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ENVIRONMENTAL MODELLING OF SBR RUBBER DAMPING FOR NOISE VIBRATION REDUCTION

AHMED SAMIR NAJE*[1], HUSSEIN A. M. AL-ZUBAIDI[2], ZAID ABED AL-RIDAH[1]

[1]*Collage of Water Resource Engineering, AL-Qasim Green University, Babylon 51031, Iraq.*
[2]*Department of Environmental Engineering, College of Engineering, University of Babylon, Babylon, Iraq*

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ABSTRACT

Since the SBR rubber has been used for vibration damping, an environmental enhancement was performed in laboratory to reduce the noise generated by vibration. Ferrites ($MgFe_2O_4$ and $MnFe_2O_4$), which have been prepared using co-precipitation reaction method, were mixed separately with SBR rubber to form rubber composite of well damping characteristics, resulting in less noise vibration. The specific gravity, hardness, and shock reflection were explored in the lab to show the effect of ferrites ratio in the mixture on the damping properties of the rubber composite. Results showed that the rubber damping was improved with increasing the ferrites ratio, reducing the shock reflection ratio and damping time and increasing the hardness. In addition, slightly higher hardness, higher wave reflection ratio, and higher wave reflection time are associated with using magnesium ions compared to manganese ions.

KEY WORDS : Environmental modelling, Noise pollution, SBR rubber, Vibration dampers, XRD test

INTRODUCTION

Recently, vibrations and noise have become popular environmental pollutants associated with mechanical movement in different ways around the world. In order to reduce the effects of these kinds of environmental pollutants, damping isolation by using the damping padsthat connect engine with its frame have been used. Different other techniques have been implemented too such as controlling the natural vibration, using isolation barriers, or reducing vibration wave amplitude by using a vibration force of the same frequency and amplitude in opposite phase (Akrill *et al.,* 2011; Aso *et al.,* 2006; Furuya and Kurabayashi, 2008; Al-Zubaidi and Wells, 2020).

It is possible to use mineral and air springs, as well as rubber dampers and pads, which are known as special systems to reduce the noise arising from the operation of engines and machines. Rubber pads are considered one of the most important for the ease of use and low cost. In order to improve the properties of the materials used in these applications, several studies have been carried out by finding additions to the rubber material, which is the basic material used in the vibration dampers.For example, adding silica (SiO_2) in different grain sizes and studying its effects on the NBR rubber, the vibration wave reflection goes down as the grain size becomes less due to the increase in the surface area of the silica grains. This leads to an increase in the hardness and decrease in the elasticity values. Also, increasing the ratio of silica to black carbon leads to a decrease in the wave reflection (Naje *et al.,* 2016).

In addition, other ceramic materials in the form of powders can be added to the rubber material such as ferrites, which are highly effective in dealing with electromagnetic waves or below. Ferrites have excellent electrical resistance and electronic movement, making its electrical characteristics and magnetic properties excellent. This enables the interaction of the coming waves with their electric and magnetic components; therefore, it is a wave absorbent material and has been commonly used for absorbing radar waves. Different kinds of ferrites exist such as soft ferrite, hard ferrite, and granite. Because these materials are inexpensive and characterized by its high efficiency, ferrites have been widely used in practical applications. However,there is a specific response for each compound of a certain chemical formula (Moskowitz, 1995; Snelling, 1988).

Chemically, these materials are stable with dark gray or black color. Many of these materials have a spinel structure. Several previous studies have been conducted on their use as composite materials with rubber with a certain thickness to absorb waves within a wide range of frequencies and according to the type of composite used. One of these studies was carried on by Hansaka (2005). In this study, magnetic rubber mixed with ferrites of (5-10) µm grain sizes was used for isolating railroads over bridges in order to reduce noise and absorb the vibration. This mixture decreased the noise by 3 dB at 12.5 m from railroad center. In addition, the mixture kept its high efficiently on a wide range of temperature compared to the traditional damping materials.

SBR is a kind of rubber with moderate wave damping due to the moderate degree of glass transition, T_g = -62 °C. Because of the presence of the relatively large phenyl group, there is an overlap in the molecular mass in addition to an increase in the entropy function and the number of synthetic data due to the vibration and twist movement variety. Thus, the objective of this research is to investigate the effect of some types of soft ferrites on the properties of SBR (rubber damping) and its utilization to manufacture absorbent pads for acoustic or mechanical shock.

