

Obtaining and Investigation of Compositions with Improved Performance Properties Based on SKI-3 Rubber

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ABSTRACT

Obtaining and investigation of compositions with improved performance properties based on SKI-3 rubber is devoted to obtaining rubber based on SKI-3 grade rubber with improved physical-mechanical properties. For carrying out this work, for modification of SKI-3 rubber, butadiene-nitrile rubber of BNK-18 grade and polymethyl methacrylate (PMMA) were used. At the same time model rubber mixtures based on the optimal formulation were prepared. Based on the study of properties of model rubber mixtures of non-crystallizing special-purpose rubber BNK-18 and crystallizing general-purpose rubber SKI-3 it was established that in the composition of formulations of industrial elastomer compositions it is most expedient to use mechanically activated material in a planetary mill for 3 min. To study the rheological properties of binary systems SKI-3 + BNK-18 compositions were prepared on rolls at a temperature of 140°C during 15 minutes and the obtained single-phase compositions under different loads and temperatures (from 130 to 173°C) had the melt flow indices of this composition determined. Thus as a result the technology of processing rubber mixtures based on SKI-3 + BNK-18 was determined; namely; processing temperature 175°C and pressure 12 MPa. On the basis of SKI-3 + BNK-18 rubber mixtures were prepared and vulcanization parameters were determined; vulcanization time 23 min and temperature 160°C. Study of physical-mechanical properties of vulcanizates showed that the tensile strength of the obtained rubber is 23 MPa, these indicators are 1.6 times greater than the standard.

Keywords: SKI-3 and butadiene-nitrile rubber of BNK-18 grade, modification, vulcanization, melt indices of the composition, tensile strength.

INTRODUCTION

For modification composite of isoprene rubber (SKI-3) many authors on the basis of silicon dioxide was developed and obtained using multifunctional silane, 2-aminoethyl-2-(3triethoxysilylpropyl) aminoethyldisulfide (ATD) as coupling agent [1-7]. Such modification significantly improved dispersion of silicon dioxide in the corresponding composites, which was confirmed by SEM observation. And hardness, tensile strength, stress at certain elongation, tear strength and increase of temperature, as well as value of dynamic loss coefficient in the range from 0°C to 80°C of vulcanized silica/IR composites, significantly improved, especially at low dosage of ATD (2–4 phr) [8-14]. This modification of IR composite based on silicon dioxide using ATD as coupling agent provides simple and effective way of obtaining rubber composites based on silicon dioxide with improved mechanical properties and low hysteresis. Elastomer materials for sealing devices operated in conditions of the Far North, including in the Republic of Sakha (Yakutia), must possess resistance to working media, frost resistance and wear resistance at acceptable physical-mechanical properties. Some of the listed properties are mutually exclusive and not always achievable in materials based on individual rubbers. Thus one of the promising methods of sealing elastomer materials is the use of rubber mixtures [15-19]. In this work model mixtures based on butadiene-nitrile (BNKS-18), butadiene (SKD) and isoprene (SKI-3) rubbers were investigated [20-25]. As component of mixture responsible for resistance to working media butadiene-nitrile rubber was chosen, and as components responsible for frost resistance – diene rubbers (SKD and SKI-3). Addition of SKI-3 also suppresses crystallization of butadiene rubber SKD. Increase of BNKS-18 content increases physical-mechanical properties, wear resistance and resistance to non-polar oils. Also decrease of low-temperature properties and resistance to

polar oils was observed [26-29].

METHOD

In this work on the basis of SKI-3 and BNKS-18AMN formulation of model rubber mixtures was developed. (Table1).

Table 1. Formulation of model rubber compounds based on SKI-3 and BNKS-18

Ingredient	Based on BNKS-18AMN	Based on SKI-3
SKI-3	–	100.0
BNKS-18AMN	100.0	–
Ground sulfur	1.7	1.0
Altax (accelerator)	–	0.6
Zinc oxide	3.0	5.0
Guanidine F	–	3.0
Sulfenamide C	1.0	–
Industrial oil (SMZh)	40.0	40.0

Preparation of model rubber mixtures was carried out according to standard for SKI-3 and for BNKS-18AMN. Samples for comparison were model elastomer compositions filled with industrial filler – low-grade carbon black of N772 grade according to ASTM D1765-03.

