Creation of elastomer-based compositions with special characteristics for the wheel-engine block of thermal locomotives

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Abstract. In the article, the measures aimed at preventing vibrations generated in the wheel motor unit, one of the main most responsible units of mainline locomotives, are mentioned. There are different types of gears in the wheel motor unit, and the additional vibration is higher in the gear wheels of the assembled form. Because the gears of this assembly form are made of resinotechnical materials. This suspension element is made of V14 rubber technical material. The original purpose of the article is to use synthetic nitrite rubber SKN-18M instead of V14 rubber technical material based on local standards. It was studied that by changing the ingredients in SKN-18M and the sequence of their addition, it is possible to obtain a detail with improved vibration resistance and load bearing capacity. It was found that the amount of carbon-rubber gel and the vulcanization network of the material increased, the vulcanizate swelling level decreased, which is mainly due to the presence of oligomeric components on the surface of carbon particles. It is shown that the inclusion of this raw material in elastomeric compositions based on butadiene nitrile rubber increases the interaction at the "rubber-filler" boundary and the formation of additional bonds between rubber macromolecules and functional groups of the oligomer, and as a result, the overall technological and technical properties of the compositions are improved.

1 Introduction

Today, in the world, special importance is attached to increasing the efficiency of the use of mainline locomotives, increasing the service life of units and parts of wheel-motor units of locomotives. Currently, in developed countries, it is required to increase the service life of the wheel-motor unit of locomotives, to increase the efficiency of locomotives. In this regard, special attention is being paid to scientific research in the direction of, among other things, the justification of technical solutions to reduce the parameters of the traction force fluctuations of the traction transmission of the main locomotive, the mathematical

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justification of the malfunctions that cause vibrations in the wheel-motor unit of the main locomotives [1-3].

Two types of gears are used to connect electric motors and locomotive wheel pairs in the wheel motor unit. That is, the integral gear wheel (Fig. 1) and the assembled gear wheel (Fig. 2) [4-5].

Fig. 1. A toothed wheel of integral construction in the wheel-motor unit of main locomotives

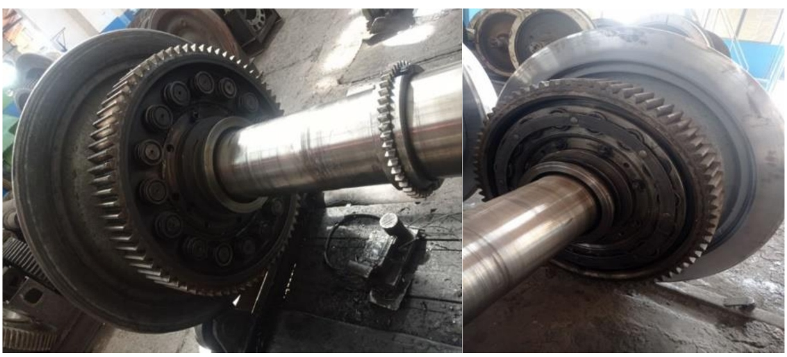
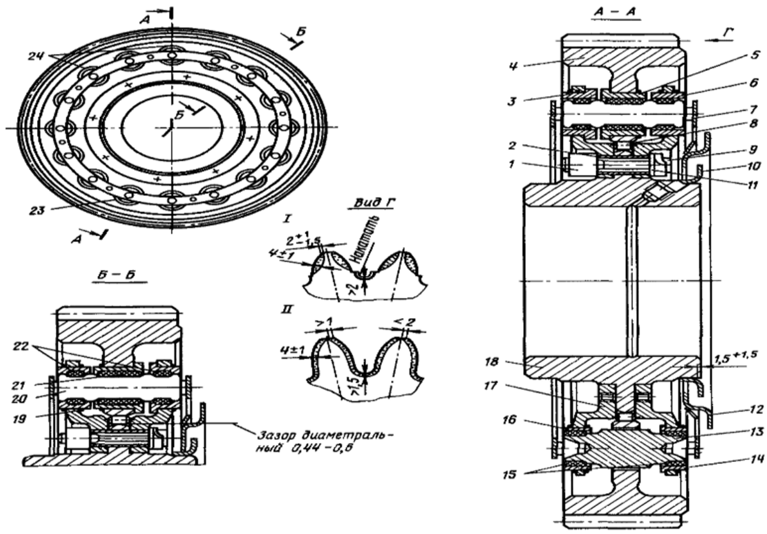


Fig. 2. A toothed wheel of assembled construction in the wheel-motor unit of mainline locomotives

23, 24 spring elements are used to rigidly connect the 18-stupitsa and 4-tooth vanes to each other in gear wheels in the form of assembly (Fig. 3) . These elastic elements consist of rollers and rubber shock absorbers. Rubber shock absorbers are made of oil-gasoline-resistant V14 elastomer composition. The hardness of these shock absorbers is 70-80 us.ed. prepared equally.



