The Effect of Straining on the Quality Indicators of Vulcanized Rubber Compounds for Rires of Agricultural Machinety

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Abstract: The article presents the results of the analysis of the rubber compound used in the production of tires for heavy agricultural machinery. The research was carried out in order to increase the reliability of the machines and increase the period of their maintenance-free operation in the field. The structure of the elastomeric matrix of vulcanizates was studied before and after straining the rubber mixture using the electron microscopy method. The solidity of vulcanizates and their physical and mechanical characteristics were evaluated on a Zwick/Roell breaking machine in a climate chamber in accordance with GOST. It is noted that the use of an additional technological operation "straining" increases the characteristics of physical and mechanical properties, the solidity of the rubber array and the density of the elastomeric matrix, which positively affects the quality of tires for transport vehicles used in the agro-industrial complex.

1 INTRODUCTION

The development of the agro-industrial complex is one of the priority areas of Russia's economic development. Mutually beneficial cooperation of the subjects of the Russian Federation makes it possible to increase the effectiveness of their activities, ensure the efficient use of resources, and reduce the time required to complete work without violating the optimal deadlines (Kolokolov, Stepanova, Semerkhanova and Mikhal, 2012) The management of a modern enterprise of the agro-industrial complex should cover all aspects of the production of the main types of products (Myalo, Prokopov, Myalo, Soyunov and Demchuk, 2020). The efficiency of agricultural work is largely determined by the conditions of their implementation, in particular, the level of condition of heavy equipment intended for use in the field and the level of its maintenance (Myalo, Solomkin, Prokopov and Soyunov, 2019; Trotsenko, 2019). Machines for agricultural production must meet the criteria of reliability, have high cross-country performance and speed, be easy to maintain and replace individual components. The route of such vehicles is characterized by the conditions of rough terrain, the variety of the path profile, the presence of curved sections and single obstacles on it (Apping, 2001). In this regard, research on the use of modern high-strength and environmentally friendly materials for the creation of various types of tire sizes for agricultural machinery is relevant. Special attention is paid to improving the physical and mechanical characteristics of tires (Chemisenko, From and Breiter, 2016).

Work in the field of improving the quality of tires has been carried out since the production of the first automobile wheel and continues to this day in many areas, and the issues of increasing the walking capacity, increasing the grip of the tire on the road and, as a result, the safety of the vehicle are acute for manufacturers. They can be solved only by improving the design of tires and improving the quality of the ingredients used for their production (Chemisenko, Rogachev and Filenko, 2016).

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The analysis of the reasons for the loss of performance of tires showed that an important aspect of the issue of safety of equipment is the solidity of the tire design, which is achieved with high-quality performance of all technological operations-starting from the procurement of materials and ending with the vulcanization process. One of the frequent problems that arise during the operation of tires is the separation of the tread pattern with a sufficiently good condition of the frame that can last for more than one thousand kilometers, or the stratification of the layers of the frame themselves (Figure 1).

Figure 1: Tire defects.

Defects can be the result of the operation of tires, as well as the result of the conditions for the implementation of the technological process of their manufacture. In particular, the use of dirty carbon black leads to the production of a rubber mixture with traces of foreign inclusions (Figure 2).

Figure 2: Rubber compound with traces of foreign inclusions.

The production of products made of composite materials based on elastomers, characterized by high wear resistance, is possible using a multi-level structural modification (Mashkov, Chemisenko and Maliy, 2018). To increase the uniformity of the raw material composition in the production of treads, an additional technological operation is used – straining, which involves passing the rubber mixture through a filter press (Rauvendaal, 2006). The change in the structure of the polymer matrix and the characteristics of its physical and mechanical properties after straining the raw material composition was the subject of this research.

2 MANUSCRIPT PREPARATION

The research was carried out on the basis of the research laboratories of SKITU (branch) Moscow State Technical University named after K. G. Razumovsky (PKU) and Omsk State Agrarian University.

Objects of research-vulcanizates of an elastomeric matrix from a rubber compound for manufacturing tires of agricultural machinery:

- without straining;
- after straining.