MATERIALS AND METHODS

First of all, ferrites ($MgFe_2O$ and $MnFe_2O_4$) were prepared in the lab by using$MnCO_3$, $FeCl_3$, and $MgCO_3$ and by implementing the method of co-precipitation reaction. This was done by dissolving each of the above salts in distilled water after mixing them with the appropriate weight ratios of $FeCl_3$ to form saline solutions for each type of proposedferrites. Also, $NH_4(OH)$ was used to make PH = 7.

After filtering the solutions and drying the settled materials, the remains were heated at 200 °C for 24 hours using an electric furnace to be smashed manually until forming the two ferrites ($MgFe_2O_4$ and $MnFe_2O_4$). Then, these ferrites were heat-treated in an oven to a temperature of 800 °C for a period of four hours. This process help facilitate the solid-solid reaction to form the spinel phase. After cooling the oven, the powders are grinded to form a homogeneous mixture. To verify the formation of the spinel phase, the XRD was used.

Second, the following steps were followed to prepare rubber composite:

1. The rubber was squeezed to obtain a pure rubber sheet. After that, carbon black was added with oil in small quantities and then rolled up to 15 times to reach the homogenous state. This process was repeated with adding the carbon black until reaching the required carbon black ratio, see Table 1.
2. ZnOwas added to the composite as an activating agent according to step 1 until reaching the homogenous state.
3. The TMTD, an accelerator, was added to the composite and rolled to homogeneity.
4. Finally, sulfur (S) was added and rolled until homogenization is achieved.

After preparing the rubber composite as illustratedabove, magnetic rubber was made by adding and mixing $MgFe_2O_4$ and $MnFe_2O_4$ separately using a ratio of (20, 40, and 80) in a similar way to what was done in step 1 of rubber composite preparing. Using a thermal piston of 15 MPa pressure and 70 °C temperature for 10 min, three discs of ferrites were formed with a diameter of 50 cm and thickness less than 0.4cm for each type of ferrites. The purpose of these discs was to conduct tests and measurements on them to determine the specific gravity (S.P), hardness (IRHD), and shock reflection ratio (R%).

RESULTS AND DISCUSSION

Figure 1 and Figure 2 show the XRD test results of the prepared ferrites. The results revealed how the

Table 1. Ratio of materials used for SBR rubber preparation.

Material type	SBR	Black carbon	Oil	ZnO	Citric acid	Phenolic resin	TMTD	S
pphr	100	40	4	3	1.73	0.5	0.6	2

materials reached the spinel phase well. The formation of the spinel phase is affected by several factors, including heat treatment, aspect ratios, and homogeneity of the constituent materials. However, the XRD tests showed that this phase is well formed by the appearance of the main peaks compared to ASTM even though the thermal treatment was done using 800 °C to avoid the granular growth that loses the Nano property from the material because the material was prepared chemically, which gives such a granular size. This result is consistent with the study of Ali *et al.* (2019).

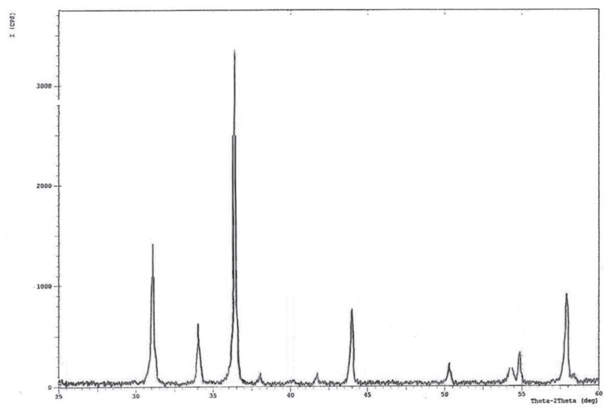

Fig. 1. The XRD test of $MgFe_2O_4$.

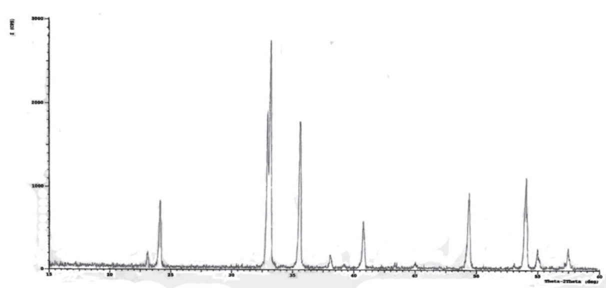

Fig. 2. The XRD test of $MnFe_2O_4$.

