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DETERMINING MECHANICAL PROPERTIES OF A PRESSURE FIRE HOSE THE TYPE OF «T»

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Представлені експериментальні дослідження з визначення механічних властивостей (пружних та дисипативних) напірного пожежного рукава типу «Т» із внутрішнім діаметром 66 мм в умовах статичного навантаження. Експеримент проведено на дослідній установці, яка дає можливість заміру сили та деформації. В ході роботи проведено низку натурних експериментів на розтяг зі зразком в умовах статичних циклів навантаження-розвантаження. Випробування складались з 5 циклів (режими) навантаження-розвантаження, які проводилися із двохвилинним інтервалом. З урахуванням експериментальних даних визначено модуль пружності при розтяганні матеріалу рукава у поздовжньому (вздовж основи) напрямку. Встановлено, що чисельні результати механічних властивостей залежать від «історії» навантаження рукава, тобто на перших двох режимах навантаження модулі пружності збільшувалися і лише потім на наступних – стабілізувалися. Вказане, разом із суттєвим зменшенням залишкових деформацій, посилює пружні властивості матеріалу пожежного рукава.

Результати проведених досліджень показали, що при перших двох циклах матеріал демонструє прояв короткочасної повзучості, яка стабілізується на 4–5 режимі. Для узагальнення експериментальних досліджень результати апроксимовано відповідними лініями трендів. Було визначено криві деформування зразків, що в умовах циклічного навантаження-розвантаження формували петлі гістерезису. Отримані петлі гістерезису в ході дослідження показали, що при перших двох режимах петлі зазнають кількісних та якісних змін, а саме, зменшується нахил петлі гістерезису та її площа.

Встановлено, що зміна властивостей матеріалу пожежного рукава при послідовних циклах деформацій навантаження-розвантаження є зворотною, проміжки між циклами деформування призводять до часткового відновлення механічних характеристик, наближаючи їх до початкових значень. Час релаксації становить від кількох годин до кількох діб і навіть тижнів, що в значній мірі залежить від величини попередньої відносної деформації

Ключові слова: напірний пожежний рукав, модуль пружності, гістерезис, дисипативні властивості

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1. Introduction

The current state of industrial development is characterized by the application and advanced use of composite materials consisting of an elastomer, particularly rubber, matrix and various cord reinforcement. This type of materials is widely used in modern technology, construction, automotive building, apparatuses, and devices. In particular, special hoses and pressure hoses that transport different liquids, gases, steam, pulp, abrasive mixtures and bulk materials as flexible pipelines under high pressure found a wide application. In addition, these composite materials are used in manufacturing pressure fire hoses (PFH), which can consist of several layers of rubber and cord, which in turn are structurally similar to special hoses. In addition, rubber-cord composites are used in manufacturing automotive and aviation tires. Thus, composite materials affect the characteristics of reliability of machines, their functional characteristics and operation safety.

Pressure fire hoses, together with other fire equipment in the departments of Emergency and Rescue units (ERU), is one of the main types of fire equipment (FE) and success of fire extinguishing depends on their proper functioning [1, 2]. Fire extinguishing is a complex process which is accompanied by pollution of the atmosphere [3] from incomplete combustion products, long-term adverse effects of high temperature, destruction of building structures, etc., in the event of complicated fires such as landscape fires [4] or in hazardous sites, such as the sites of oil and gas industries [5], the ERU use a large quantity of fire equipment and machinery. However, successful work of the ERU in fire extinguishing depends not only on the time of concentration of forces and facilities in the place of the call [6], but also on the indicators of faultless operation of fire equipment [7]. The process of fatigue accumulation goes on in the PFH during its operation, which can lead to their fault.

Reliable and safe use of the PFH is determined by keeping to regulatory requirements for their operation and maintenance, among which the prominent place is occupied by hydraulic tests for tightness at excessive pressure. Tests of fire hoses are carried out during scheduled inspections not less than once a year, as well as after repairs. This test method determines only the integrity and tightness of pressure fire hoses and is aimed at simplified assessment of the product reliability.

However, the fault (damage) of the pressure fire hoses increases the time of fire suppression, which in turn can lead to significant losses, and, sometimes, to catastrophic consequences.

