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Indexes objectively reflecting performance evaluation of technical rubber goods

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Abstract

In order to choose a characteristic index which objectively reflects performance evaluation of technical rubber goods, accelerated thermal-oxidative ageing of rubbers was carried out. It has been demonstrated that as the index accountable for maintaining workability the rate of set at compressing or tension relaxing at pressing of technical rubber goods in a statically deformed state is usually taken. Besides, breaking elongation or tensile strength of technical rubber goods in a free state can be taken as an index, as well. It has been educed that the most sensitive index which reflexes the structural changes in the rubber of the rubber-cord casing (RCC) during the process of ageing is breaking elongation, the value of which is drastically dropping in the initial period of the thermal ageing and monotonously changing thereafter.

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Keywords: rubber; ageing; characteristic index of ageing; rubber-cord casing (RCC); rubber-cord goods (RCG)

1. Introduction

At present the products made out of rubber have been widely applied in various industries. During storage and exploitation of the rubber goods, the processes of ageing occur, which leads to the deterioration of their fundamental physical and mechanical properties and to the decrease of their lifespan. Evaluation of longevity and remaining lifetime of technical rubber goods workability is a current issue in the scientific and industrial practice. Another similar issue is the choice of the main index, which reflects an objective performance evaluation of technical rubber

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goods. It is important to choose an index which will be accountable for characterizing the changes in the structure of rubber since such an index helps to predict the working properties of rubbers during RCG storing and exploiting.

While choosing a characterizing index, it is necessary to consider the functional purpose of the rubber in the product. Such an index must view the rubber as constructional material consisting of separated RCG elements. Also it must be the most sensitive to the ageing process, change monotonously and be the most acceptable for carrying out predictive calculations.

Hence, the following is usually taken as the index, which is accountable for maintaining workability:

- The rate of set during pressing or tension relaxing at technical rubber goods pressing in a statically deformed state;
- Breaking elongation or tensile strength for technical rubber goods in a free state [1].

The critical indexes include:

- The rate of set – 80%;
- Tension relaxing – 0.2;
- Breaking elongation – 50% from the initial values [2].

In this work, we look into the indexes of workability applicable to such absorbing and vibro-isolating technical rubber goods as rubber-cord casings.

2. Theoretic prerequisites for carrying out the work related to rubber-cord casings

To give an objective estimation of RCG workability, the following steps are needed:

- Select control method for the properties of the product material;
- Choose a characteristic of the material (ageing index) which will be the most sensitive to the changes of its properties during degrading; meanwhile, the resource will be defined by limit values of the ageing index, which is defined by the practical application of the product.

The main characteristics which define the working properties of rubber-cord casings (RCC) are tensile strength, modulus of elasticity, hysterisis (mechanical) losses and breaking elongation. Here, we also can include fracture work of rubber at extension.

In carrying out the construction calculations, among the mentioned above indexes the modulus of elasticity is mainly used. In the process of rubber ageing both monotonous elongation of the equilibrium modulus (GOST 11053-75) and conventional stress under tension (GOST 270-75) are observed.

On the one hand, the application of these indexes for predicting the calculations is complicated by the fact that the noticeable changes are not observed for all kinds of rubber during the process of ageing. On the other hand, due to the relational phenomena the unified way of determining the flexibility method does not exist. The same can be said about the indexes of the mechanical losses, which are determined for the rubbers which function under the conditions of dynamic loading. Besides, hysteresis losses are determined practically only for a few kinds of loadings and a range of the test results is usually such that the processing of these results, with the purpose of creating a predicting equation, presents a real problem. Tensile strength also cannot be taken as a characteristic index of the structural changes in rubber since the strength for the most kinds of rubber can alter while ageing relying on various kinetic dependencies. The index, which reflects the simultaneous changes in rubber, conventional stress, tensile strength, and elongation, is fracture work at extension (GOST 23.020-78). The changes in such fracture work at the ageing process are monotonous for all kinds of rubber. However, the use of such index is only possible when there are enough experience data [2].

