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STUDY OF MECHANICAL PROPERTIES OF VULCANISATE BASED ON SRI-3 RUBBER AND BIOPOLYMER

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ABSTRACT

This study investigates the mechanical properties of vulcanizates based on SRI-3 rubber with the addition of a natural biopolymer derived from grape leaves. The aim of the research was to develop composite materials with improved performance characteristics and enhanced environmental safety by utilizing renewable plant-based components. Various curing methods for SKI-3-based rubber compounds modified with the biopolymer were examined, including classical sulfur vulcanization. The results showed that the main vulcanization parameters — such as scorch time, tensile modulus, and total vulcanization time — remain comparable across the studied systems. The use of grape leaf as a modifier demonstrated that the resulting vulcanizates possess very high mechanical properties. The tensile strength reaches 24 MPa, which is 1.5 times higher than that of standard SKI-3-based rubber. The study also revealed that the residual elongation of the developed rubber is only 2%.

KEYWORDS: plastification, polymeric materials, composition,rubber, vulcanization, biopolymer, mechanical properties.

INTRODUCTION

Relevance of the Topic. In recent decades, there has been a steady increase in interest in the development of environmentally friendly and functionally efficient polymer materials. Given the tightening of environmental regulations and the depletion of traditional hydrocarbon resources, the use of renewable raw materials in compositions based on synthetic rubbers has become particularly important. One promising direction in this field is the modification of rubbers with natural plant-based components that possess biological activity and high availability. In particular, grape leaves — an agricultural byproduct — contain natural polysaccharides, phenolic compounds, and other active substances that can influence the structure and properties of the polymer matrix.

The synthetic rubber SKI-3 (stereoregular polyisoprene) offers several advantages, such as structural and mechanical similarity to natural rubber, high strength, and good elasticity. However, its modification with bio-additives remains insufficiently studied. The use of crushed grape leaves as a biopolymer additive can not only affect the vulcanization process but also significantly alter the mechanical properties of the resulting vulcanizate, opening up new opportunities for recycling agricultural waste and creating environmentally friendly materials.

— *The objective of this research is to study the effect of a biopolymer derived from grape leaves on the mechanical properties of SRI-3 rubber vulcanizate and to establish the relationship between structural changes and the strength characteristics of the resulting material.*

METHODOLOGY

The rubber compound was prepared using a laboratory mixer for 12 minutes at a temperature of 130°C during the first stage, without the addition of sulfur. After cooling the mixture to 90°C, sulfur was added to the composition in order to avoid "pre-vulcanization."

IR spectra of films up to 100 µm thick were recorded using a VR spectrometer with NaCl and LiF prisms in the 700 cm^{-1} region. X-ray structural analysis (plate 1.5 × 2.5 mm) was performed using a URS-50 IM setup with ionization detection.

Thermal analysis of the samples (granules 1 × 2 mm) was carried out using a derivatograph system developed by F. Pauli, I. Pauli, and L. Erden, in a platinum crucible within a temperature range of 25–600°C at a heating rate measured in degrees per minute.

DISSERTASION

For conducting the research work, using the formulation from Table 1 as a basis, the compound was prepared on laboratory rollers. The composition was obtained at a temperature of 30–60°C with mixing carried out for 12 minutes.

Table 1: Characterization of the Structure of Polymer Blends in a 1:1 Ratio.

N° п/п	Rubber Compounds Based on SBR	Mooney Viscosity ML_4 at 100°C	Microvolume Index (MKM).
1	SKI-3	90/53	6
2	PVC	50/53	0,5
3	Woodstone	53/50	2

As a result of the conducted work, compositions based on SRN-40 and woodstone were used for the first time.

The resulting compound was vulcanized at a temperature of 150°C for 30 minutes.

The physical and mechanical properties were determined. The obtained data are presented in Table 2.

Table 2: Key Indicators of Vulcanizates Based on SRI-3, PVC, and Woodstone.

Indicator names	Indicators				
	1	**2**	**3**	**4**	**5**
1. Tensile Strength, MPa	20	19	19	19	21
2. Elongation at Break, %	450	350	340	280	340
3. Residual Elongation,%	20.0	16.0	16.0	12.0	12.0
4. Hardness by TM-2, arbitrary unit	75	80	84	85	82
5. Tear Resistance, kN/m	72	68	60	65	74
6. Bond Strength of Rubber-Metal System, MPa	6.0	5.8	6.0	5.5	6.2
7. Brittleness Temperature,℃	-18	-22	-12	-10	-11
8. Abrasion Resistance, m³/KC	66.6	37.3	54.7	75	58.3
9. Mass Change Upon Swelling (20°C, 24 hours), % Isooctane-Toluene Mass (1:1)	14	23.1	22	30	12
10. Thermal Resistance Coefficient (100°C, 48 hours) Kσ	1.04 0.60	0.85 0.70	1.05 0.77	1.03 0.64	0.95 0.64
11. Elasticity %	10	11	10	10	10
12. Ozone Resistance, 25°C, 72 hours, deformation - 20%, O_3 = 0.01% by volume	Не остон.	Не остон	Не остон.	Не остон.	Остонов-в течен27 часов

The composition based on SRI-3 + Woodstone + PVC contained the following ingredients per 100 parts by weight of the composition: technical stearin - 10, thiuram - 1.5, Captax - 0.5, zinc oxide - 5.0, technical carbon P-324 - 50, sulfur - 2.0. The vulcanization conditions were 150°C for 30 minutes.