Thus, the measures aimed at obtaining a comprehensive characteristic of the reliability of fire hose materials and the means of their reliable testing are an important scientific and practical task.

2. Literature review and problem statement

Fire hoses as one of the important types of fire equipment are the focus of a large number of scientific works, which in turn mostly boil down to the calculation of pressure consumption in hydraulic networks. In papers [8, 9], the experimental data on hydraulic resistance of pressure fire hoses during the water flow in the middle of the hose were obtained. Pressure losses were determined and it was found that when adding gel to water, hydraulic resistance decreases. The task of the research did not include determining the reliability of PFH during its operation.

Papers [10, 11] show the results of theoretical and experimental research into the strength of the power frame (weave cover) of pressure fire hoses. It was found that the power frame completely accepts the forces, caused by the existence of hydraulic internal pressure of a fluid inside a hose. The authors developed the procedure of rational designing the PFH, determined the appropriate parameters of the woven bearing membrane. The examined works are of fundamental importance for the improvement of the PFH structures and their production technologies. However, the problem of estimation of the PFH reliability in case of defects in operation was not explored.

The structure of pressure fire hoses is very similar to the structures of some rubber hoses and pressure hoses used as flexible pipelines for connection and compensation of reciprocal displacements of the elements of various types of machines. Therefore, it is advisable to expand the literary search in terms of reliability of structural elements of these pressure hoses.

The failure of pressure hoses is a typical phenomenon in engineering. The analysis of hose failures was presented in [12]. It was established that about 30 % of all failures in machines are caused by the damage to pressure hoses. The most common types of failure include the damage to the hose surface [13, 14] and its lamination [15, 16]. The causes of failure are power overload, fatigue accumulation as a consequence of the cyclic action of the load [15, 17, 18] and the damage that was formed due to the aging and degradation of the properties of material [19, 20]. This in turn should be taken into consideration when studying the reliability indicators of the design of rubber-like materials [21]. It was determined that an increase in braid layers leads to the growth of stiffening of the hose structure, which in turn reduces the hose elasticity during bending, and the discontinuous pressure at the same time increases insignificantly. In these works, the causes of failures of hoses were determined and analyzed in detail, but the factors leading to these failures and their impact on the reliability of the hoses in operation were not studied.

Papers [12, 13] present the results of analysis of the choice of the method of non-destructive control. Accordingly, a method for diagnosis was chosen for each work. Article [12] considers the acoustic method for testing, which determined the pattern of changing the parameters of the technical state of hoses. The purpose of this research was to solve the problem of detection of a hidden defect and prediction of sudden failures of hoses on special machines. Accordingly, the periodic control of the technical state of hoses was proposed. Paper [13] proposed a modern diagnostic method, which consists in the use of industrial tomography (Zeiss Metrotom 1500). This paper was directed to the analysis and description of the destructive process of the rubber surface of hoses. Modern methods of testing were proposed in these studies, but their cost and labor intensity under actual conditions at present are problematic.

Articles [14, 15] considered the cyclic deformation of brake hoses, the studies show that there is a relatively weak inter-layer strength, and as a consequence of the action of appropriate loads, there appear internal initial cracks that gradually reach the external rubber layer resulting in a final rupture. In papers [17, 18], studies of cyclic deformation of composite materials used for the production of pressure hoses were conducted. It was experimentally determined that experimental samples are self-heated during cyclic deformation, which leads to a decrease in the operation resource. Article [18] studied the changes in cyclic deformations during air temperature drops (from –20 °C to 40 °C). It was determined that at reduced air temperature below zero, the level of stresses in the material significantly increased. In [16], visual and microscopic defects were examined, it was determined that due to mixing of different types of rubber in the material of the hose, there appear defects because of the insufficient mechanical connection of the individual components. Studies [19, 20] report results of the degradation of physical properties of different elastomers, which are used for manufacturing pressure hoses. The results, which are presented in article [19], are aimed at studying the comparative degradation of physical properties of the material of the hose under the influence of palm biodiesel. Experimental research was carried out by dipping the hose into certain types of diesel fuel and its keeping for thousands of hours. Changes of properties were recorded every 250 hours. Paper [20] presented the results of studying a high-pressure hose that collapsed in the course of operation due to the rupture. To study the hose, optical microscopy was applied, which found that reinforcing layers (weaving) degraded and turned into glass-like materials, which further led to a rupture. In these studies, the causes of failure of hoses were determined and analyzed in detail, but the impact of these factors on the reliability of hoses in operation was not explored.

