UDC 62-752.2:608.2
DOI: 10.15587/2706-5448.2024.302534

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DETERMINATION OF THE LIMITS OF OPERATIONAL LOADS OF RUBBER SHOCK ABSORBERS DURING COMPRESSION

Determining the limits of operational loads of rubber shock absorbers is an urgent task in the development of methods of non-destructive control of their condition. Therefore, the object of research is the influence of the limit values of the parameters of rubber shock absorbers during their static compression under harsh operating conditions. One of the most problematic issues is cylindrical shock absorbers with a form factor of less than 1.0.

In the work, rubber shock absorbers of different hardness were used, which are model samples for tests of cylindrical shock absorbers with a form factor of 0.42, which were carried out on a laboratory stand. The study of compression process of rubber shock absorbers is an urgent task in modelling the conditions of their operation. The obtained results make it possible to simulate the most effective diagnostic parameter of rubber shock absorbers during compression and to establish its limit and permissible values. It has been established that different rubber hardnesses provide different compression rates, which can be used to study non-destructive testing of shock absorbers, especially under which conditions they can be used in practice. According to the indicators of relative deformation during compression, the use of rubber shock absorbers from the group of high hardness is recommended for more severe load conditions during exploitation. Soft and medium-hard rubbers are characterized by an increased relative deformation of the shock absorber's geometric size (height) during compression, which can lead to their destruction under increased loads.

The obtained results on model samples can be checked on rubber shock absorbers manufactured in industrial conditions. The conducted research allows to create methods of choosing rubber shock absorbers for certain operating conditions depending on the coefficient of its shape. Limits of indicators simulating operating loads for different types of rubber shock absorbers have been established, which can be used when choosing a type of rubber for certain load conditions, and choosing a reinforcing material for the rubber array of the shock absorber and its shape.

Keywords: *rubber shock absorber, vibration insulator, operational loads, static compression, rubber hardness, shock absorber bending.*

Received date: 15.02.2024
Accepted date: 19.04.2024
Published date: 26.04.2024

How to cite
Assin, I., Zybaylo, S. (2024). Determination of the limits of operational loads of rubber shock absorbers during compression. Technology Audit and Production Reserves, 2 (3 (76)), 27–30. doi: https://doi.org/10.15587/2706-5448.2024.302534

1. Introduction

Rubber shock absorbers are used in industry to dampen vibrations from machine vibrations in the mining, metallurgical, and chemical industries [1], which are subject to high operational requirements [2]. For the production of these shock absorbers, shock-absorbing type rubbers [3] are used, which have different physical and mechanical indicators; work in dynamic mode and static load mode [4], the properties of rubber shock absorbers and their service life depend on their values.

Studying the process of increasing the durability of rubber shock absorbers is a necessary task in the operation of bridges and multi-story buildings, since human casualties are possible when it fails [5]. For this type of shock absorbers, resistance to shock loads is critical [6] and the most important factor is dynamic stiffness, which determines the dissipated elastic energy [7]. The characterization of viscoelastic and hyperelastic properties of rubber shock absorbers is of crucial importance, especially for studying the dynamic response of systems where shock absorbers are used [8].

Thus, an experimental study of the dynamic properties of shock-absorbing blocks, which are provided in bridges to soften the effect of impact, showed that the kinematic energy of the block controls the force of the impact and the deformation of the shock-absorbers. Experiments were conducted on three types of shock absorber samples. This made it possible to establish that the hysteresis characteristics of shock absorbers depend on the type of rubber [9].

The form factor, volume, material and shape of the rubber shock absorber are considered as control variables. When three of these factors are held constant, the results of static loading experiments have shown that the larger the form factor, the greater the compressive stiffness under static loading. The volume of the rubber shock absorber had little effect on its compressive stiffness under static loading, which remained largely unchanged. The shape affects the compression efficiency under static loading: the square

ISSN 2664-9969

rubber sample had slightly higher compressive stiffness than the cylindrical sample [6].

In the works of scientists from different countries [6–12], studies of operational loads were carried out for shock absorbers with a form factor greater than 1.0, therefore it is relevant to study and establish the compression conditions of rubber shock absorbers with a smaller form factor.

The aim of this research is to establish the compression patterns of various types of shock absorbers, which will allow to reveal the limits of their operational loads.

2. Materials and Methods

The operational properties of model rubber shock absorbers are investigated in the form of a regular cylinder with a diameter of 32 mm and a height of 37.5 mm (Fig. 1) made of rubber of different hardness (IRP 1346, IRP 1347, IRP 1348 brands), which was determined according to Shore A (ISO 7619-1-2009). Rubber rebound elasticity is determined using a pendulum (DSTU ISO 4462-2019).