SKI-3 Modification with PB and PMMA

The SKI-3 modification with PB and PMMA wires was tested at various temperatures (°C): 1 – 85; 2 – 90; 3 – 95; 4 – 100; 5 – 105. The images obtained are shown in Figures 1 and 2.

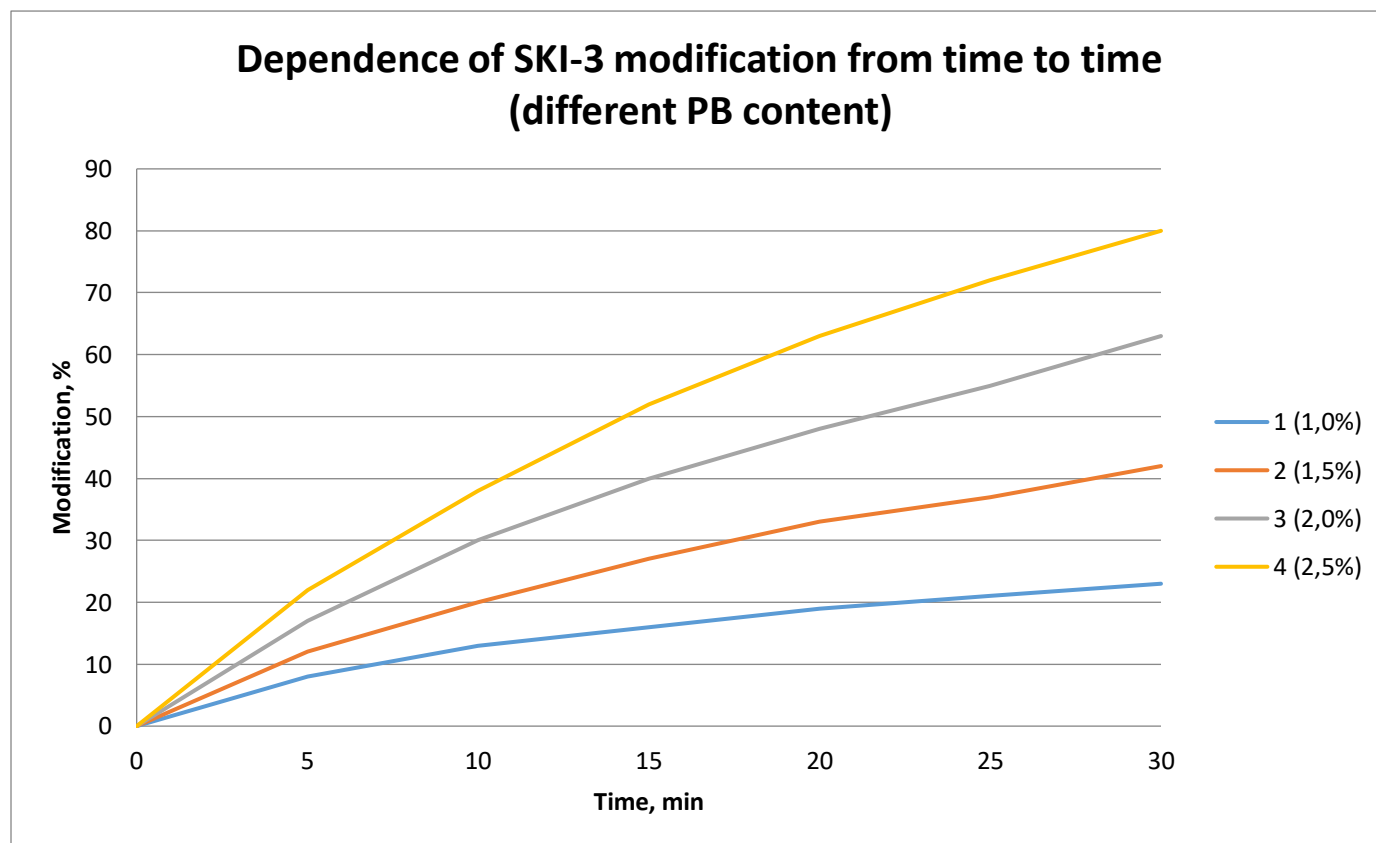


Figure 1.SKI-3 modification versus modification reaction time at various temperatures.

As can be seen, the best results are achieved with a reaction time of 30 minutes and a temperature of 105°C.

SKI-3 conversion versus modification reaction time at various PB contents, % (wt): 1 – 1.0; 2 – 1.5; 3 – 2.0; 4 – 2.5.

