably due to the chemical interaction during the curing process with the presents the RR. Carbon dioxide gas (CO_2) behaves as an efficient solvent in most rubbers; the CO_2 molecules stack interstitially between the rubber chains, hence increasing the mobility of the polymer chains as well as enlarge the free volume consequently [5].

The measurement of the minimum torque (M_L) represents the hardness of an unvulcanized rubber by consider at the lowest level of the curve, while the maximum torque (M_H) represents the value of hardness or the shear modulus of the fully vulcanized rubber and also used to estimate the Crosslink density of the rubber. The M_H and M_L from all samples were summarized in Table 2, indicating that the M_H and M_L increase with an increasing of RR contents due to the presence of cross-linked gel in the RR as mentioned in elsewhere [9].

Ingredients (phr [a])	S1	S2	S3
SBR	100	80	60
RR	0	20	40
Zinc oxide	4	4	4
Stearic acid	2	2	2
CBS [b]	1	1	1
6PPD [c]	1	1	1
Sodium bicarbonate	10	10	10
Sulfur	1.5	1.5	1.5
Cure characteristics			
M_H (dNm)	3.58	9.83	11:59
M_L (dNm)	1.05	2.27	2.46
T_{s1} (min)	8:07	1:48	1:42
t_{90} (min)	11:52	12:19	14:25
Physicomechanical Properties			
Tensile strength (Mpa)	0.667	2.033	3.056
Elongation at break %	203	485	617.5
Cross link density (mole. m^{-3})	50.45	70.63	81.13
Average apparent density (g.cm^{-3})	0.643	0.686	0.769

[a] Part per hundred parts of rubber.
[b] N-Cyclohexyl-2-benzothiazole sulfenamides
[c] N(1,3-dimethyl-butyl)-N'-phenyl-P-phenylenediamine

TABLE 2. MIX FORMULATION AND CURE CHARACTERISTICS OF THE SBR/RR BLENDS.

B. PHYSICOMECHANICAL PROPERTIES

The physicomechanical properties of SBR/RR blended with various compositions of the RR are shown in Table 2. The elongation increases with an increasing RR content in the composites due to the addition of the RR into SBR compounds spontaneously increase a carbon black concentration in the mixture. This results in a molecular interaction between the carbon black and the rubber phase. Moreover, the tensile strength also increases with RR concentration due to increasing of the crosslink density. Table 2 illustrates that the adding the RR and sodium bicarbonate influence the crosslink density. The additional of RR into fresh SBR led to enhance the crosslink density due to presence the active crosslinking sites in the RR. Greater RR material added means large active crosslinking density sites for the crosslink formation as reported by Kumnuantip and Sombatsompop [10].

The average apparent density of samples is given in Table 2, indicating that the density of the SBR/RR foams increases with an increasing of RR content as well, and the foaming effectiveness decreases similar found by Kim and his group [11].

C. SOUND ABSORPTION

All rubber foams samples shown superior for sound absorption as depicted in Figure 1. Foamed SBR foam with zero RR (sample S1, line with circles) reveals maximum acoustic absorption coefficient (α) around 500 Hz. The frequency which provide highest acoustic absorption peak is called a resonance frequency. For a sample S2 (line with triangles) and S3 (line with crosses) contained 20.0 phr and 40.0 phr of RR respectively, the second resonant frequency shift to the higher frequency around 800 Hz due to the solid structure and morphology of materials were influenced by presenting the RR and present of high concentration carbon black obtained from the RR (see Table 1). This leads to a reduction in the sound absorption similar found by Zhao et al. [12]. They claimed that when incidence sound waves reached materials with high carbon black composition, the sound wave will involve dispersion, diffraction, refraction and reflection phenomena, led to a reduction in the acoustic absorption coefficient.

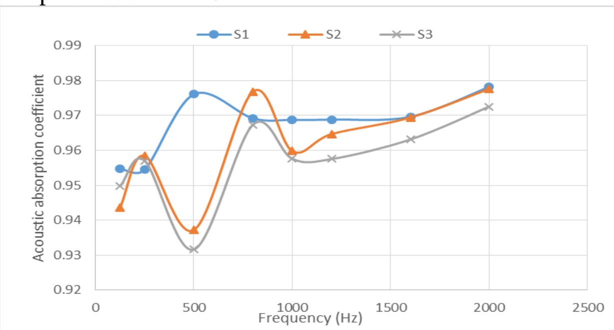

Figure 1. Acoustic absorption coefficient of SBR/RR foams as a function of frequency.

