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Mechanoactivation Treatment of Ground Vulcanizates

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Abstract

Effect of preliminary mechanical activation of ground vulcanizates on the elastic-strength properties and structure of components was studied. Rubber crumbs were obtained by grinding different model elastomer compositions and real wastes from the production of rubber goods.

Key words: recycling, ground vulcanizates, rubber crumbs, rubber goods, mechanical activation

INTRODUCTION

Secondary polymers comprise a huge but poorly used resource of polymer raw materials. In rubber industry, there are substantial reserves of secondary raw materials in the form of worn-out tyres and inevitable industrial wastes; the present level of processing the latter does not exceed 30 % [1]. Different strategies of recycling of polymer wastes are proposed and developed; among them, the best progress was achieved in mechanical and chemical processing. Mechanical processing (grinding) allows one to conserve the characteristics of initial materials and to process them into new hardware or use them in various composite materials [2].

Grinding (crushing) of rubber wastes is considered to be the most efficient processing method because in this case the products of processing conserve the physical characteristics of rubber. Grinding methods include comminution at positive temperatures and cryogenic crushing. Practice demonstrated that the operating costs for grinding at positive temperatures are not very high but the cost of the equipment is higher than that for the case of low-temperature (cryogenic) crushing [3].

In general, calculations and the experience with different kinds of equipment provide evidence that grinding at positive temperatures is a less energy-consuming process [1, 4]. However, choosing a technology in each specific case, it is necessary to take into account technical, economical and ecological conditions.

EXPERIMENTAL

The wastes from the production of rubber for general purposes at the Experimental Industrial works of mechanical rubber goods of the Institute for Petroleum and Gas Problems, SB RAS (Yakutsk) were chosen as the raw material for obtaining round vulcanizates. Grinding was performed in the cutting mill (Fritch) without the cryogenic technology; a sieve with mesh diameter of 0.75 mm was used. The matrix for filling was frost-resistant rubber of industrial grade V-14 based on butadiene-styrene caoutchouc VNKS-18. Before adding the rubber grit to the elastomer matrix, its mechanical activation was performed in AGO-2 planetary mill for 3 min. The parameters of planetary mill AGO-2: two cylinders 150 mL in volume, the average diameter of milling bodies (steel) 8 mm, the mass of milling bodies loaded into the cylinders 200 g, the mass of material under treatment 15 g, the frequency of carrier rotation 800 rpm, the frequency of cylinder rotation 1820 rpm.

The grit was introduced on the rolls into the raw rubber mix in the amount of 20 and 40 mass %.

Investigation of the materials with real wastes requires enormous statistical selection of data that is why we also studied model mixtures of established composition along with the above-mentioned materials (wastes from rubber production). The model mixture included rubber V-14 (based on caoutchouc BNKS-18), rubber 51-3050 based on BNKS-26), rubber 51-1481 (based on ethylene-propylene caoutchouc).

RESULTS AND DISCUSSION

Micrographs taken with a scanning electron microscope JSM 6480 LV are presented in Fig. 1. One can see that mechanical activation in the composition nitrile caoutchouc–nitrile caoutchouc promotes obtaining the material with more uniform structure in comparison with the material with non-activated rubber crumb.

In the case if the matrix and the filler have different polymer composition (polar nitrile caoutchouc–nonpolar ethylene-propylene caoutchouc), structural inhomogeneity is observed.

Table 1 shows results obtained in the investigation of the effect of rubber crumb composition on the properties of vulcanizates. It was established that relative elongation of rubber filled with crumb made of 51-3050 and V-14 grades increases up to 30 % in comparison with the initial rubber, while for the samples filled with the crumb of 51-1481 rubber it decreases to 24 %. Conditional strain at 100 % elongation somewhat decreases for all the indicated filled kinds of rubber. Conditional tensile strength of the samples with the mass fraction of crumb equal to 20 %, made of 51-3050 and V-14 grade rubber, remains at the level of the initial material, while for the mixture filled with crumb of 51-1481 grade rubber it decreases to 20 %.