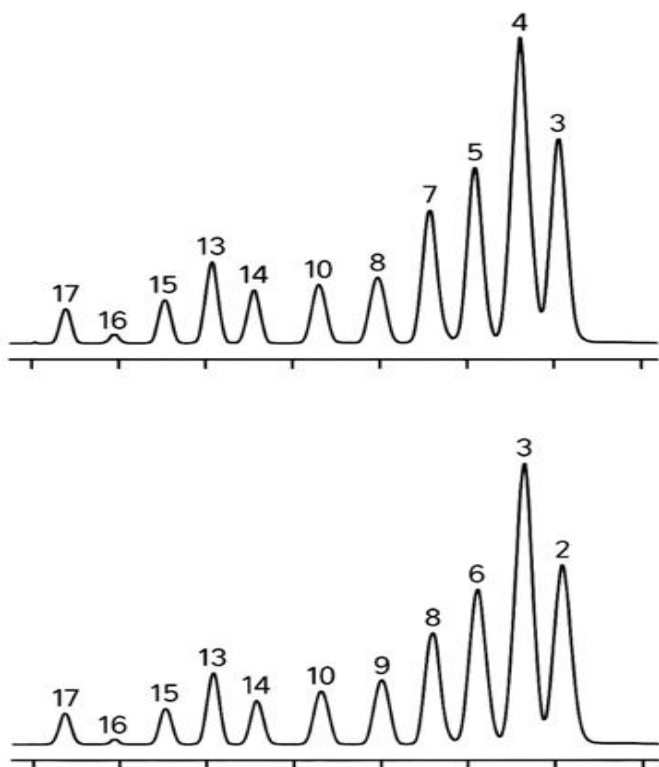


Figure 2. SKI-3 modified with PB.

To confirm the modification, IR spectra of SKI-3 modified with PB (2.5 wt%) were obtained. The data are presented in Figure 3.

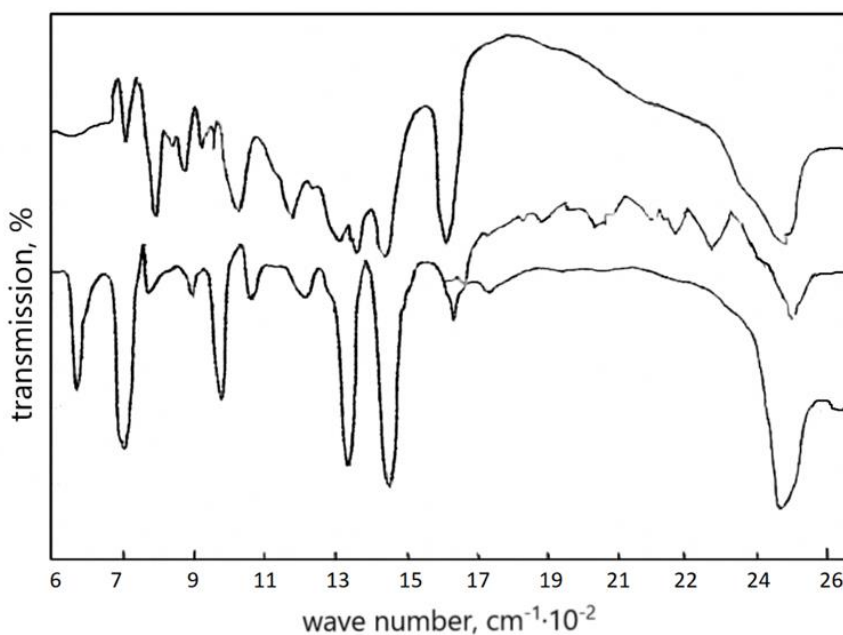


Figure 3. IR spectra of SKI-3 modified with PB (2.5% by weight).

The dependence of the SKI-3 modification rate constant on temperature and PB concentration was subsequently determined (Figures 3, 4, and 5).