In addition, this present study found that the RR in the composition restricted the foam efficiency and reduce the pore size [13], consequently, reduce the amount of sound energy absorbed in the material. The sound pressure along a solid structure may can lose energy by deform the skeletal. If the solid surface of the materials is highly porous, fraction of the sound pressure infiltrates the material before coming across a strong surface. While for nonporous surface, incident energy reflects back into the environments. A great energy can transpose to the whole structure by the internal reflections through frictional losses and efficiently absorb sound. To achieve higher acoustic absorption performance, the pressure wave must go deep enough inside the material and not be reflected back directly into the surroundings. When the pore size is too small, more energy is reflected back from the surface and less is transferred into the solid structure, the material become less useful as an acoustic absorber [2].

IV. CONCLUSION

The reclaiming of tires in alternative applications is actually the use of based polymer in new formulations with simultaneous cost saving in raw material and preserving both natural resource and environment. As a conclusion, the composites made from the SBR/RR foam have been investigated. The results indicated that the maximum and minimum torque, elongation at break, tensile strength, crosslink density and density increase with an increasing of the reclaimed rubber content. The resonant frequency with maximum sound absorption coefficient for the SBR foam was observed at 500 Hz, while the resonant frequency of SBR/RR form shift to higher frequencies at 800 Hz found from both compositions independent with amount of RR contents. Therefore, adding RR into SBR results in the shifted of resonant frequency to a higher frequency. By adding chemical blowing agent sodium bicarbonate, a number of microstructure open cells were increased, resulting in enhancement of acoustic absorption of the material.

ACKNOWLEDGEMENTS

The authors would like to thank the SAT Scholarships for International Students of Faculty of Science and Technology – Prince of Songkla University (SAT-PSU) for financial support throughout this work.

REFERENCES

[1] Yang HS, Kim DJ, Lee YK, Kim HJ, Jeon JY, Kang CW (2004) Possibility of using waste tire composites reinforced with rice straw as construction materials. Bioresource Technology 95: 61-65.

[2] Maria AK, James CJ (2011) Acoustic absorption in porous materials. . Report No. NASA/TM.316995.

[3] Mahasaranon S, Horoshenkov KV, Khan A, Benkreira H (2012) The Effect of Continuous Pore Stratification on the Acoustic Absorption in Open Cell Foams. Journal of applied physics 111: 084901.

[4] Benkreira H, Khan A, Horoshenkov KV (2011) Sustainable acoustic and thermal insulation materials from elastomeric waste residues. Chemical Engineering Science 66: 4157-4171.

[5] Najib NN, Ariff ZM, Bakar AA, Sipaut CS (2011) Correlation between the acoustic and dynamic mechanical properties of natural rubber foam: Effect of foaming temperature. Materials & Design 32: 505-511.

[6] Najib NN, Ariff ZM, Manan NA, Bakar AA, Sipaut CS (2009) Effect of Blowing Agent Concentration on Cell Morphology and Impact Properties of Natural Rubber Foam. Journal of Physical Science 20 (1): 13-25.

[7] Sombatsompop N, Lertkamolsin P (2000) Effects of Chemical Blowing Agents on Swelling Properties of Expanded Elastomers. Journal of Elastomers and Plastics 32: 311-328.

[8] Gayathri R, Vasanthakumari R, Padmanabhan C (2013) Sound absorption, Thermal and Mechanical Behavior of Polyurethane Foam Modified with Nano Silica, Nano Clay and Crumb Rubber Fillers. International Journal of Scientific & Engineering Research 4(5): 301-308.

[9] De D, De D (2011) Processing and Material Characteristics of a Reclaimed Ground Rubber Tire Reinforced Styrene Butadiene Rubber. Materials Sciences and Applications 2: 486-496.

[10] Kumnuantip C, Sombatsompop N (2003) Dynamic Mechanical Properties and Swelling Behavior of NR/Reclaimed Rubber Blends. Materials Letters 57: 3167-3174.

[11] Kim JH, Choi KC, Yoon JM (2006) The Foaming Characteristics and Physical Properties of Natural Rubber Foams: Effects of Carbon Black Content and Foaming Pressure. J. Ind. Eng. Chem. 12 (5): 795-801.

[12] Zhao J, Wang XM, Chang JM, Yao Y, Cui Q (2010) Sound Insulation Property of Wood-Waste Tire Rubber Composite. Composites Science and Technology 70: 2033-2038.

[13] Xin ZX, Zhang ZX, Pal K, Kang DJ, Lee SH, Kim JK (2009) Effects of Waste Ground Rubber Tire Powder (WGRT) and Chemical Blowing Agent Content on the Cell Morphology and Physicomechanical Properties of Injection-Molded Polypropylene/WGRT Foams. Journal of Vinyl & Additive Technology 15(4): 275-280.