The analytical models and methods for calculation of pressure hoses (rubber-cord hoses), based on the introduction of some assumptions and simplifications, are used in papers [21–23]. Practical application of these methods is not advisable, since the design and geometric features of the structural elements of pressure hoses were not taken into consideration in the papers.

Studies [14, 16, 24–30] examined the methods based on the use of the method of finite elements. Papers [24, 25] explored the issues of reliability of brake hoses. It was found that during the operation of the anterior brake system of a vehicle, vertical and horizontal deformations [25] and torsion deformation [24] occur in brake hoses during the turn. It was established in [24] that the use of the fabric layers in braiding will enhance the reliability of the product by homogenizing the material of a hose. The detailed model of geometry of the fabric layer in braiding is considered. The studies of hose twisting revealed that the maximum twisting angle of the hose was 180°. The model showed a significant deviation from the experimental research, so the work needs further research. Paper [25] is a continuation of paper [24] and the issues of vertical and horizontal deformation are discussed in more detail. Using the finite element method, cyclic tensions occurring during these deformations were simulated. These works [26–30] consider the problems of reliability of fastening in the joints of pressure hoses. Paper [26] presents the results of analysis of failure of high-pressure hoses. It was determined that one of the factors of failure of hoses is external damage, which was formed under the influence of sharp metallic bushings. Using the finite element method, the distribution and concentration of stresses on the hose surface were analyzed. Articles [27, 28] focus on the study of the destructive process in places of connecting fitting. It has been determined that microdefects (cracks) [27] occur on the outer surface of rubber during pressing, in addition, there is a different cross-section geometry on the outer edges in some samples, which in turn contributes to the formation of concentration of stresses. In studies [28–30], it was found that during pressing of connecting fittings, there occur tensions that deform not only the high-pressure hoses [29, 30], but also the nipple itself [28].

Thus, the method of finite elements is one of the modern and promising methods for studying the parameters of both finished products and materials used in manufacturing rubber hoses and pressure hoses. It should be noted that the papers on the simulation of pressure fire hoses using the methods of finite elements were not found. This is due to both significant non-linearity of the corresponding mathematical models, and the existence of orthotropy of mechanical characteristics and heterogeneity of the structure of pressure hoses. Given that during operation, fire hoses are subjected to various types of loading, which directly change their mechanical properties, the process of modeling is much more complicated.

As a result of reviewing the literary sources [8–30], it was found that the mechanical properties of hoses, specifically, elasticity modules and dissipation coefficients at different strains were not studied by other authors. The absence of such data is explained by the fact that this problem was not related to the research topics of the corresponding authors. It made it possible to state the problems of theoretical research in the estimation of the PFH operation reliability. For greater reliability, it is necessary to carry out a complex of tests to determine the mechanical characteristics, specifically, elastic and dissipative properties of pressure fire hoses of type «T» with the inner diameter of 66 mm.

3. The aim and objectives of the study

The aim of this study is to determine the elastic and dissipative properties of pressure fire hoses under conditions of static loading-unloading cycles for the following calculations of fire hoses reliability.

To achieve the aim, the following tasks were set:

– to conduct experimental studies on determining elastic properties of pressure fire hoses;

– to conduct experimental studies on determining dissipative properties of pressure fire hoses.

4. Methods of experimental research on determining elastic and dissipative properties of pressure fire hose of type «T»

The work involved conducting a series of field experiments on stretching the samples of new pressure fire hoses of type «T» with the inner diameter of 66 mm under conditions of static loading-unloading cycles and statistical treatment of results.