A decrease in the physicochemical characteristics of the samples filled with the crumb of rigid rubber of 51-1481 grade based on nonpolar ethylene-propylene caoutchouc in comparison with the samples of initial rubber can be explained by inhomogeneity of the struc-

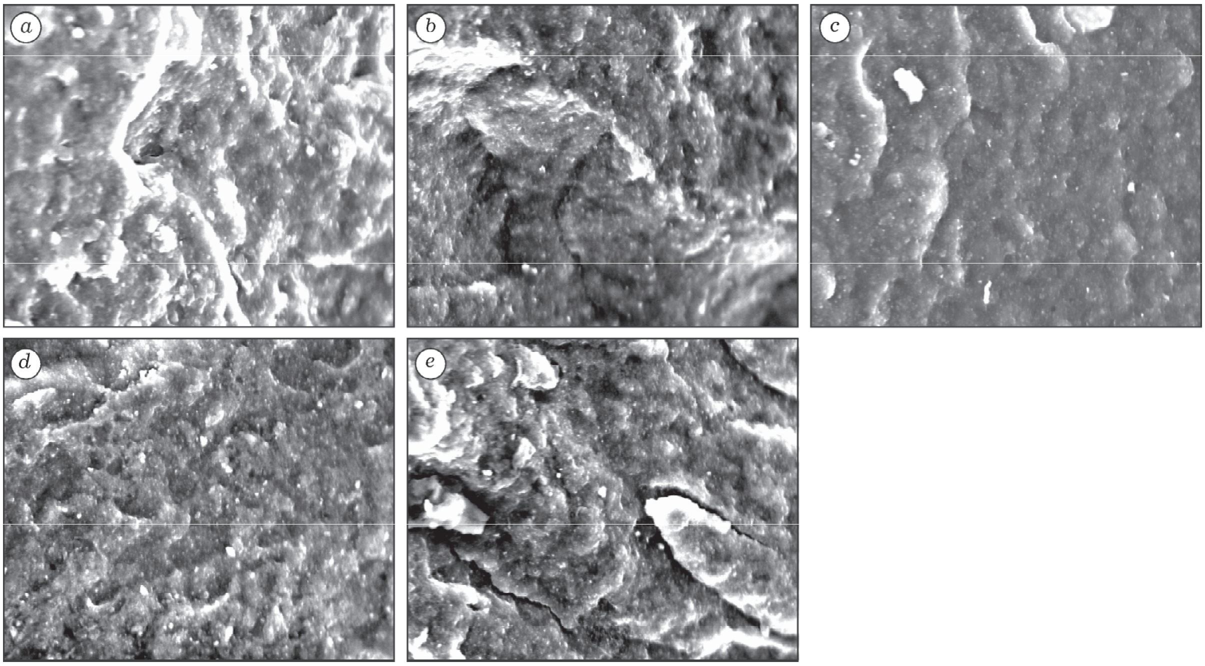

Fig. 1. Structure of rubber samples modified with rubber crumb (crumb content: 40 %): *a* – initial rubber of V-14 grade; *b* – the same + crumb of V-14; *c* – the same + mechanically activated crumb of V-14; *d* – the same + crumb of 51-1481; *e* – the same + mechanically activated crumb of 51-1481. Magn.: 1000.

TABLE 1

Effect of the composition of rubber crumb and mechanical activation on the strength characteristics of rubber V-14

Filler (rubber grade)	Relative elongation, %	Conditional stress at 100 % elongation, MPa	Conditional tensile strength, MPa
Without filler	146	7.4	9.4
Rubber crumb (51-1481)	111/113	5.3/5.6	5.7/6.3
The same, activated	131/137	5.6/5.7	7.1/7.5
Rubber crumb (V-14)	183/202	5.1/5.5	8.8/10.0
The same, activated	188/206	5.2/6.7	8.9/10.1
Rubber crumb (51-3050)	161/189	5.3/5.6	8.2/10.1
The same, activated	186/199	5.5/5.9	9.3/10.1
Rubber crumb from rubber production wastes	142/144	5.7/6.1	7.9/8.6
The same, activated	149/153	5.9/6.5	7.9/9.7

Note. 1. Elastomer matrix is rubber of V-14 grade. 2. The first value stands for rubber crumb content 20 %, the second value for 40 %.

ture of the material obtained by combining the caoutchouc systems having different polarities. The physical and mechanical characteristics of the samples of compositions filled with crumbs of V-14 grade rubber based on butadiene-nitrile caoutchouc BNKS-18 and 51-3050 grade based on butadiene-nitrile caoutchouc VNKS-26 increase or remain at the level of the initial rubber. This is connected with the fact that the matrix and filler have similar compositions (except for the content of nitrile groups).