1-nut, 2- Prieon bushings, 3, 5, 6, 14, 16- bushings, 4- ring gear, 7- restrictor ring, 8 -roller, 9-bolt, 10-reflective ring, 11-washer, 12- half ring, 13, 20- fingers, 15, 21, 22- shock absorbers, 17-plate; 18- hub, 19-spring collar, 23, 24-spring elements, I-sector hardening of teeth with HDTV, II- contour hardening of teeth.

Fig. 3. Gear wheel

As a result of the subsidence of the rubber part of these elastic elements, cracks are formed. These grooves then cause the wheel motor block to change the distance between the axles of the reducers, the number of gear transmissions (Table 1).

Table 1. The main geometrical parameters of the UZTE16M main locomotive reducer

No	Parameters	Gear	Gear wheel
1	Teeth the number	17	75
2	communication module, mm	10	
3	Ila swelling corner	20^{0}	
4	Correction factor	0.505	0.437
5	The distance between the axes, mm	468.8	
6	Follow up _ the number	4,412	

As a result, it causes additional vibrations in the wheel motor units of mainline locomotives. The additional generated vibrations in turn lead to a decrease in the wheel-rail coupling coefficient of the mainline locomotives and a decrease in the power output from the diesel. Taking into account the above, in this work, the process of grinding of the teeth of the gear wheel of the UZTE16M type main locomotive was studied. The following table lists the geometrical parameters of the UZTE16M main locomotive traction reducer.

In order to reduce the negative impact on the sharp decrease in power of modern mainline locomotives, instead of the V14 rubber material of the spring elements on the gear wheels, it was considered appropriate to reduce its hardness and settling period by preparing spring elements from the special characteristic SKN-18M brand based on localized butadiene-nitrile elastomers.

Therefore, scientific research is being carried out on creating the composition of composite elastomer materials, developing the ingredients to be added to the composition, studying their required properties, determining the structure, and developing the technology of making details based on the created material.

2 Materials and methods

The objects of study are furan oligomers and secondary raw materials for the production of acetylene; as a standard rubber mixture, we used nitrile butadiene rubber [6,7]. The production of rubber mixtures was carried out on laboratory mixing rollers RC-WW 150/330 (Rubicon, Germany). Determination of Mooney viscosity of rubber mixtures was carried out using a Mooney MV 2000 viscometer (Alpha Technologies, England). The relaxation of tension test is performed on the same samples as the Mooney viscosity immediately after the viscosity measurement is completed by stopping the rotor rotation very quickly and measuring the drop in the resulting Mooney viscosity over time. The kinetics of vulcanization of rubber mixtures was determined using an ODR 2000 rheometer (Alpha Technologies, UK). Technological and technical indicators were determined according to the relevant GOSTs: 10201-2015 - rigidity and elastic recovery according to Defoe, 415-2015 - plasticity, 10722-2016 - viscosity according to Mooney (ML 4-373 K), 38.05244-91 - amount of free sulfur, 262 -2013-tear resistance, 263-1973 Shore-A hardness, 270-2015-elastic strength properties in tension, SEV1217-78-residual deformation in compression under conditions of constant deformation, 261-2014-multiple tensile testing of rubber under constant deformation, 2048-2015 - heat generation, residual deformation and fatigue endurance under repeated compression, 6950-2013 - rebound elasticity were determined using a Shoba type device.

3 Results and Discussion

The effects of the amount of ingredients in the mixture and the sequence of their addition to the composition of the composition were studied on the properties of elastomeric compositions. As a result of studies in the standard composition of butadiene-nitrile rubber, the amount and mixing sequence of rubber and ingredients were selected as follows (Table 2), focusing on the uniform distribution of ingredients among the rubber macromolecules.

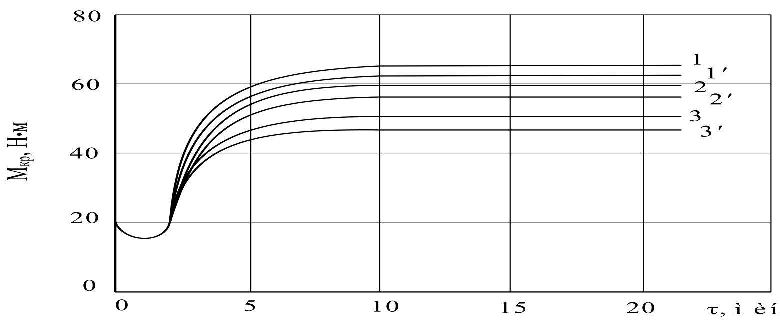
Composite materials with special properties created on the basis of butadiene-nitrile rubber with the addition of local raw materials, rubber engineering products used in machine building and the wheel motor block of main locomotives. However, in order to meet the demand for rubber-technical products, it is necessary to change the production content and technologies, taking into account the physico-chemical and structure of the ingredients based on local raw materials, the essence of the proposed technology.