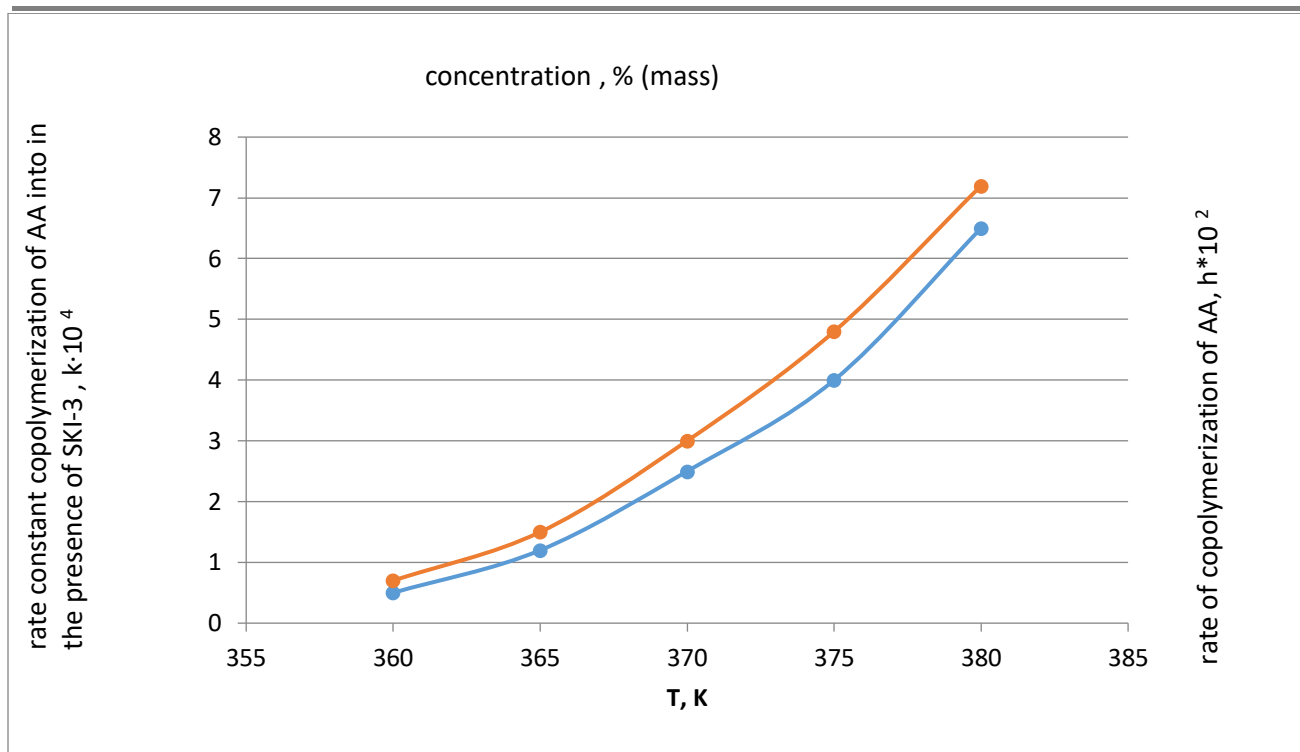


Figure 4. Dependence of the rate constant of modification of SKI-3 on temperature and on the concentration of PB.