Pressure fire hoses (PFH) are made in accordance with DSTU 3810-98, their structure consists of a power frame (weaving cover) (3), the inner elastic waterproof layer (1) (Fig. 1). In some cases, the power frame is impregnated with external elastic coating (4), which serves to protect it from abrasive wear and active substances.

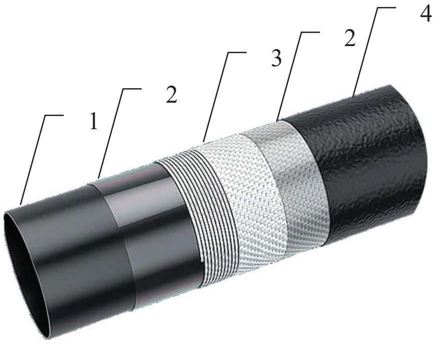

Fig. 1. Structure of a pressure fire hose:
1 – sealing layer; 2 – adhesive layer; 3 – power frame;
4 – protective coating

The experimental sample was separated from the fire hose of type «T» with the inner diameter of 66 mm produced by TOV MIK according to DSTU 3810-98 cert. UA 1.182.066877-13. The fragments of the material of hoses had the actual total length of the sample of 100 mm and the working area of the length l=78 mm (Fig. 2), the width of 100 mm and the thickness of 1.6 mm.

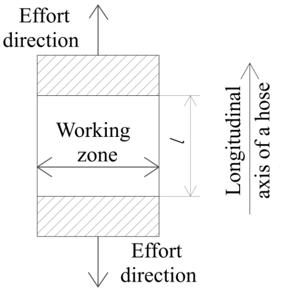

Fig. 2. Test sample of a fire hose

To carry out the appropriate work, the experimental setup TD–30 M (Plant of test machines, USSR) was used. The sample was fixed in the experimental setup with the help of mechanical clamps. Rigid load was assigned, that is, the fixed values of the deformation of the samples were assigned, and the forces were measured by a regular mechanical dynamometer. The mechanical dynamometer before use was tested by sequential loading with the application of a reference dynamometer and by subsequent construction of relevant characteristics and determining the necessary coefficients.

The samples were loaded with continuous sample extension (Δ=0.5 mm). Experiments were conducted in two separate versions. The first were the experiments to determine the elasticity module in the longitudinal direction. The second version of the experiments included tests to determine visco-elastic properties of the material.

Each experiment was performed with the samples that were separated from different sections of various types of hoses, that is, at least 9 samples with subsequent statistical treatment of the results, and also for checking their repeatability.

4. 1. Experimental research into longitudinal elasticity of pressure fire hoses

The initial (1) loading cycle was performed with the non-deformed fragment of a fire hose with a length of 78 mm.

Maximal magnitude of deformation was: $\Delta l_1^{\max}=9.5{\cdot}10^{-3}$ m at loading of $F_1^{\max}=1128$ N. The results of tests are given in Table 1.

After unloading, residual deformation of the fragment was $\Delta l_1^{res}=5.0{\cdot}10\ ^{3}$ m.

During the second cycle (2), which was performed after two minutes, the maximal magnitude of deformation was $\Delta l_2^{res}=9.5{\cdot}10^{-3}$ m at loading $F_1^{\max}=1080$ N.

After unloading, residual deformation of the fragment was $\Delta l_2^{res}=6.0{\cdot}10^{-3}$ m.

The numerical parameters of the next three cycles of loading (3)–(5), which were carried out with the same two-minute intervals, practically do not differ from each other, which made it possible to average them. The maximum magnitude of deformation on these modes was: $\Delta l_{3-5}^{res}=9.5{\cdot}10^{-3}$ m at the average loading $\Delta l_{3-5}^{res}=9.5{\cdot}10^{-3}$ m.

There was no residual deformation after unloading.

