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Study of properties of fillers based on natural bentonite and their effect on the rubber compounds

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Abstract

The paper deals with the proposal and preparation of the suitable rubber compounds in which materials are based on natural bentonite. It is important to point out that the mentioned materials were used in the function of the fillers. In relation to the prepared rubber compounds, vulcanization and rheological properties were determined (minimum torque - M_L, maximum torque - M_H, processing safety - t_S, optimum vulcanization time - $t_{C(90)}$, rate coefficient of vulcanization - R_v). Prepared vulcanizates were evaluated from the aspect of physical and mechanical properties (tensile strength, elongation, hardness) and heat aging of vulcanizates was also evaluated. These characteristic features were compared with those which are typical for standard rubber compounds used in the rubber industry while standard filler is carbon black of N339 type.

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Keywords: bentonite; rheological properties; physical and mechanical properties; fillers; physical and mechanical properties;

1. Introduction

In many industrial applications, elastomers are mixed with fillers to improve their performance properties (stiffness, toughness, tensile properties) as well as to enhance the durability of rubber compounds and to reduce the cost of the final product. Fillers are relatively inexpensive, solid substances that are added in a large amount to polymers in relation to volume, weight, cost, surface, color, processing behavior, mechanical strength and other properties. They can be divided into non-reinforcing fillers, semi-reinforcing and reinforcing fillers [1, 2].

For decades, carbon black and amorphous silica have been used as reinforcing fillers in the rubber industry. Although both fillers have effective influence on strength and performance properties as well as durability of elastomer materials, other types of fillers have been sought as competitive alternatives for commercial scale applications [3, 4].

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In the material research of the polymeric materials, the current trend includes research of polymers in combination with clay minerals. The economic as well as environmental aspects are the reasons for the mentioned investigation of clay minerals with polymers. Compared to conventional types of filler, small amount of clay mineral can have beneficial effect on modification of the physical and chemical properties relating to polymeric materials. The influence of filler on polymeric materials depends on its physical properties, such as particle sizes, surface reactivity, surface area, particle electrical charge as well as chemical properties, such as reactivity with accelerators and pH [5-8].

2. Experimental

2.1. Materials

The natural bentonite used in this study was extracted from the locality with name Lieskovec. The chemical composition of natural bentonite was: SiO_2 60 %, MgO 4 %, Fe_2O_3 3 %, CaO 2 %, fineness of grinding was min. 95 % under 0.015 mm and the content of montmorillonite was 75 %. For preparing rubber compounds, the natural bentonite (NB) was dried in dryer at temperature of 70 °C for 24 h. Prepared bentonite was added into the compound replacing the conventional filler in an amount of 1 phr, 5 and 10 phr, respectively (parts by weight per hundred parts of rubber).

2.2. Preparation of rubber compounds

Preparation and mixing of rubber compounds is one of the most important processes of rubber technology. The rubber compounds were prepared by two-step mixing in 70 mL mixing chamber of Plastograph-Brabender at the mixing speed of 50 rpm. The procedure was performed according to STN 62 1425 (Slovak Technical Standard). The proper order of steps in relation to additives and vulcanization system was performed as it is predetermined. In Table 1, there is composition of fillers in samples. The mixed rubber compounds were homogenized during the first and the second steps in laboratory two-roll mill device. Prepared rubber compounds were vulcanized [9].

Table 1 The composition of fillers in samples

Samples	Filler	[phr]	Filler	[phr]
Standard	CB	87	-	-
NB 1	CB	86	NB	1
NB 5	CB	82	NB	5
NB 10	CB	77	NB	10

Rheology and vulcanization properties of rubber compounds were measured using the Monsanto 100 at temperature 150 °C according to STN. Minimum torque (M_L), maximum torque (M_H), processing safety (t_S), optimum vulcanization of ($t_{C(90)}$) and rate coefficient of vulcanization (R_v) were determined.