For the correct ranking of the investigated rubber shock absorber, its form factor k is determined according to the formula [10]:

$$k = \frac{d}{2h_0}, \tag{1}$$

where d – the sample diameter; h_0 – the initial height of the sample.

The influence of load modes on the test sample is studied at room temperature (20 °C) according to the standard method of the compression process and determination of natural vibrations on FM 250 type HGiN (Veb Thuringer Industrie Werk Rauenstein 1544/28 Germany) with an oil stabilizer of vibrations (Fig. 2).

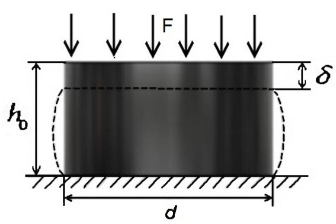

Fig. 1. Shock absorber deflection model

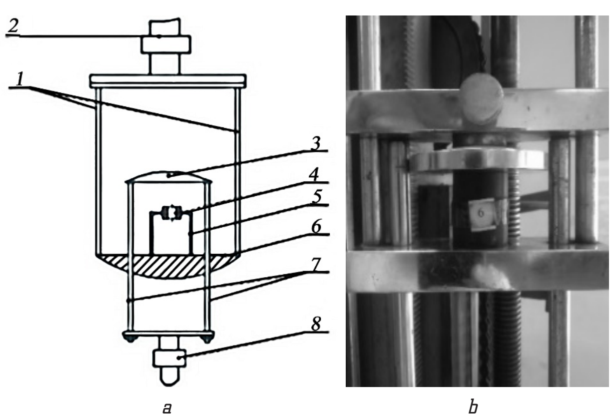

Fig. 2. Shock absorber compression test: *a* – test scheme of a cylindrical compression shock absorber; *b* – photo of the compression test of the experimental shock absorber: 1 – upper clamp, 2 – rod of the upper clamp, 3 – upper platform, 4 – shock absorber, 5 – metal ring, 6 – lower platform, 7 – lower clamp, 8 – rod of the upper clamp

The dimensions of the deflection of the shock absorbers are determined with an electronic caliper with a measurement accuracy of up to 0.01 mm.

In the work, the load is applied and the compression is measured, setting the accepted load at least three times for each experimental shock absorber divided by its area (S_o=803.84 mm^2) [13]. Statistical processing of research results is carried out by the method of regression analysis [14].

3. Results and Discussions

Experimental rubber mixtures are vulcanized according to the recommended vulcanization regimes to obtain optimal physical and mechanical properties. According to the Shor A scale, shock-absorbing rubbers are divided into solid – 70 conventional units, soft – 50 conventional units, and medium hardness – 60 conventional units [15]. The rebound elasticity of the experimental shock absorbers is in the range of 40–42 %.

Taking into account the coefficient k, which for model shock absorbers is less than 1.0 (k=0.42) and their high elasticity, compression tests are performed for the third group of loads in the range of 20–400 N.

According to the measurement data, the static stiffness of the shock absorber is calculated according to the formula:

$$C_{COMP} = \frac{F}{\delta}, \tag{2}$$

where F – compression force (load on the shock absorber); δ – relative compression strain:

$$\delta = h_0 - h_{COMP}, \tag{3}$$

where h_{COMP} – the height of the sample after compression.

The results of the calculations and the dependence of the static stiffness on the load on the shock absorber are shown in Fig. 3.

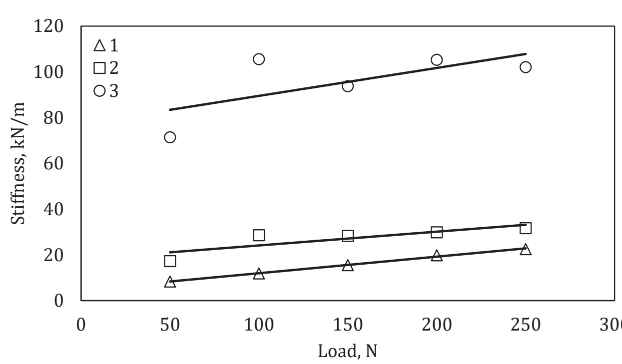

Fig. 3. The effect of load on the static stiffness of rubber shock absorbers: 1 – soft, 2 – medium hardness, 3 – hard

The operational characteristics of the rubber shock absorber are determined by the compression modulus, which is calculated according to the formula [16]:

$$E_F = \frac{\sigma_F}{\varepsilon}, \tag{4}$$

where σ_F – compressive stress; ε – relative deformation of the sample during compression.