The most sensible index, which reflects the structural changes in rubber in the ageing process, is breaking elongation, the value of which is drastically dwindling in the initial period of the thermal ageing and continues to change momentously from then on. Breaking elongation, like no other physical and mechanical properties, suites as a characteristic index of bringing rubber coating and sealing layers, the sealing chamber (RCC) to the aged condition [3].

For rubbers of the sealing layer (hermetically sealed cavity) together with the above mentioned indexes, characterizing the ageing process, the gas impermeability coefficient is used, which decreases during rubber ageing process or, in some cases, it remains unchanged.

For RCC sidewalls, if they exist, the typical indexes of rubber ageing are the residual compressive deformation or stress relaxation, it is associated with the control of the necessary seal of the flange coupling and with sealing of article during its given service life. The indexes of the RCG efficiency resource, which are in a statically deformed state, as well as RCC sidewall, were not considered in this paper.

3. Study subject

The study subject was the typical rubber ageing indicators for predicting changes in their properties during storage and exploiting conditions as exemplified by the rubber ageing of the following marks: K-15-1, K-15-2, K-15-3, K-15-4, the compositions of which are given in Table 1. Accelerated oxidative ageing of the experimental samples was conducted in a free state in thermostats VN-5805 with air exchange at temperatures of 50, 70, 90, 100 ^{0}C in accordance with GOST 9.713-86 and ISO 11346.2014 [1,4]. The samples of rubber were produced in accordance with GOST 270-75 (Type I, thickness 2 ± 0.3 mm), before and after the ageing they were tested in accordance with GOST 270-75. The number of samples for each test period was 25.

For a better understanding of the nature change in the rubber properties, in the process of thermal-oxidative ageing for setting up an experiment, the most typical rubbers were chosen for manufacturing such a significant class of rubber products as rubber-cord casings.

The presented rubbers differ in the composition of the polymer part, including the most significant commonly used rubbers, various curative systems (sulfur, sulfur-thiuram, thiuram-sulfur), technical carbon of different activity and structure.

Table 1. Rubber composition, marks: K-15-1, K-15-2, K-15-3, K-15-4.

Ingredients	Rubber, mass. p. per 100 mass. p. content			
	K-15-1	K-15-2	K-15-3	K-15-4
NR	–	–	–	100.0
BSSR-30 ARK	80.0	–	–	–
EPDM-60	20.0	–	–	–
BR	–	50.0	–	–
ISR-3	–	50.0	100.0	–
Ground sulphur	0.2	1.3	2.2	2.0
White zinc WZ	5.0	5.0	5.0	5.0
Vulcanizating accelerator	2.55	1.0	1.0	0.7
Plasticizing and softening agent	10.0	14.0	7.0	10.0
Adhesible additions	3.0	1.5	4.0	1.0
Antiageing agent	1.0	4.0	1.5	1.0
Antiscorcher	0.5	0.9	1.0	0.5
Mineral filler	–	–	5.0	5.0
Technical carbon	50.0	55.0	45.5	55.0
Total:	172.75	182.7	172.2	180.2

NR – natural rubber;

BSSR-30 ARK – butadiene-styrene synthetic rubber;

EPDM-60 - ethylene propylene diene monomer;

BR – butadiene rubber;

ISR – isoprene synthetic rubber.

4. Method of research

The changes in the properties of the rubber during the long-term thermal-oxidative ageing process were assessed by the change of the conventional stress at 300% elongation, nominal tensile strength and the breaking elongation. The results of physical and mechanical testing of the rubbers K-15-1, K-15-2, K-15-3, and K-15-4 after the accelerated thermal-oxidative ageing are shown in Fig. 1-12.

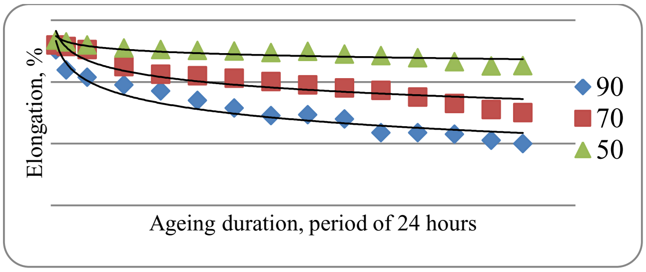

Fig. 1. Breaking elongation of rubber K-15-1 at accelerated thermal-oxidative ageing in air.