Table 1

Results of experimental tests of PFH

Δ, mm	Loading – *F*, N				
	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
	N	N	N	N	N
0.0	0000	–	–	–	–
0.5	0192	–	–	–	–
1.0	0288	–	–	–	–
1.5	0312	–	–	–	–
2.0	0336	–	–	–	–
2.5	0360	–	–	–	–
3.0	0432	–	–	–	–
3.5	0456	–	–	–	–
4.0	0480	–	–	–	–
4.5	0528	–	–	–	–
5.0	0600	0000	–	–	–
5.5	0672	0192	–	–	–
6.0	0720	0336	0000	0000	0000
6.5	0768	0432	0240	0192	0240
7.0	0840	0600	0432	0336	0432
7.5	0912	0720	0576	0456	0528
8.0	0960	0864	0720	0672	0720
8.5	1,008	0960	0912	0768	0864
9.0	1,080	1,056	0960	0912	1,008
9.5	1,128	1,080	1,080	1,008	1,104

4. 2. Results of experimental research into longitudinal elasticity of pressure fire hoses

The diagrams that correspond to statistically treated results of testing with loading are shown in Fig. 3.

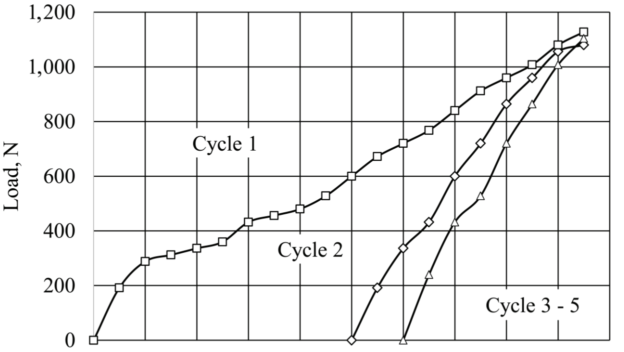

Fig. 3. Diagrams of loading the sample of PFH material

An almost linear dependence between loading and deformation of fire hose fragments makes it possible to determine in the first approximation (without taking into account the changes in the dimensions of the sample due to deformation) the averaged module of elasticity (E) of its material in the longitudinal direction:

$$E_i=\frac{F_i^{\max}\ell}{\left(\Delta\ell_i^{\max}-\Delta\ell_{i-1}^{res}\right)\delta S}, \tag{1}$$

where E_i is the elasticity module determined for the i-th cycle; $F_i^{\max}$ is the maximum loading of the i-th cycle; ℓ is the length of the working zone; $\Delta\ell_i^{\max}$ is the maximum deformation of the i-the cycle; $\Delta\ell_{i-1}^{res}$ is the residual deformation of the previous cycle; δ is the thickness of the material of the sample; S is the width of the working zone of the fragment.

Taking into consideration the statistically processed experimental data (Table 1) for the relevant load cycles, elasticity module is:

$E_1=60.7$ MPa;

$E_2=117$ MPa;

$E_{3-5}=148$ MPa.

Thus, first, elasticity modules increase and are stabilized during 3–5 tests.

4. 3. Experimental research into dissipative properties of pressure fire hoses in the longitudinal direction

Experiments to determine the dissipative properties of the PFH in the longitudinal direction were conducted simultaneously with determining elastic characteristics. Results of research after statistical treatment are shown in Table 2.

Table 2

Results of experimental tests of PFH

Δ, mm	Loading – *F*, N									
	Cycle 1		Cycle 2		Cycle 3		Cycle 4		Cycle 5	
	L	U	L	U	L	U	L	U	L	U
0.0	0000	–	–	–	–	–	–	–	–	–
0.5	0192	–	–	–	–	–	–	–	–	–
1.0	0288	–	–	–	–	–	–	–	–	–
1.5	0312	–	–	–	–	–	–	–	–	–
2.0	0336	–	–	–	–	–	–	–	–	–
2.5	0360	–	–	–	–	–	–	–	–	–
3.0	0432	–	–	–	–	–	–	–	–	–
3.5	0456	–	–	–	–	–	–	–	–	–
4.0	0480	–	–	–	–	–	–	–	–	–
4.5	0528	–	–	–	–	–	–	–	–	–
5.0	0600	0000	0000	–	–	–	–	–	–	–
5.5	0672	0048	0192	–	–	–	–	–	–	–
6.0	0720	0144	0336	0000	0000	0000	0000	0000	0000	0000
6.5	0768	0240	0432	0120	0240	0048	0192	0048	0240	0048
7.0	0840	0408	0600	0240	0432	0144	0336	0096	0432	0120
7.5	0912	0480	0720	0384	0576	0240	0456	0240	0528	0240
8.0	0960	0600	0864	0600	0720	0384	0672	0360	0720	0432
8.5	1,008	0720	0960	0720	0912	0576	0768	0480	0864	0672
9.0	1,080	0960	1,056	0864	0960	0720	0912	0792	1008	0864
9.5	1,128	1,128	1,080	1,080	1,080	1,080	1,008	1,008	1,104	1,104