Table 2. The sequence and amount of mixing rubber and ingredients

Name of rubber and ingredients	Amount of rubber and ingredients, wt.b.	
SKN-18	100.0	100.0
Sulfur	2.0	2.0
Zinc oxide	5.0	5.0
Mercaptobenzthiazole	1.5	1.5
Carbon P 803	20, 40, 60	-
VSPA	-	20, 40, 60
Stearic acid	1.5	1.5
DBF	5, 10, 15	-
FO	-	5, 10, 15

The study of the effect of furan oligomers on the vulcanization kinetics of rubber compounds based on SKN-18M rubber made it possible to determine the increase in the vulcanization rate of cis-1,4-polyisoprene in its thiuram vulcanization system, and the time to achieve optimal vulcanization was reduced. However, the degree of vulcanization has decreased significantly. The use of a sulfur vulcanization system activates the vulcanization process, which was found to be due to the presence of active functional groups (-ON, -COON, etc.) in its composition. The observed effect was confirmed by IKS studies of furan oligomers and thiuram reaction products at high temperature. A sharp decrease in intensity at 1720 cm^{-1} associated with the C=O group of the carboxyl group and a slight decrease in its intensity in the range of 360-300 cm^{-1} (ON group) indicate the formation of furan oligomers. Combined with thiuram, new compounds are formed with the participation of these groups [8,10] .

The kinetics of sulfur binding with rubber macromolecules during vulcanization shows that the formation of vulcanization networks in mixtures with the above-selected vulcanizing ingredients is sufficiently intense (Fig. 4).



100 heavy.b. 5 (1.1 ^{1}) i 15 (3.3 ^{1}) heavy to rubber.b. FO and DBF, temperature 428K.

Fig. 4. Kinetics of vulcanization of rubber mixtures based on SKN-18M rubber

It was found that vulcanizing substances and furan oligomers contribute to the maximum absorption of atoms on various surfaces of fillers, and thereby affect the formation of more durable vulcanization structures. This effect shows that the combination of ingredients and different reactivity in the composition not only activates, but also accelerates the process of vulcanization structure formation (Table 3).

Table 3. Influence of furan oligomers on the formation of vulcanization network of elastomer composition

Elastomers	Ingredient	Planted orchards, %			
		-CS $_x$ -C-	-CSSC-	-CSC-	-CC-
SKN-18M	DBF	32	34	24	10
	FO	30	26	25	19

As can be seen from the table, when furan oligomers are included in the composition , macromolecules are somewhat more active in terms of the rate of sintering during vulcanization, which was shown by the increase in the sintering rate and the decrease in cross-link sulfidity.

As a result of the study of sol-gel fractions of composites, when furan oligomers were added, the intensity of wear and tear processes decreased and the percentage of vulcanization net active chains increased significantly. It was shown that this situation depends on the structure and chemical properties of furan oligomers of selected resin mixtures. The analysis showed that the furan oligomer added to the composition causes additional structuring in the vulcanizate, and as a result, the density of the vulcanization network in the composite increases, and as a result, its hardness increases and the value of its relative length decreases. This allows for purposeful control of the structure and physical-mechanical properties of composites [11 , 15] .

In the research work, furan oligomers 10 wt.b. the composition and technology of obtaining more than one hundred thickening rubber engineering products used in internal combustion engines based on butadiene-nitrile rubbers was created (Table 4). The obtained results showed that it was observed that FO increased the resistance of rubber engineering products to heat, friction and oils by 20-30% compared to currently used rubber engineering products. The reason for this can be considered stabilization of the properties of FO rubber engineering products during operation.

Elastomer composition contains 70 wt.b. SKN-18 and 30 heavy.b. SKI-3 rubbers, at the same time 10 heavy.b. FO was prepared by adding and removing engine pads from it. When studying their dynamic properties, it was found that they improve compared to the currently used rubber engineering products and increase the service life by 40%.

Table 4. Operational properties of rubber shock absorber (rubber compound based on SKN-18M rubber with 10 wt.p. FO added instead of DBF)

Indicators	Rubber damper	
	Standard content	Suggested content
Softness (R) , relative	0.35-0.40 _	0.40
Tensile strength (F_r) , MPa	9 , 0-11.0	12,3 _
Elongation at break (E_{otn}) , %	60-100	80
Crushing (L_{izg}) , %	4-6 _	3
Tensile strength (R_a) , kN/m	4 0-50	5 9
Coefficient of heat resistance (K_t), relative to tensile strength. b.	0.85-0.95	0.98
The coefficient of dissolution (K_i), relative. b.	0.88-0.96	0.96
Oil resistance coefficient (K_m), relative. b.	0.88-0.96	1.0
Tverdost, us.ed.	70-80	78

VSPA) in the production process of acetylene made it possible to obtain rubber engineering products with new indicators and used in complex conditions (Table 5).