Stress and relative deformation of the sample during compression are calculated according to the formulas [12]:

$$\varepsilon = \frac{\delta}{h_0}, \quad (5)$$

$$\sigma_F = \frac{F}{S_o}, \quad (6)$$

where F – load on the sample; S_o – initial cross-sectional area of the sample.

The results of calculations of relative deformation and compression modulus are shown in Fig. 4 and Fig. 5.

Dependencies in Fig. 5 indicate the possibility of using rubber shock absorbers from the group of high hardness for harsher load conditions during exploitation. Soft and medium-hard rubbers are characterized by an increased relative deformation of the shock absorber's geometric size (height) during compression, which can lead to their destruction under increased loads.

The obtained results on model samples can be verified on rubber shock absorbers manufactured in industrial conditions.

The conducted research allows to create methods of choosing rubber shock absorbers for certain operating conditions depending on the coefficient of its shape.

The results of this study can be applied to rubber shock absorbers with Shore A hardness from 50 to 70 units. and maximum compression stress of 0.5 MPa.

This study was carried out during the martial law and aggression of the Russian Federation, which has a decisive impact on the possibility of conducting scientific research and discussing the results.

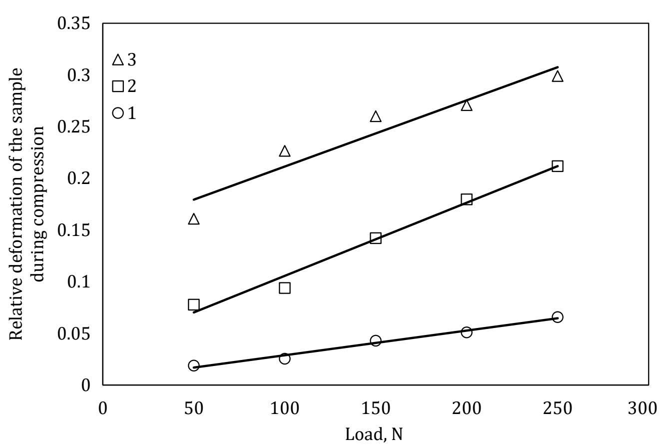

Fig. 4. The effect of load on the relative compression deformation of the rubber sample: 1 – hard, 2 – medium hardness, 3 – soft

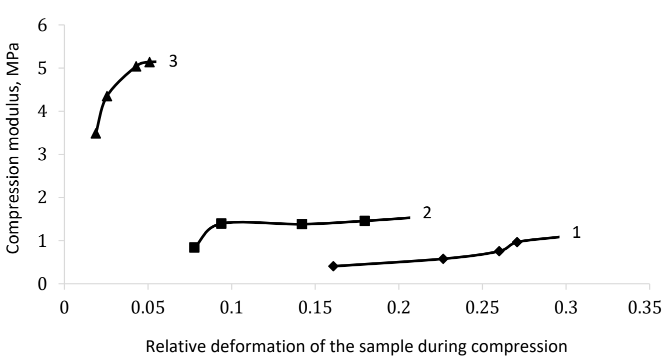

Fig. 5. The influence of relative deformation of model shock absorbers on their compression modulus from rubber: 1 – soft, 2 – medium hardness, 3 – hard

It is advisable to further study the properties of rubber shock absorbers with a form factor of less than 1.0 under the action of dynamic loads.

4. Conclusions

The compression indicators of the rubber shock absorber, determined in the work, make it possible to estimate the maximum level of load on the model rubber shock absorber. At the same time, the decisive influence of the hardness of tires according to Shore A on the deformation of the dimensions of the shock absorber during compression, which is connected with the different density of the spatial grid and the filling of the array of the rubber shock absorber, is determined.

The statistical stiffness of a rubber shock absorber depends not only on its form factor, but also on the hardness of the rubber: for each hardness group, not only the level of statistical stiffness is determined, but also the relative deformation and modulus during their compression.

In order to reduce the deformation during compression of soft and medium hardness rubbers, reinforcement of their array is required parallel to the area of compression, thus it is possible to increase the level of their static stiffness in operating conditions.

The hardness of the rubber mass according to Shore A affects the relative deformation of the shock absorbers during their compression: an increase in hardness leads to its decrease, which significantly affects the operation of the rubber shock absorber.

The compression modulus for hard rubber does not exceed 5.2 MPa, for groups of medium hardness and soft rubber – does not exceed 1.5 MPa.

Conflict of interest

The authors declare that they have no conflict of interest concerning this research, whether financial, personal, authorship or otherwise, that could affect the study and its results presented in this paper.

Financing

The study was performed without financial support.

Data availability

The paper has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating this work.

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ISSN 2664-9969

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