The results of statistically processed experimental research (Table 2) are approximated by corresponding trends, the diagrams of which are shown in Fig. 4–6.

The diagrams in Fig. 4 correspond to the trends of the initial cycle 1 of loading-unloading of non-deformed fragments of the material of the PFH.

The diagrams in Fig. 5 correspond to polynomial trends of cycle 2 of loading-unloading of the fragments of the material of the PFH.

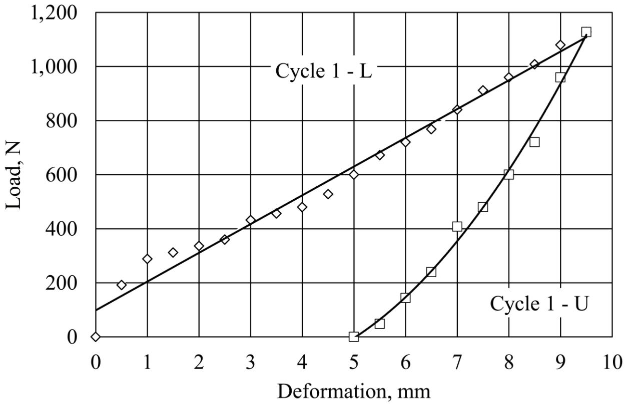

Fig. 4. Diagrams of trends of cycle 1: L — loading, U — unloading

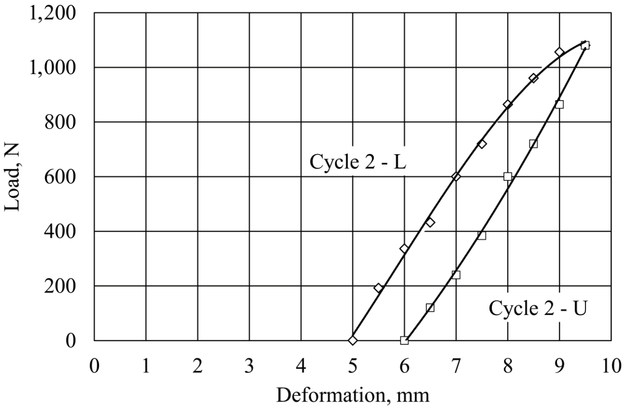

Fig. 5. Diagrams of trends of cycle 2: L — loading, U — unloading

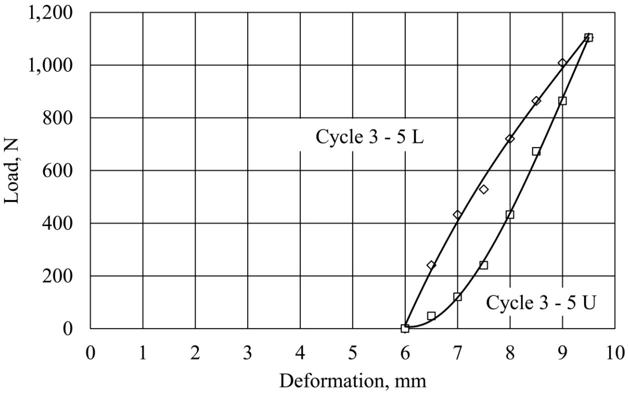

Fig. 6. Diagrams of trends of cycles 3—5: L — loading, U — unloading

The following three cycles of loading-unloading were performed with the similar time intervals. The numerical parameters of the tests practically do not differ from each other, which made it possible to average them.

The diagrams in Fig. 6 correspond to polynomial trends of cycles 3–5 of loading-unloading of the fragments of the material of the PFH.