Figure 3 shows the increase in the specific weight of rubber composite by increasing the additives ($MgFe_2O$ or $MnFe_2O_4$) in the mixture. Because the density of the ferrites material is much higher than the rubber, such an increase was expected. This, in turn, affectedthe rubber hardness in which the increase in the ferrites amount ofthe rubber composite led to increase the hardness, see Figure 4 and Figure 5. However, the values of hardness in case of $MgFe_2O$ are slightly higher than $MnFe_2O_4$. This is due to the fact that the magnesium ions are smaller than the manganese ions, making the magnesium ions more homogenous and better overlap with the rubber materialsthan the

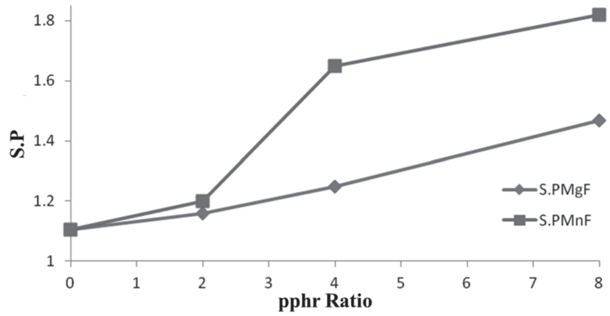

Fig. 3. Specific gravity (S.P) variation with pphr ratio in the composite rubber.

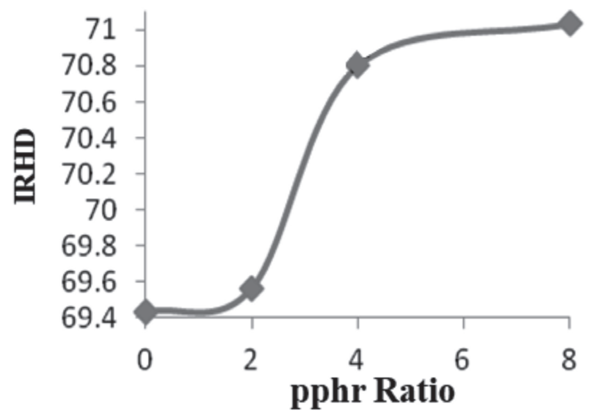

Fig. 4. Effect of increasing MnFe2O4 in the rubber composite on the hardness.

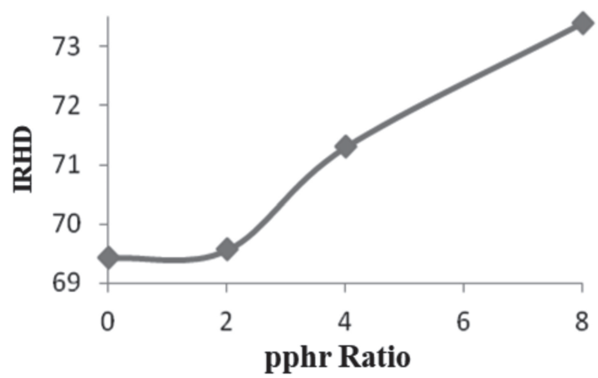

Fig. 5. Effect of increasing $MgFe_2O_4$ in the rubber composite on the hardness.

manganese ions (Al-Zubaidi and Wells, 2018).

The effect of both kinds of ferrites on the rubber shock reflection ratio was identified in Figure 6 and 7. The R% was improved clearly with the increase of the ferrites in the rubber composite. In addition, the best R% improvement was happened when $MnFe_2O_4$ was used because of the larger manganese ion volume, 0.8A° for manganese compared to 0.65A° for magnesium. This affects the cell unit in the compound structure, in turn. After reaching the spinel phase in the previous stage, the positive ions are compacted in two structures (a tetrahedral structure leads to A-site groups and octahedral one gives B-site groups) (Clarricoats 1961; Baden Fuller, 1987; Naje *et al.,* 2019). Therefore, the size of the ion deposited in these spaces will increase or decrease the size of the cell unit.

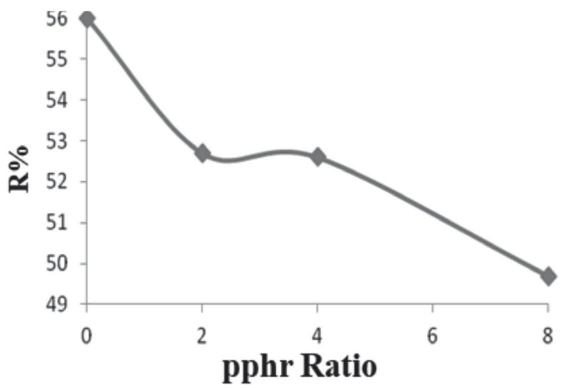

Fig. 6. Effect of increasing $MnFe_2O_4$ in the rubber composite on the wave reflection ratio.