2.3. Preparation of vulcanizates

Prepared vulcanizate test specimens in the shape of the double-sided blades were mechanically cut out from the vulcanized slabs. Physical and mechanical properties were measured before and after heat aging at room temperature using Instron universal testing machine at deformation rate of 50 $mm.min^{-1}$. Tensile strength and elongation at loading were determined. Hardness was measured by IRHD hardness tester.

The method of accelerated heat aging includes monitoring of the physical properties of the test specimens exposed in the non-deformed state to the effect of air circulation for specified time at the constant temperature in the thermostat while these test specimens were compared with the test specimens which were not exposed to accelerated heat aging according to Slovak Technical Standard [10].

3. Results and discussion

3.1. Rheology and vulcanization properties

Effect of selected fillers based on natural bentonite on the course of sulphur vulcanization of rubber compounds was evaluated for selected parameters of vulcanization characteristics using rheometric results of vulcanization curves. Results from determination of rheology and vulcanization properties of rubber compounds are shown in Fig. 1-5.

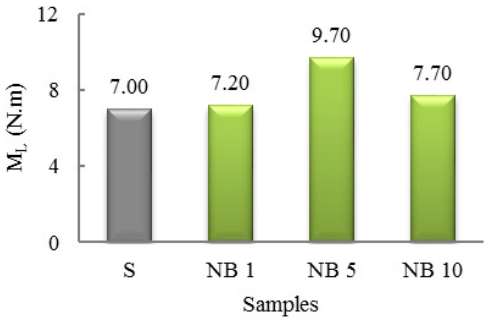

Fig. 1. Minimum torque

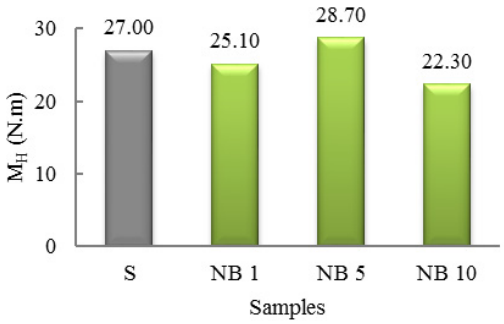

Fig. 2. Maximum torque

Figure 1 shows the variation of minimum torque values for sample NB 5 which has higher value compared with standard sample (*S*). The increase of values indicates higher stiffness as well as the higher viscosity of the prepared tread compounds at the beginning of vulcanization. The resulting values of the minimum torque (M_L; Fig. 1) for samples NB 1 and NB 10 were the close to reference sample, indicating good compatibility of rubber matrix with the filler.

In the case of maximum torque (M_H; Fig. 2), the samples NB 1 and NB 10 exhibited lower values in comparison with standard sample. The sample NB 5 had higher maximum torque than samples NB 1 and NB 10. The increase of values indicates higher stiffness as well as the higher viscosity of the prepared tread compounds at the end of vulcanization.

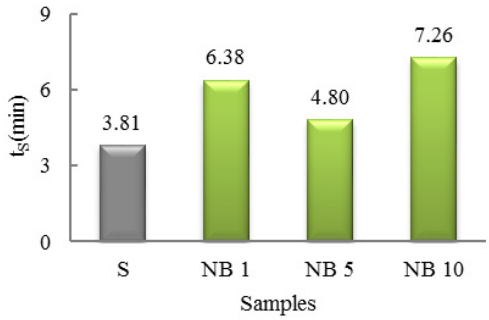

Fig. 3. Processing safety

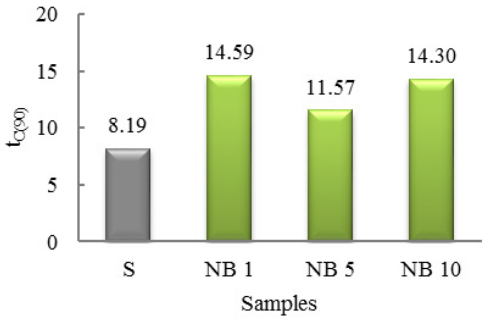

Fig. 4. Optimum vulcanization time

From the results of the processing safety (t_S; Fig. 3), it can be seen that the all prepared samples (NB 1, NB 5, NB 10) exhibited higher values in comparison to standard sample. Higher values of the processing safety can be characterized by a positive effect on the treatment of compounds and physical and mechanical properties of