The results of elemental analysis of the surface of rubber crumb are shown in Fig. 2. It was established that mechanical activation of rubber crumb leads to the appearance of a number of active chemical groups on the crumb

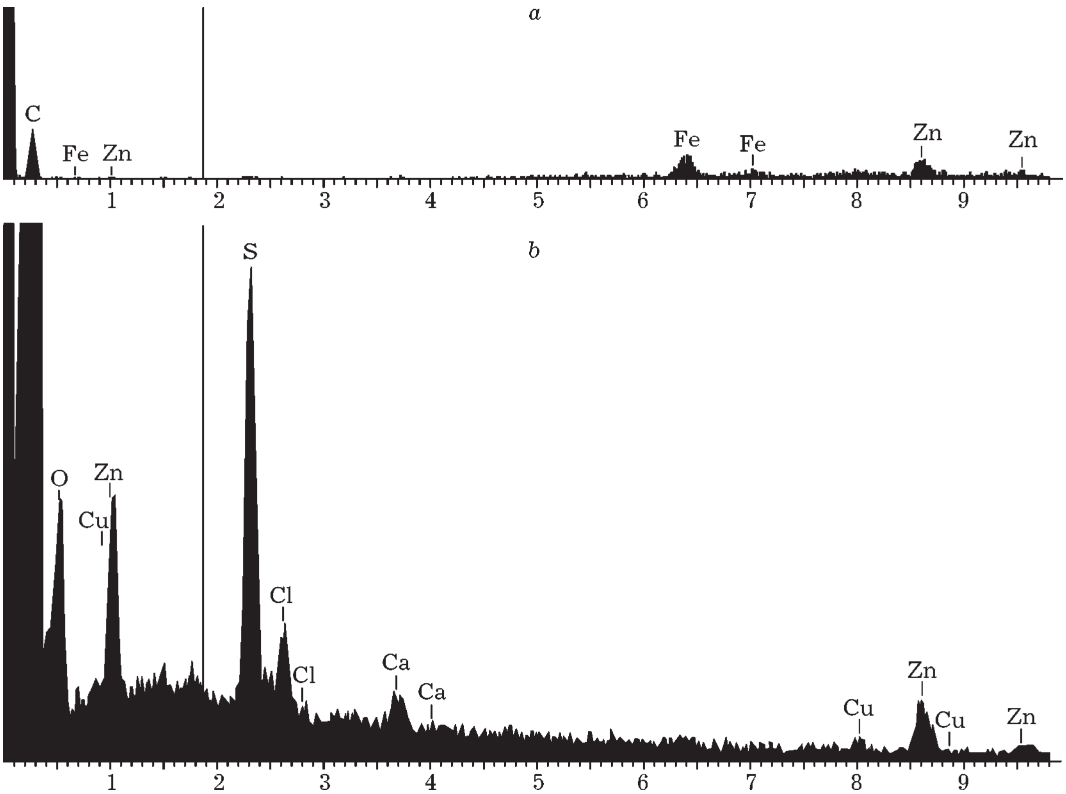

Fig. 2. Distribution of elements on the surface of non-activated (*a*) and mechanically activated (*b*) rubber crumb.

surface. It is especially important that migration of sulphur to the surface of rubber crumb was revealed, which points to the intensification of co-vulcanization processes at the interface between rubber mixture and rubber crumb.

CONCLUSION

Thus, physical and mechanical studies showed that mechanical activation has a positive effect on almost all the strength characteristics of the studied rubber samples filled with rubber crumb of caoutchouc with the composition analogous to the composition of the initial matrix. Mechanical activation leads to the migration of sulphur to the surface of rubber crumb, which promotes co-vulcanization at the interface between rubber mixture and rubber crumb.

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