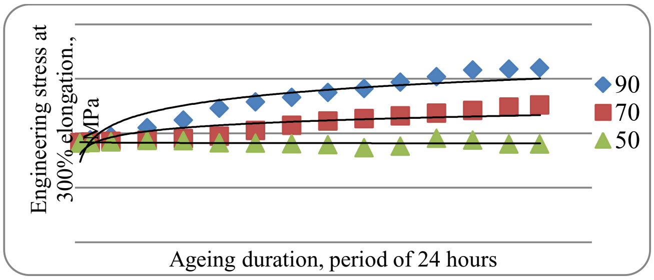

Fig. 2. Engineering stress at 300% elongation of rubber K-15-1 at accelerated thermal-oxidative ageing in air.

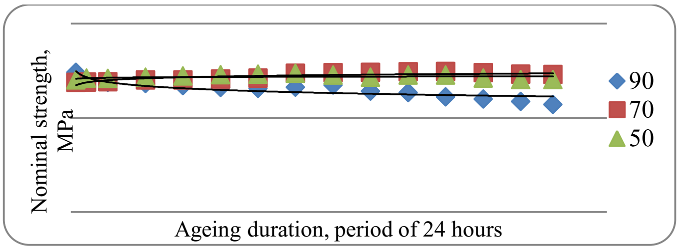

Fig. 3. Nominal tensile strength of rubber K-15-1 at accelerated thermal-oxidative ageing in air.

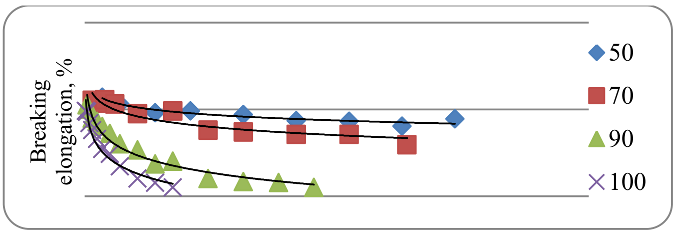

Fig. 4. Breaking elongation of rubber K-15-2 at accelerated thermal-oxidative ageing in air.

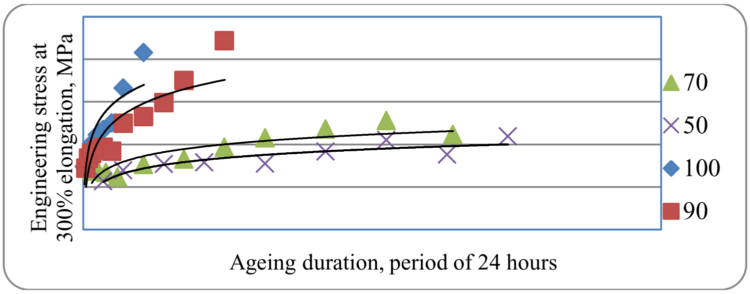

Fig. 5. Engineering stress at 300% elongation of rubber K-15-2 at accelerated thermal-oxidative ageing in air.

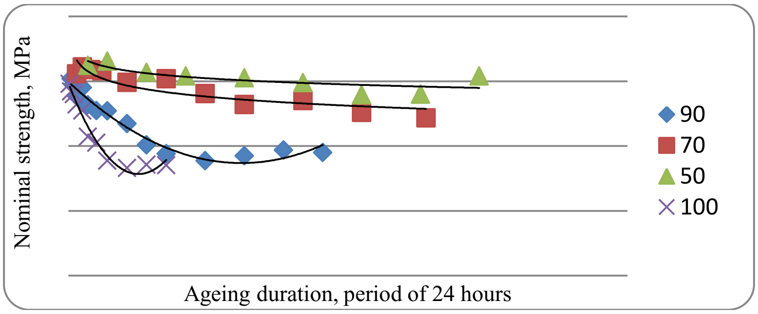

Fig. 6. Nominal strength of rubber K-15-2 at accelerated thermal-oxidative ageing in air.