We studied the swelling of the woodstone polymer. The obtained data are shown in Figure 1.

It was determined that, as a result of vulcanization, spatial networks are formed in the macromolecule of the rubber, which significantly enhance the oil and fuel resistance of the rubber products.

As a result of this work, rubber was obtained that functions as seals and gaskets in aggressive environments.

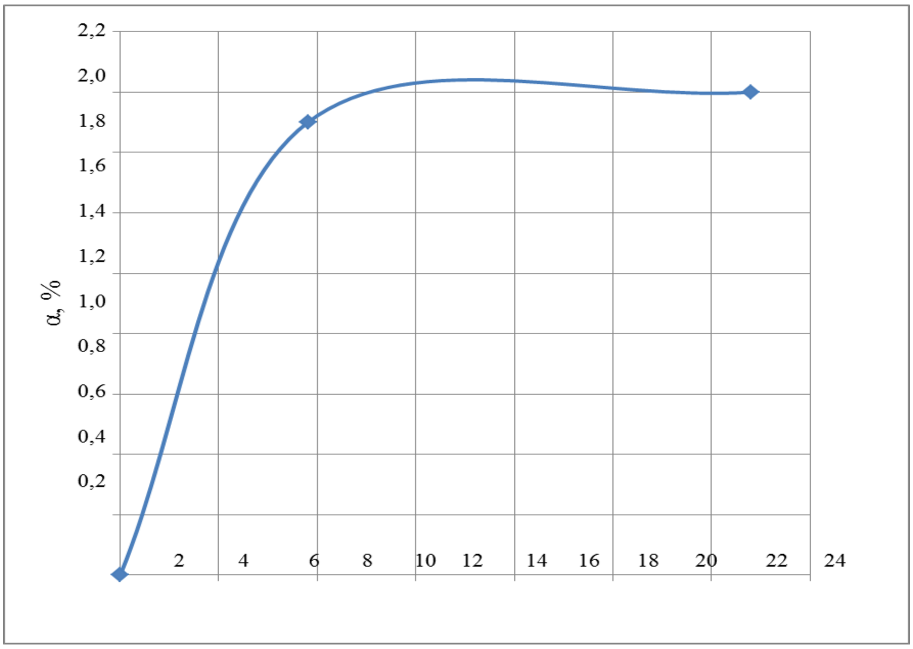


Figure 1: Swelling of the Polymer in Woodstone.

№	Compound code / Components	1	2	3	4	5
1	SRI-3	100	100	100	100	100
2	Woodstone	-	5	7.5	10	12.5
3	Stearic Acid	1.0	1.0	1.0	1.0	1.0
4	Atlax	0.6	0.6	0.6	0.6	0.6
5	NeoZone-D	3.0	3.0	3.0	3.0	3.0
6	ZnO (Zinc Oxide)	5.0	5.0	5.0	5.0	5.0
7	Technical Carbon PN-524	50	50	50	50	50
8	Sulfur	2	2	2	2	2
	Total					

№	Compound code / Indicators	1	2	3	4	5
1	Tensile Strength, MPa	20.7	21.2	22.1	21.8	20.9
2	Conditional Stress at 300%, MPa	2.25	3.6	3.9	3.8	3.2
3	Conditional Stress at 500%, MPa	5.25	5.95	6.1	6.21	5.8
4	Elongation at Break, %	620	630	630	645	650
5	Residual Elongation, %	14.8	14.9	14.8	14.5	14.9
6	Separation Resistance, kN/m	34.8	35.7	36.8	37.1	36.3
7	Hardness by TM-2, Arbitrary Unit	44	44	44.1	45	44.9
8	Rebound Elasticity, %	58.7	58.2	60	60.1	59.9
9	Adhesion to Metals, MPa	3.9	4.0	4.2	4.1	41.8

№					
	Load, kg	11.75	11.75	11.75	11.75
	Temperature, ºC	100	130	150	170
1		0.0624	0.5774	0.2407	0.4376
2		0.2116	0.5774	1.4582	3.3284

To make sure that the modification between the polymer and the biopolymer took place, we determined the ICS analysis of the samples and the data obtained are shown in Tables 2 and 3.