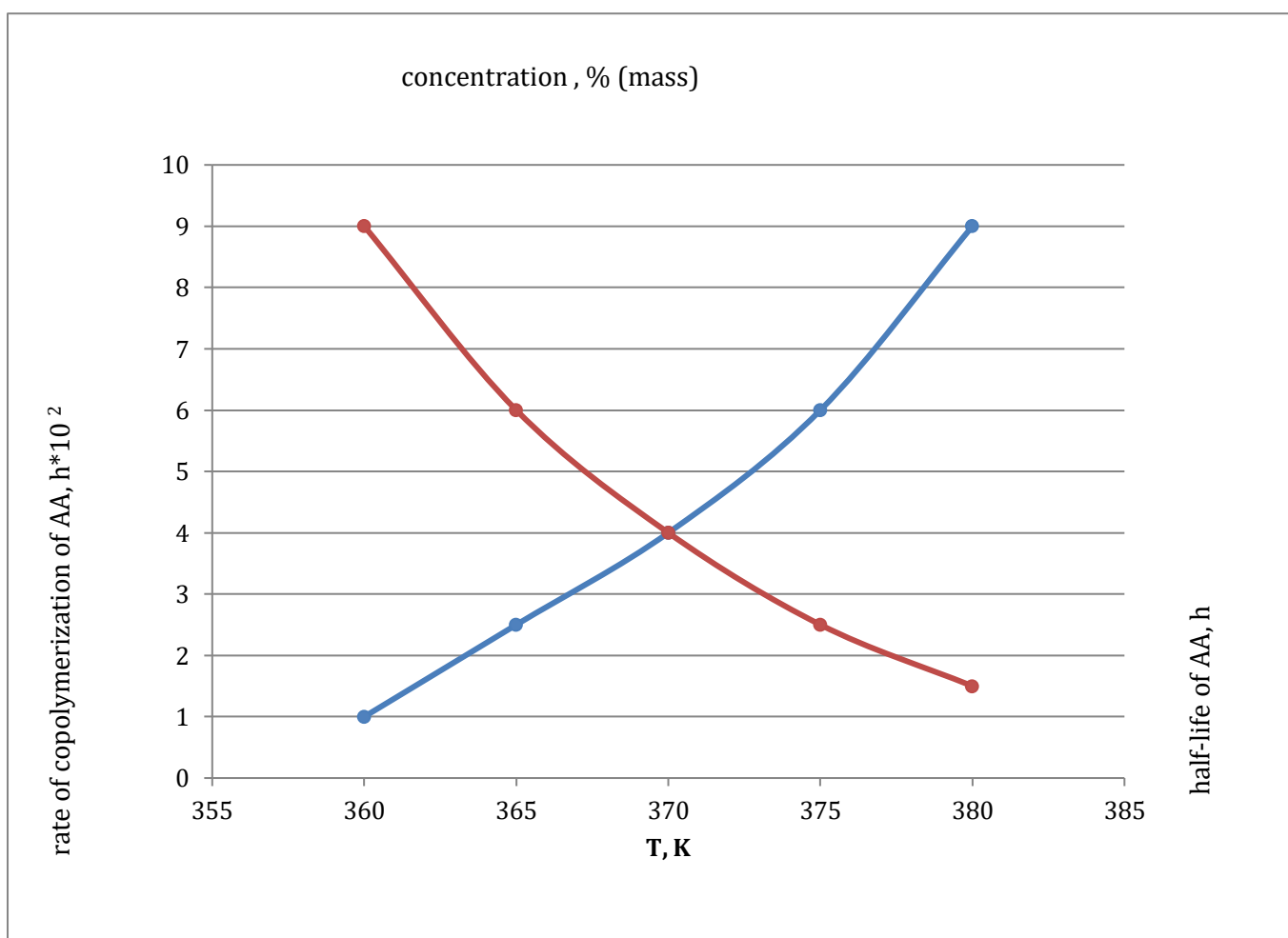


Figure 5. Dependence of the modification rate of SKI-3 on temperature at a PB initiator concentration of 1.5% (mass).