Research methods:

- electron microscopy (JEOL microscope);
- a method for determining the elastic-strength properties under tension according to the indicators: tensile strength, elongation at break, stress at a given elongation (GOST 270-75).

Experimental samples were studied in three-fold analytical repetition. The results were processed using standard methods of mathematical statistics.

3 RESULTS AND DISCUSSION

Vulcanizates of a rubber compound made without straining have large particles of foreign inclusions and voids in the elastomeric matrix (Figure 3).

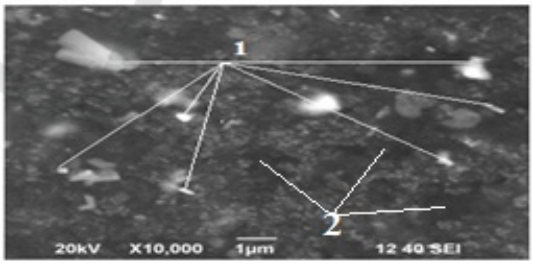

Figure 3: Structure of the vulcanized.

1-foreign inclusions; 2-pores in the matrix.

The looseness of the structure has a negative impact on the walking ability of the tire due to the creation of many stress concentration centers. Under dynamic loads, the area of the stress centers increases, which contributes to the formation of cracks and, as a result, the separation of the tread array. A comparative analysis of the vulcanizate structures using the electron microscopy method showed a change in the pore size in the matrix after straining the rubber mixture (Figure 4).

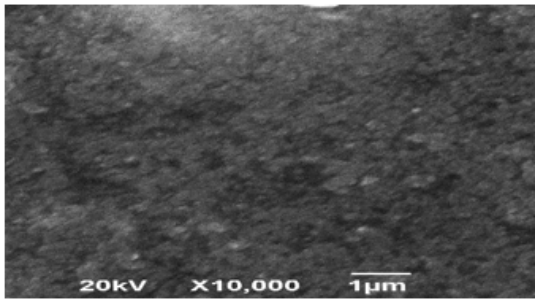

Figure 4: Structure of the vulcanized rubber compound after straining.

Vulcanizates subjected to an additional straining operation had a denser elastomeric matrix. The density of the matrix increased due to a significant reduction in the pore size and mechanical grinding of foreign inclusions during straining of the raw composition when it was passed through the filter press. The use of a filter press in the preparation of a polymer composition for vulcanization allows the rubber mixture to be dispersed to a more homogeneous state than the state of the mixture after the rubber mixing chamber. The increase in the density of the elastomeric matrix visible under an electron microscope causes an increase in its solidity and the solidity of rubber products after straining.

When evaluating the quality of vulcanizates, the characteristics of their physical and mechanical properties are taken into account. The indicators of a number of characteristics obtained in the studies are shown in Table 1.

Table 1. Physical and mechanical characteristics of vulcanizates.

Vulcanizate	Modulus, 300%, MPa	Tensile strength, MPa	Elongation Ɛ, %
Without straining	6.3	.7	1000.2
After straining	8.1	15.6	1113.8
NSR 05	1.4	2.1	-

The use of straining has led to a change in the characteristics of the physical and mechanical properties of vulcanizates. There was a significantly significant increase in the modulus of 300 % by 1.8 MPa, the tensile strength by 2.9 MPa, and the relative elongation by 113.6 % of the prototypes. The increase in the physical and mechanical properties of the rubber compound during straining occurred within the technologically acceptable limits and is evidence of the growth of the monolithic rubber not higher than the quality indicators allowed by the technical conditions for the production of tires for agricultural machinery.

The research was carried out using the equipment of the center for collective use of the Omsk State Agrarian University "Additive Technologies and Materials Processing".

4 CONCLUSIONS

An increase in the density and solidity of vulcanizates after straining the rubber mixture for the production of tires for agricultural machinery was established by electron microscopy.

When straining the rubber mixture under technologically recommended conditions, a significantly significant increase in the characteristics of the physical and mechanical properties of vulcanizates was noted: the modulus of 300% by 1.8 MPa, the tensile strength by 2.9 MPa, and the relative elongation by 113.6 %.

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