Table 5. 40 heavy. Operational properties of molding rubber products with VSPA

Indicators	Rubber damper	
	Standard content	Suggested content
Softness (R) , relative	0.35-0.40 _	0.40
Tensile strength (F_r) , MPa	9 , 0-11.0	12.7 _
Elongation at break (E_{otn}) , %	60-100	74
Crushing (L_{izg}) , %	4-6 _	3
Tensile strength (R_a) , kN/m	4 0-50	61
Coefficient of heat resistance (K_t), relative to tensile strength. b.	0.85-0.95	0.98

The coefficient of dissolution (K_i), relative. b.	0.88-0.96	0.96
Oil resistance coefficient (K_m), relative. b.	0.88-0.96	1.0
Tverdost, us.ed.	70-80	79

As it can be seen from the obtained results, based on the proposed compositions, it was proved that it is possible to obtain rubber-textile, rubber-metal products, which are used in complex conditions in machine building, and their operational properties meet the required standards. The obtained results were based on the production conditions of the results obtained in the third chapter of the dissertation on the effect of 12% oligomer in VSPA on the properties of elastomeric compositions [16,18] .

In the study, the combined effect of ingredients based on local secondary raw materials on the properties of rubber compounds was also studied. As a result, it was found that it is possible to create elastomer compositions for use in special conditions by adding them together, and when they are used together in rubber mixtures, synergism is formed during the vulcanization process, and the properties of the obtained vulcanizates are improved (Table 6).

As a result of the use of the proposed raw materials, the elastomer compositions created for use in machine building and the rubber engineering products used in complex conditions obtained on their basis were obtained on the basis of the created technological conditions without changing the technological equipment used in enterprises. [19,20] .

Table 6. Butadiene-nitrile rubber-based rubber compounds 40 wt.b. VSPA and FO 10 are heavy.b. operational properties of added moldable rubber-technical products

Indicators	**A composition for obtaining a moldable rubber engineering product**			
	According to GOST	**40 heavy.b. Added VSPA**	**10 heavy.b. FO added**	**40 heavy.b. VSPA + 10 heavy.b. FO added together**
Softness (R), relative.	max. 0.2	**0.2**	**0.2**	**0.2**
Density (d), kg/m ^{3}	2400-1700	**2550**	**2550**	**2550**
Tensile strength (F_r) , MPa	22 - 2 5	**2 7.3**	**26.2**	**29,3**
Elongation at break (E_{otn}) , %	20 0 -300	**2 40**	**20 0**	**2 2 0**
F_{izg}, MPa	1 3- 15	**1 5**	**13**	**14**
TIR hardness , relative unit	80 - 90	**80**	**80**	**8 4**
Residue in heat , % K_t K_m	0.2-0.6 min. 0.8	**0.4** **0.9 1**	**0.5** **0.97**	**0.56 _** **0.99**
Consumption by weight , mg/hour	min. 0.9	**0.98**	**0.98**	**0.99**
Acid tolerance	min. 0.7	**0.84**	**0.87**	**0.95**
Alkali resistance	min. 0.75	**0.82**	**0.79**	**0.91**
Resistance to oils	min. 0.60	**0.76**	**0.69**	**0.94**

4 Conclusion

Furan oligomer added to the composition was found to cause additional structuring in the vulcanization process, and as a result, the density and hardness of the vulcanization network in the composite increased and the value of the relative length decreased. The optimal amount of furan oligomers in the composition of rubber mixtures is 10 wt.b. 100 heavy.b. was shown to be equal to rubber.

With the inclusion of the secondary product of acetylene production in the elastomer compositions, it was found that the amount of carbon-rubber gel and the vulcanization network increased, and the level of vulcanizate shrinkage decreased, which was shown to be mainly due to the presence of oligomeric components on the surface of carbon particles. It has been shown that the inclusion of this raw material in the composition of elastomeric compositions based on butadiene nitrile rubber enhances the interaction at the "rubber-filler" boundary and the formation of additional bonds between rubber macromolecules and functional groups of the oligomer, and as a result, the general technological and technical properties of the compositions are improved.

In the study, the combined effect of ingredients based on local secondary raw materials on the properties of rubber compounds was also studied. As a result, it was found that it is possible to create elastomer compositions for use in special conditions by adding them together, and when they are used together in rubber mixtures, synergism is formed in the process of vulcanization, and the properties of the obtained vulcanizates are improved.

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