vulcanizates. In the case of NB 5 sample, the value of the processing safety was the closest to the value of standard sample (*S*).

In the case of optimum vulcanization time ($t_{C(90)}$; Fig. 4), the all prepared samples exhibited higher values compared with standard sample. The extension of the optimum vulcanization time can be helpful for application in thick-walled rubber products where it is necessary to make vulcanization process slower.

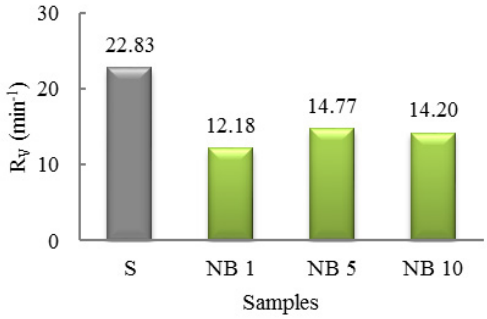

Fig. 5. Rate coefficient of vulcanization

In comparison with standard compound, the lower value of the rate coefficient (R_V; Fig. 5) of vulcanization was observed for all prepared compounds (NB 1, NB 5, NB 10), it can characterize lower interaction of ingredients used in the vulcanization system and slower course of vulcanization.

3.2. Physical and mechanical properties

The selected physical and mechanical properties were tested and evaluated. Effect of fillers, based on natural bentonite, on physical and mechanical properties is shown in Fig. 6-8.

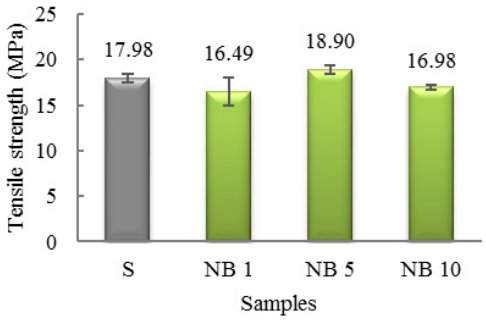

Fig. 6. Tensile strength

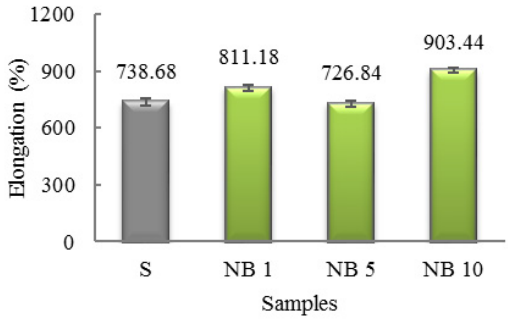

Fig. 7. Elongation

The higher values of the tensile strength (Fig. 6) in comparison with standard compound were observed only at NB 5 sample. The improvement of the tensile strength was probably related to a higher degree of dispergation of dominating carbon black due to presence of natural bentonite in given amount in rubber matrix.

In the case of elongation (Fig. 7), NB 1 and NB 10 samples show a higher elasticity in comparison with standard and it can be utilized in applications where high elasticity of products is required. The NB 5 sample has lower value of elongation than standard sample (*S*).

In comparison to standard sample, the sligthy lower values of the hardness (Fig. 8) are shown by NB 1 and NB 10 samples and it indicates good incorporation of the filler into to compound and good compatibility with the rubber matrix.