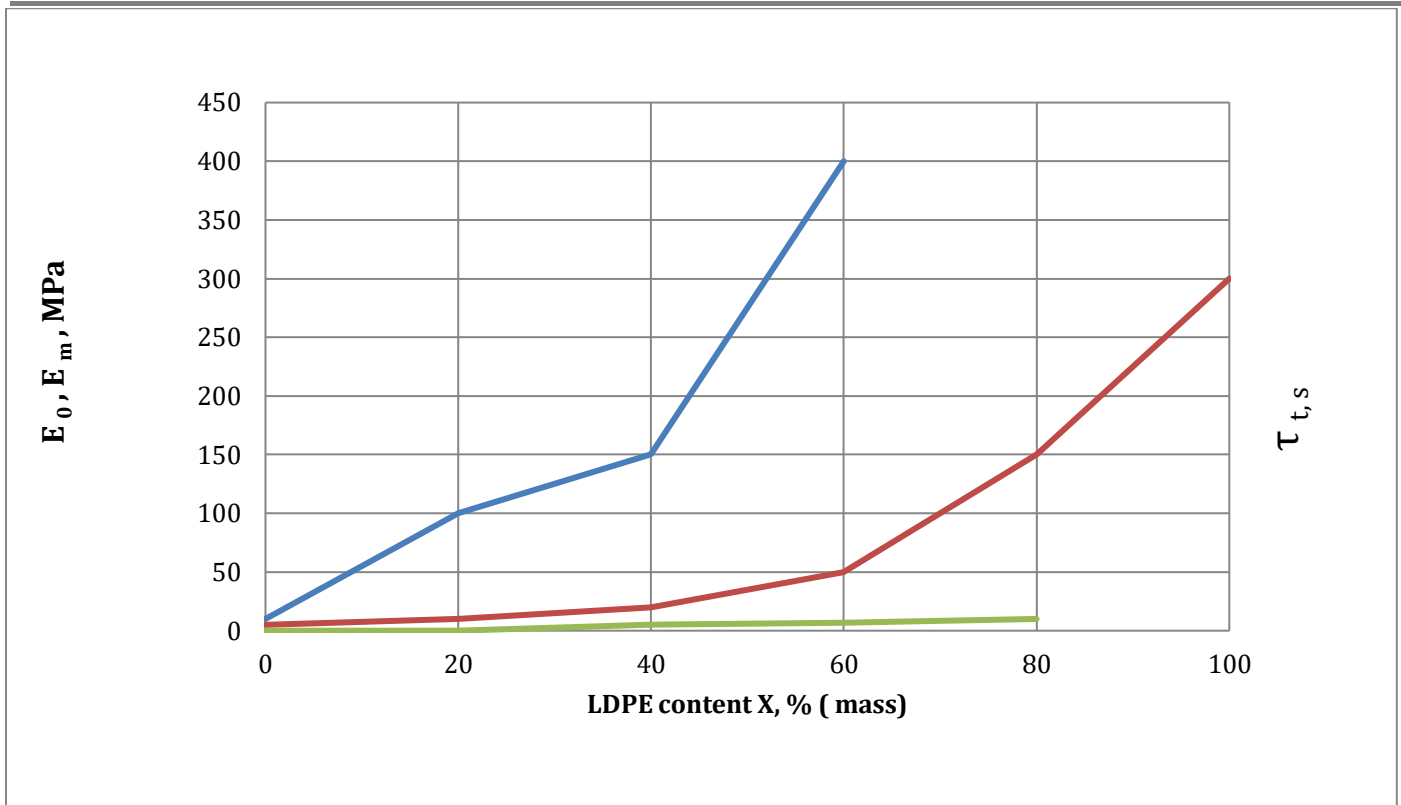


Figure 6. Dependence of E_0 (1), E_m (3) and q_m (2) of SKI-3 modified with PB on the PB content.

A study of the derivatograms of SKI-3 modified with PB (2 and 2.5; 3 and 5.0% by weight) showed that after modification the composition increases its mechanical strength, which is clearly seen in Figure 6.

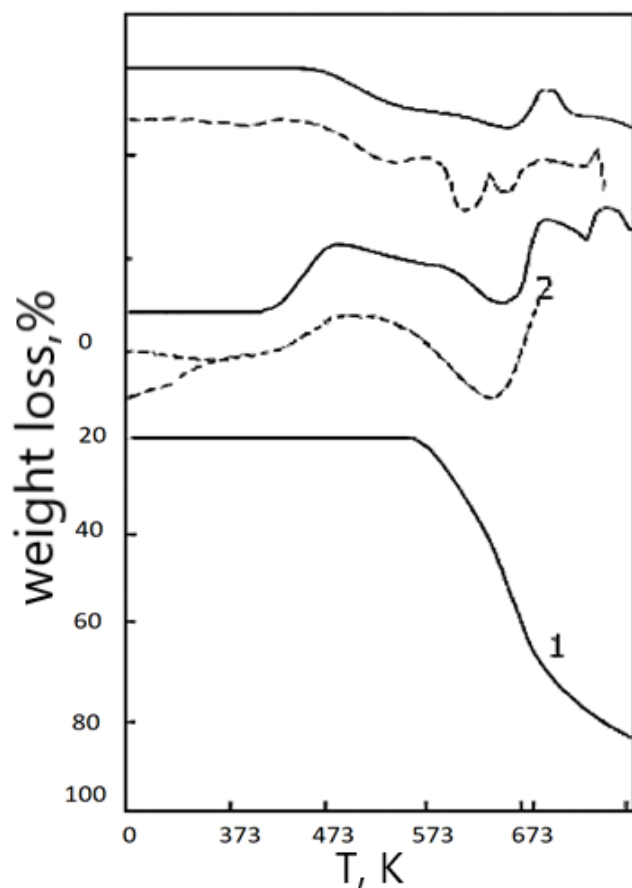


Figure 7. Derivative patterns of SKI-3 modified with PB.

A study of the IR spectra of the original SKI-3 and modified PB (2.5% by weight) showed that the modification provides the best performance at a content of 2–5 parts by weight.