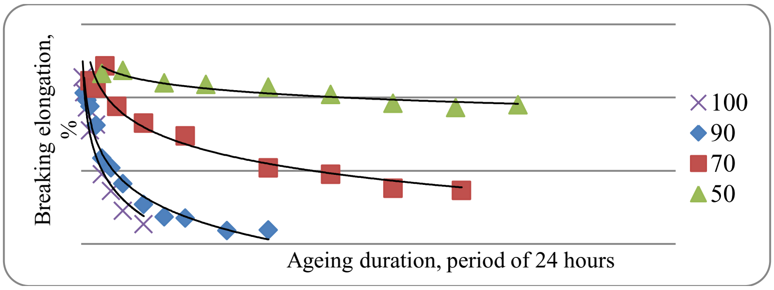

Fig. 7. Breaking elongation of rubber K-15-3 at accelerated thermal-oxidative ageing in air.

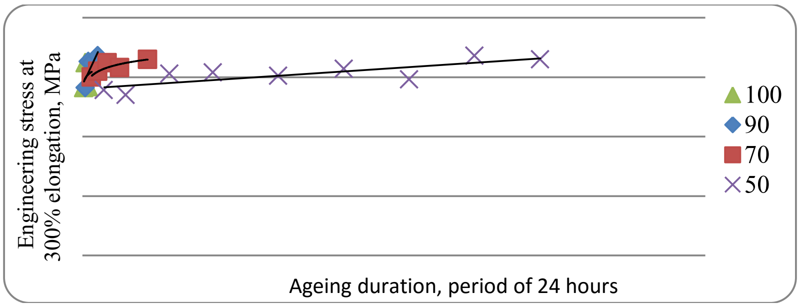

Fig. 8. Engineering stress at 300% elongation of rubber K-15-3 at accelerated thermal-oxidative ageing in air.

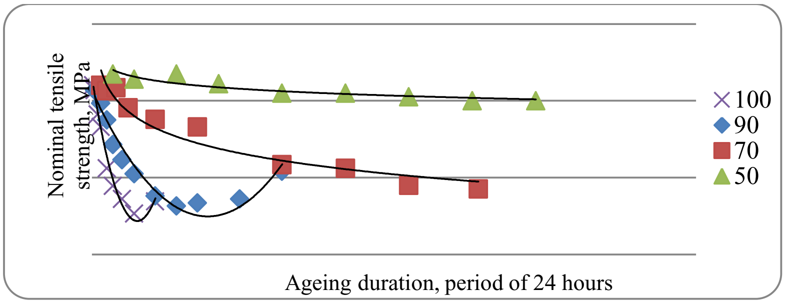

Fig. 9. Nominal strength of rubber K-15-3 at accelerated thermal-oxidative ageing in air.

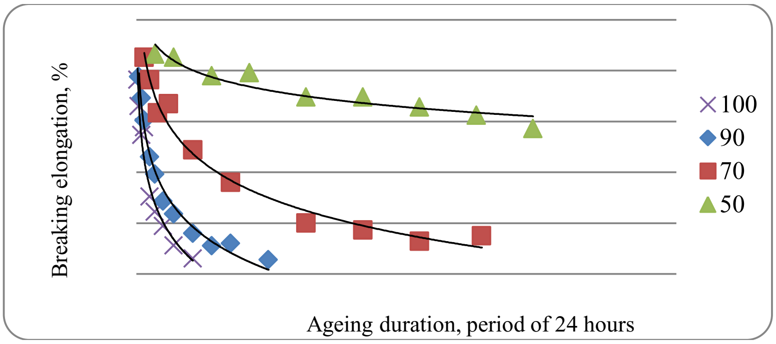

Fig. 10. Breaking elongation of rubber K-15-4 at accelerated thermal-oxidative ageing in air.