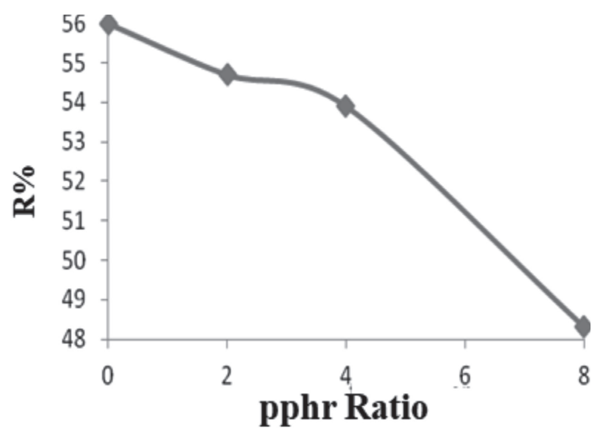

Fig. 7. Effect of increasing $MgFe_2O_4$ in the rubber composite on the wave reflection ratio.

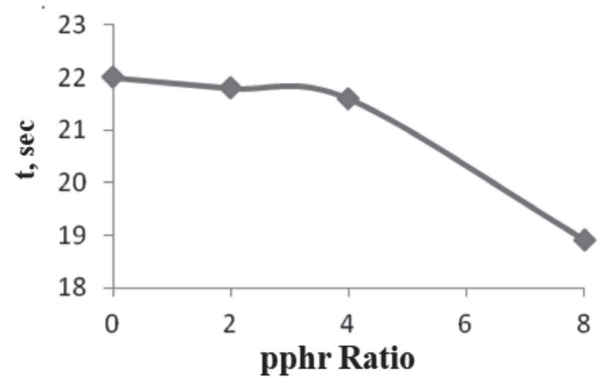

Fig. 8. Effect of increasing $MgFe_2O_4$ in the rubber composite on the damping time.

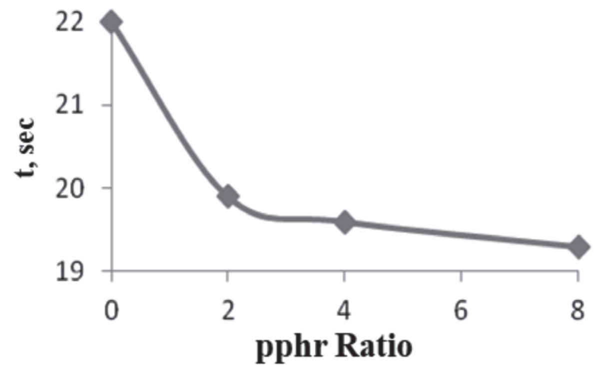

Fig. 9. Effect of increasing $MnFe_2O_4$ in the rubber composite on the damping time.

Also, another advantage of using the magnesium ions is that the magnesium atomic weight is much lower than the atomic weight of manganese, and $MnFe_2O_4$reaches the spinel phasewith minimum crystal energy (Miller, 1959). This is the main factor to make the damping better when used. Figure 8 and 9 show that the increase in the ratio of ferrites in the rubber composite helped to reduce the time taken to dampen the vibrations, leading to an improvement in the rubber composite properties.

CONCLUSION

In order to improve the SBR rubber vibration damping, the highly wave and energy absorbents, ferrites ($MgFe_2O$ and $MnFe_2O_4$), were prepared in the lab and added to the rubber material to form the magnetic rubber composite. The manufactured rubber mixture revealed well characteristics in terms of specific gravity, hardness, and shock reflection, leading to less noise vibration. Therefore, the rubber composite was tested to determine and investigate the influence of adding the ferrites to the rubber properties. The results showed that increasing the ferrites in the composite gives higher specific weight and hardness values in addition to improve the SBR rubber damping characteristics. Hence, the shock reflection ratio and damping time were reduced by increasing the ferrites amount in the mixture. Furthermore, it was found that using magnesium ions leads to a slightly higher hardness, higher wave reflection ratio, and higher wave reflection time than using manganese ions.

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