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NEW RUBBER COMPOUNDS WITH ALTERNATIVE FILLERS – PREPARATION AND PROPERTIES

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Abstract:
The paper deals with a preparation of new rubber compounds with content of alternative additives based on two kinds of industrial wastes – first from glass production and second from energetics. Named alternative fillers were used as a substitution of commonly used fillers – carbon black and silica for the new rubber compounds preparation. Rheology, cure characteristics as well as hardness and rebound resilience of vulcanizates, which are important parameters for their industrial application, have been studied in the new prepared elastomer materials. The samples of vulcanizates prepared with the addition of alternative fillers showed improvement in properties, namely high rebound resilience and low rolling resistance as well as optimum hardness values, which are important parameters for applications in automotive. Moreover, used raw material substitution can also bring significant environmental and economic effects.

Key words:
rubber compound, vulcanizate, alternative filler, hardness, rebound resilience

1 INTRODUCTION

Increasing the quality of the products and greening the production are among the main priorities of the development of industrial production. Inorganic materials and their application into organic elastomers is one of the ways to improve up of physical and mechanical properties of rubber, specifically hardness, tensile straight, modulus and also rebound resilience (Giannelis,1996). Resultant composite materials show generally better properties than pure and homogeneous materials. The positive changes have been observed at very low concentration of inorganic mineral component in polymers (Giannelis,1996; Giannelis,1998). In addition to improving the properties of the resulting elastomer in the case of the application of alternative waste-based fillers, the low cost of the resulting product and the greening of production are also of great benefit. Article deals with the preparation and study of properties of rubber blends containing two types of alternative fillers. The first used alternative filler (GW) arises as dust from the process of weighing glass raw materials. The other (EW) arises as a byproduct in the flue gas desulphurization process in energetics.

2 METHODS AND METHODOLOGY

2.1 Preparation of rubber blends with alternative fillers content

Natural rubber SMR 10 has been used as the elastomeric matrix for the preparation of rubber blends. Alternative fillers (EW, GW) were grinded and dried to constant weight and were applied into elastomeric compounds as a replacement of the commonly used fillers (silica and carbon black). The rubber compounds were prepared by two-step mixing at 90 °C in a Plastograph Brabender laboratory mixer (Dick, 2009), (Norazlina, Firdaus and Hafizuddin, 2015). Content of alternative fillers in rubber compounds is given in Table 1.

Tab. 1: *Content of alternative fillers in prepared rubber compounds*

Alternative filler	**Content (wt.%)**	
	GW	**EW**
Sample 1	13	26
Sample 2	16	25
Sample 3	22	16
Sample 4	28	11
Sample 5	30	3

EW – alternative filler from energetics, GW – alternatie filler from glass industry

2.2 Study of rheology and curing properties of rubber blends

The properties of prepared rubber compounds were studied in specialized laboratories of at the Faculty of Industrial Technologies in Púchov. Rheological properties as minimum (M_L) and maximum torque (M_H) and curing characteristics - optimal cure time (t_{c90}) and scorch time (t_{s02}) were measured using Rubber Process Analyzer RPA 2000, at the temperature of 150 °C during 15 min. after determination of rheological properties, the vulcanization process was carried out using LabEcon 600 curing pneumatic press.

2.3 Determination of hardness and rebound resilience of vulcanizates

Determination of hardness of prepared vulcanized rubber blends containing alternative fillers was carried out using hardness tester with IRHD scale. Hardness of vulcanizates was measured by hardness tester IRHD according to STN (ISO 48). Measurement of rebound resilience of prepared vulcanizates was caried out using apparatus Polymertest (ISO 4662).

3 RESULTS AND DISCUSSION

3.1 Results of rheology and curing properties measurements

Measured values of rheology and curing properties of prepared rubber blends with content of alternative fillers are given in Table 2 and in Figure 1. Minimal torque is the lowest value of torque indicated on the vulcanization curve, equal to viscosity of the compound heated to vulcanization temperature. This torque value characterizes the compound stiffness. Maximum torque is the highest value of torque indicated on the vulcanization curve, equal to the value of the vulcanized compound shear modulus at the given temperature. This torque value characterizes the vulcanizate stiffness at the end of cure process (Matador Rubber, 2007).