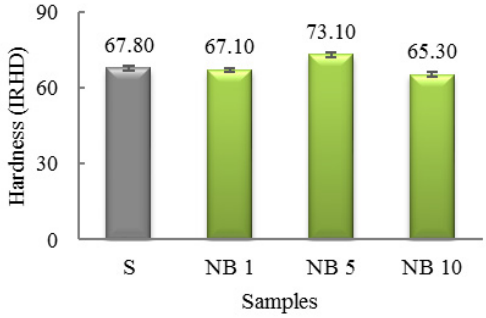

Fig. 8. Hardness of vulcanizates

3.3. Physical and mechanical properties after accelerated heat aging

The results of determination of physical and mechanical properties after accelerated heat aging at temperature of 100 °C during 72 hours are shown in Fig. 9-11, where the change of the given values is shown in percentage.

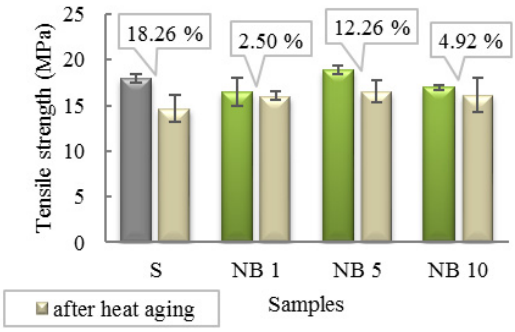

Fig. 9. Changes of tensile strength before and after heat aging

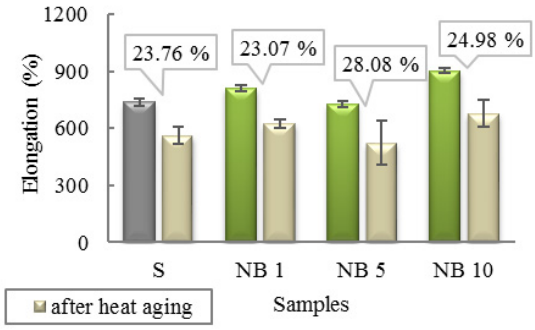

Fig. 10. Changes of elongation before and after heat aging

Based on the results, it can conclude that after the accelerated heat aging in air, there is decrease of tensile strength values for almost all vulcanizates compared with reference sample (*S*). The lowest percentage decrease in tensile strength (Fig. 9) values was monitored for the NB 1 and NB 10 samples containing fillers based on natural bentonite in an amount of 1 phr and 10 phr.

In the case of change in elongation of vulcanizates, there is a decrease in elongation values compared with the standard sample (*S*) (Fig. 10). The lowest percentage decrease of elongation is observed for NB sample 1 compared with standard sample (*S*).

In relation to results of determination of hardness after accelerated heat aging (Fig. 11), the vulcanizates containing fillers based on natural bentonite, exhibited increase of hardness. The lowest percentage increase of hardness is observed for NB5 sample compared to reference sample (*S*).

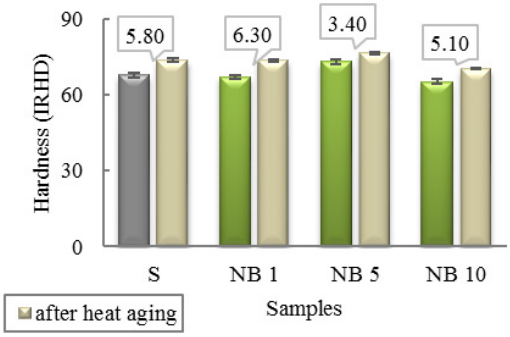

Fig. 11. Changes of hardness before and after heat aging

4. Conclusion

The main aim of the paper was to investigate effect of fillers, based on natural bentonite, on the properties of polymeric materials. The results of this research (including: rheology and vulcanization characteristics, physical and mechanical properties before and after heat aging) showed that carbon black can be replaced partially by fillers based on natural bentonite.

Acknowledgements

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