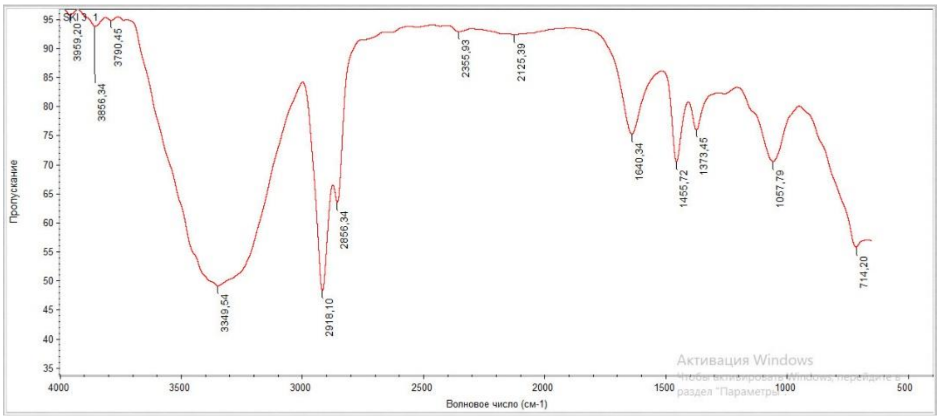
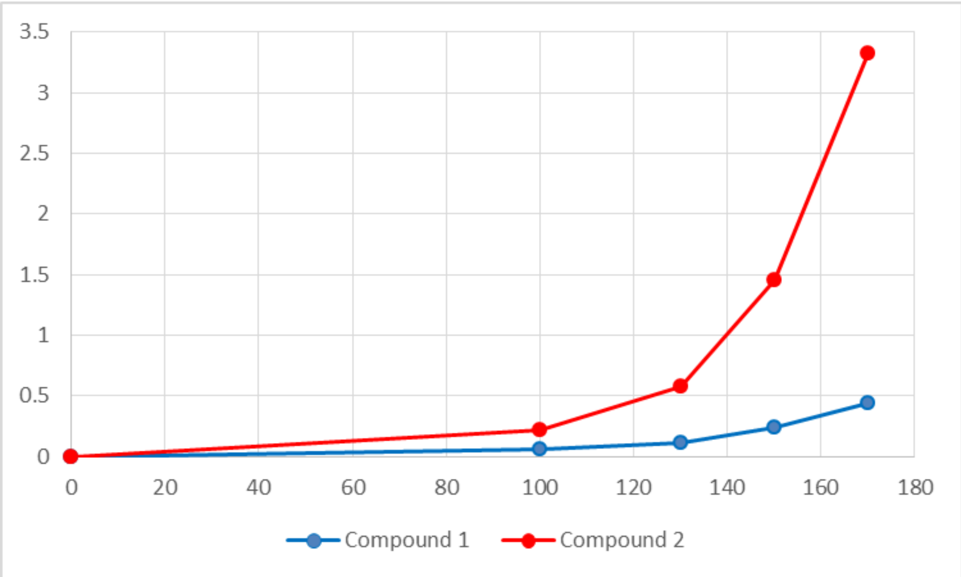


Figure 2: ICS analysis SKI-3.



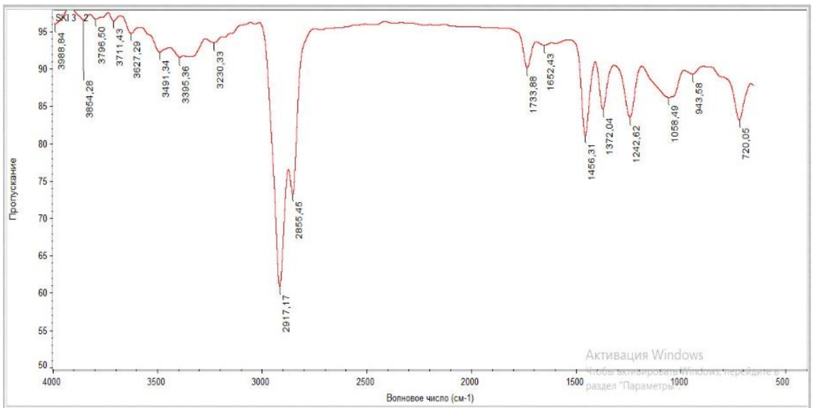


Figura 3: ICS analyzes of SKI-3 and polymer.

CONCLUSION

The addition of biopolymer from grape leaves influenced the spatial structure of the crosslinked network, increasing the density of cross-links and thus improving the strength characteristics of the rubber. Methods for determining the sol-gel fraction of the composition and thermomechanical analysis (TMA) showed that the use of the biopolymer in the composition alters the failure mechanism of the vulcanizates under radiation and mechanical stress. Additionally, the rate constants of strength change, gel-fraction content, and network density were calculated depending on the conditions of exposure. The results indicate that the use of the biopolymer filler contributes to increased degradation time and enhances the radiation and thermal stability of vulcanizates based on SRI-3 rubber. The use of the biopolymer reduces polymer destruction. The vulcanization parameters were determined in our study: time 20 minutes, temperature 155°C. Various amounts of grape leaf were added to the composition, and the optimal amount was selected as 7.5 parts by weight.

As a result of this work, prospects for creating new types of rubber materials with improved physical and mechanical properties are opened, and we recommend using these results on an industrial scale.

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