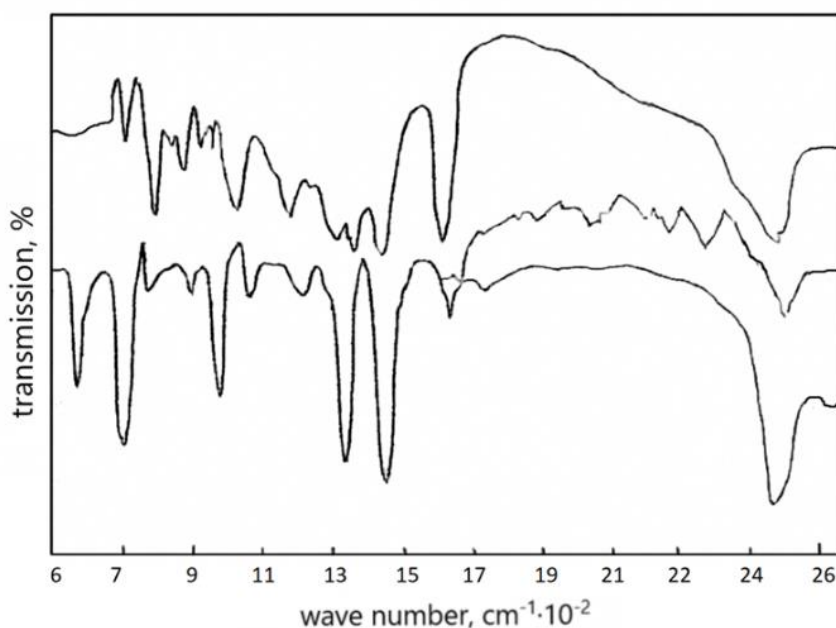


Figure8. IR spectra of the original SKI-3 and modified PB (2–5% by weight) extracted with benzene.

After the production of rubber compounds based on the formulation we selected, the vulcanization process was carried out at a temperature of 158C for 26 minutes and the main parameters of the obtained vulcanizates were determined (Table 2).

Table 2. RESULTS OF EXPERIMENTAL RESEARCH

№	Parameter name	Known value			Proposed values		
		1	2	3	4	5	6
1	Conditional tensile strength, MPa	17,4	16,3	16,7	18,3	19,9	19,8
2	Relative elongation, %	300	320	310	370	395	405
3	Relative residual deformation, %	13	16	10	13	13,6	13,9
4	Tear resistance, kN/m	62	67	69	68,7	69,4	69,1
5	Abrasion, cm³/(L·h)	66	67	62	59	55	56
6	Adhesion to metal, MPa: Steel 3	5,6	5,2	5,1	8,5	9	9,3
7	Adhesion to metal, MPa: Brass	3,1	-	3,4	5,2	6,7	7,5
8	Brittleness temperature, K	266	232	270	244	243	246
9	Stiffness TM-2, conventional unit	85	83	79	81	81	82
10	Swelling at 296 K for 24 h, isooctane–toluene (70:30), %	12,6	14,7	14,2	10,6	10,3	10,2
11	Swelling at 296 K for 24 h, gasoline–benzene (3:1), %	-	-	23,2	14,3	13,6	14,3
12	Aging coefficient after 48 h at 379 K: f_p	0,83	0,89	1,15	0,88	0,89	0,98
13	Aging coefficient after 48 h at 379 K: ε_p	0,77	0,65	0,92	0,8	0,79	0,89
14	Jumping elasticity, %	12	13	17	13,9	15	13,9
15	Ozone resistance for 27 h at 298 K (deformation 20%, ozone concentration 0.015%)	Fails	Fails	Does not fail	Does not fail	Does not fail	Does not fail

RESULTS

1. The effect of grape leaf content on the properties of SKN-3 rubber was studied, showing that at an optimal concentration of 5–10 parts by weight, the modified rubber exhibits higher tensile strength and lower residual elongation.
2. The Mooney viscosity of the rubber compounds increased at grape leaf concentrations of 5 and 6 parts by weight, but decreased at a concentration of 10 parts by weight. Thermogravimetric analysis (TGA) was used to assess thermal stability. SKI-3 modified with grape leaves demonstrated increased thermal stability compared to the control sample.
3. The addition of the modifier significantly increased the adhesive strength of adhesive composites based on SKN-3 isoprene rubber.

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