Tab. 2 *Rheology and Curing properties of prepared rubber blends*

Sample	**Rheology and Curing properties**			
	M_L (dNm)	**M_H (dNm)**	**t_{s02} (min)**	**t_{c90} (min)**
Sample 1	0.83	11.98	2.53	7.14
Sample 2	1.09	15.95	3.83	7.71
Sample 3	0.80	17.76	2.48	7.73
Sample 4	1.45	16.81	4.82	9.38
Sample 5	1.10	11.23	4.81	10.21

Maximum value of minimal torque showed Sample 4 (1,45 dNm). When evaluating the maximum torque results, it is possible to see the dependence on the quantity of alternative fillers. With increasing the content of alternative filler GW in rubber blends the value of M_H increased up to Sample 3. It is possible to assume, that Sample 3 contains optimal ratio of alternative fillers for reached maximal value of M_H. Further increase of GW content in blend (Samples 4 and 5) led to decrease of maximum torque values.

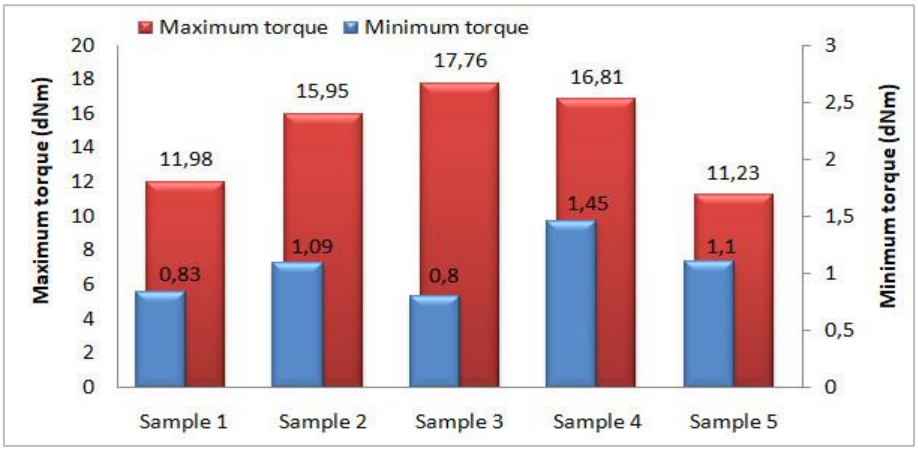

Fig.1 *Scorch time and optimal curing time values of rubber blends*
Source: Authors

Scorch time is the time required at a specified temperature (or heat history) for a rubber compound to form incipient crosslinks. Scorch time evaluation is therefore very important in determining whether a given rubber compound can be processed in a particular operation (Dick, 2009). Optimum cure time (t_{C90}) is the time required for the torque to reach 90 % of the maximum achievable torque (t_{C90}) relating to the time necessary to achieve optimal properties of the cured rubber (Khimi and Pickering, 2013). With increasing content of alternative filler EW from energetics decreased the values of scorch time (t_{s02}) and the same effect showed the values of optimal curing time (t_{c90}). This effect can ascribe to content of SO_4^{2-} in alternative filler EW, which come into curing process and accelerate it. On the other hand, alternative filler GW slows down the vulcanization process, which is due to its pH (higher SiO_2 content) (Malač, 2005). By combining both EW and GW fillers, optimal vulcanization conditions suitable for different types of products can be achieved.

3.2 Results of hardness and rebound resilience measurements

Rubber hardness and rebound resilience are two of the most important properties for industrial application of rubber blends The hardness is the measurement of the penetration of an indentor in a sample under defined conditions. Assessment of reflection elasticity is one of the known methods to determine the rubber ability to absorb mechanical energy during impact (Matador Rubber, 2007). The results are summarized in the Table 3 and in Figures 2 and 3.

Tab. 3: *Values of hardness and rebound resilience of prepared vulcanizates*

Sample	Hardness (IRHD)	Rebound resilience (%)
Sample 1	54,75± 0,61	51.15 ± 0.18
Sample 2	56.75± 0.61	50.43 ± 0.12
Sample 3	58.08 ± 0.58	48.36 ± 0.32
Sample 4	58.33± 0.61	46.05 ± 0.10
Sample 5	59.42 ± 0.58	45.22 ± 0.17

From the results of hardness measurement (Fig.2) it can be seen, that hardness values increased with increasing the content of alternative filler GW and decreasing the EW filler content. It is possible to assume, that alternative filler GW have higher stiffening effect compared to EW filler.