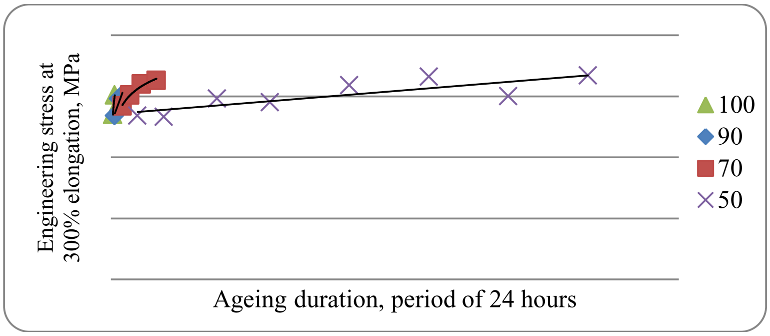

Fig. 11. Engineering stress at 300% elongation of rubber K-15-4 at accelerated thermal-oxidative ageing in air.

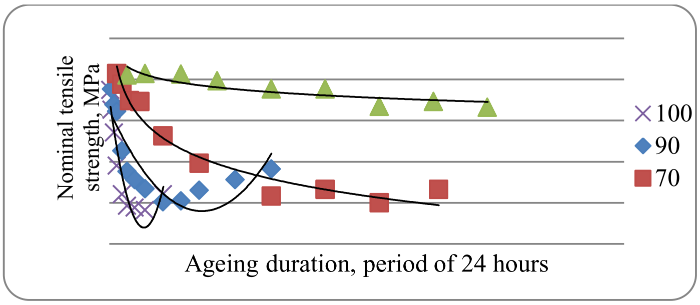

Fig. 12. Nominal strength of rubber K-15-4 at accelerated thermal-oxidative ageing in air.

5. Results and discussion

Fig. 1-12 show that rubber K-15-1 (based on the combination of 80 parts by weight of SBR and 20 parts by weight of EPDM-60) mostly structuralizes during the process of the accelerated thermal-oxidative ageing in air which is proved by an increase of the conventional stress in 300% elongation of rubber. The breaking elongation decreases much faster than the nominal tensile strength.

The other rubbers have the same type of ageing with the same difference that the ageing rate (based on the change in the breaking elongation, and the nominal tensile strength for the same period of time) may differ significantly. The conventional stress at 300% elongation of rubber K-15-1 and K-15-2 has an evident temperature dependence, while for rubbers K-15-3 and K-15-4 the monotonous increase is observed only at 50 °C, at temperatures of 70, 90, 100 °C the index increases without any distinct temperature dependence.

The nominal tensile strength of the tested rubbers decreases (for rubber K-15-1 slowly, for rubber K-15-2 faster, for rubber K-15-3 and K-15-4 very quickly). Moreover, for rubber K-15-1 the decrease shows a monotonous dependence at all tested temperatures, for all the other rubbers the decrease is similar only for the temperatures 50 and 70 °C. However, at 90 and100 °C, after a sharp decrease of the index we can observe the breaking points with an increase subsequently. This is due to the fact that at high temperatures there is a rapid cross-linking of the rubbers and a gel formation, while the rubber destruction is not observed.

Judging by the change of the breaking elongation, this index for all investigated rubbers has a well pronounced monotonic temperature dependence. This index enables us to trace the speed of this index application and the ageing degree.

This index feature for different rubbers allows us considering it as the most typical one while studying the process of rubber ageing and performance evaluation and it is applicable not only for rubber-cord casings, but also for many other technical rubber goods.

6. Conclusion

Based on this research, we can conclude that while choosing a characteristic index, it is necessary for such an index to consider the functional purpose of the rubber in the product as structural material of the IRA individual elements. Such an index must also be the most sensitive to the ageing process, must change monotonously and be the most acceptable for the predictive calculations.

It is also noted that the most typical index of rubber ageing as a component of a rubber-cord casing is the breaking elongation.

For a more detailed study of the rubber ageing process, a search for an instrumental method, which allows studying this process at the molecular level, is currently being carried out.

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