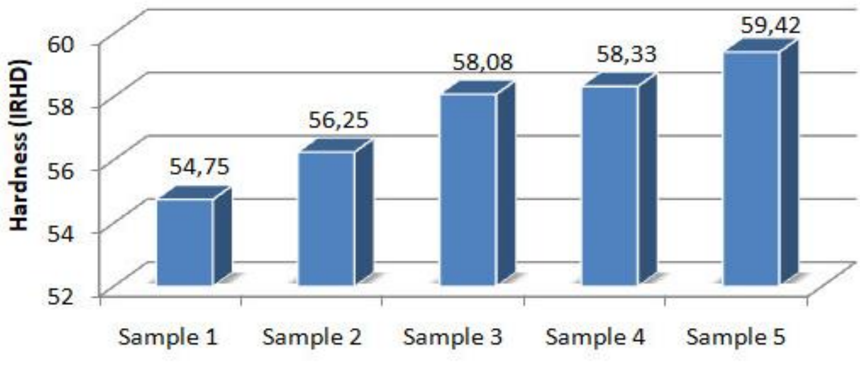

Fig.2 *Values of hardness (IRHD) of prepared vulcanizates*
Source: Authors

Hardness and rebound resilience are two properties which often excluding (especially using carbon black filler). This effect was also manifested in the case of newly prepared vulcanizates, when the highest value of rebound resilience showed Sample 1 with the highest amount of alternative filler EW (Fig.3).

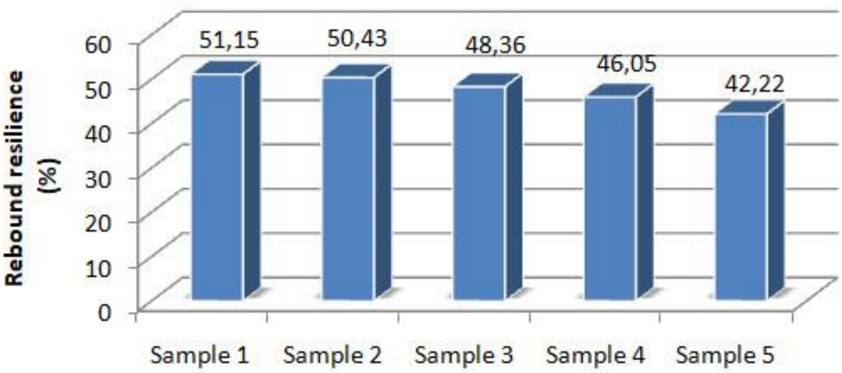

Fig. 3 *Values of rebound resilience of prepared vulcanizates*
Source: Authors

Values of rebound resilience are also influenced by degree of crosslinking of rubber vulcanizate (Bhowmick et al., 1994). Because the alternative filler EW from energetics come into curing process, it is possible to assume, that degree of crosslinking is higher and thus its positive effect on increasing the rebound resilience was manifested.

Rebound resilience is directly related to rolling resistance, which is an important property especially for the use of prepared vulcanizates in the production of car tire treads. The higher the value of rebound resilience, the lower the rolling resistance, which is reflected in the reduction of fuel consumption.

4 CONCLUSIONS

The five elastomeric systems containing new alternative fillers based on two types the industrial wastes have been prepared. Results of the curing properties determination showed, that alternative filler EW from energetics is able to accelerate the curing process, and its content in rubber blends decreased scorch time, which may not be very desirable. Conversely the alternative filler GW from glass production extended the scorch time. Both alternative fillers (GW, EW) showed significant effect on the values of hardness and rebound resilience. Alternative filler GW caused higher stiffening effect compared to alternative filler EW. The samples of vulcanizates prepared with the addition of alternative fillers showed improvement in properties, namely high rebound resilience and low rolling resistance as well as optimum hardness values, which are important parameters for applications in automotive. Moreover, used raw material substitution can also bring significant environmental and economic effects.

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