Thus, the area of the hysteresis loop first decreases and in test cycles 3–5 is stabilized.

4. 4. Results of experimental research into dissipative properties of pressure fire hoses in longitudinal direction

Energy (A_D) that was accumulated in the sample and corresponds to the dissipative properties of the material of the fire hose fragment is determined by the area of the hysteresis loop as the difference of works spent at loading (A_L) and subsequent unloading (A_U) of the sample:

$$A_D = A_L - A_U = \int\limits_{\Delta\ell_{LI}}^{\Delta\ell_{LF}} F_L(\Delta\ell)\,\mathrm{d}(\Delta\ell) - \int\limits_{\Delta\ell_{UF}}^{\Delta\ell_{UI}} F_P(\Delta\ell)\,\mathrm{d}(\Delta\ell), \qquad (2)$$

where $F_L(\ell)$ is the equation of the dependence of the acting force on the deformation of the sample at its loading; $F_U(\Delta\ell)$ is the equation of the dependence of the acting force on the deformation of the sample at its unloading; $\Delta\ell_{LI}$ is the lower integration boundary, which corresponds to the initial loading point; $\Delta\ell_{LF}$ is the upper integration boundary, which corresponds to the final loading point; $\Delta\ell_{UF}$ is the lower integration boundary, which corresponds to the final unloading point; $\Delta\ell_{UI}$ is the upper integration boundary, which corresponds to the initial unloading point.

If we accept designation of diagrams (Fig. 4–6), where the results of the experimental research (Table 2) were approximated by the corresponding polynomials of the trends, equation (2) will take the form:

For subsequent calculations, it is appropriate to determine dissipative properties of the fire hose by the dimensionless ratio or dissipation coefficient:

$$\beta = \frac{A_D}{A_L}. \qquad (2)$$

The equations of the corresponding trends were obtained after statistical processing of research results by means of Microsoft Excel 2007.

Accordingly, the loading energy of cycle 1 is $A_{L1} = 5{,}358.15 \cdot 10^{-3}$ J, and unloading energy of cycle 1 is $A_{U1} = 2{,}080.36 \cdot 10^{-3}$ J.

Hysteresis energy is $A_{D1} = 3{,}277.79 \cdot 10^{-3}$ J. Hence, dissipation coefficient of cycle 1 is $\beta_1 = 0.612$.

The same is true for another test cycle (Fig. 5).

Energies of loading-unloading of cycle 2 are $A_{L2} = 2{,}834.6 \cdot 10^{-3}$ J, $A_{U2} = 1{,}754.47 \cdot 10^{-3}$ J.

Hysteresis energy is $A_{D2} = 1{,}080.13 \cdot 10^{-3}$ J. Hence, dissipation coefficient of cycle 2 is $\beta_2 = 0.612$.

In tests cycles 3–5 (Fig. 6), the averaged experimental results allowed determining $A_{L(3-5)} = 2{,}079.67 \cdot 10^{-3}$ J, $A_{U(3-5)} = 1{,}339.47 \cdot 10^{-3}$ J, $A_{D(3-5)} = 740.2 \cdot 10^{-3}$ J, $\beta_{(3-5)} = 0.356$.

Fig. 7 shows the diagrams that graphically reflect the indicators of energy that was consumed for the implementation of five consecutive PFH loading – unloading cycles, as well as hysteresis energy.

Fig. 8 shows the dependence of changes in dissipative properties of material of the PFH of type «T» with the inner diameter of 66 mm at successive deformation cycles on the loading mode.

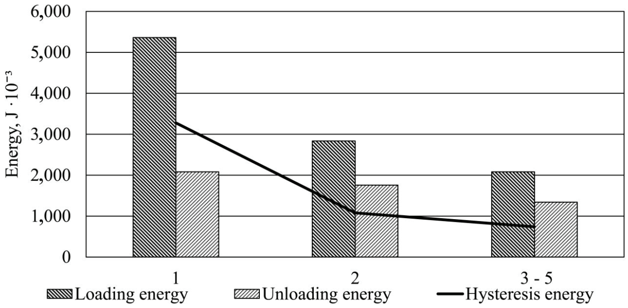

Fig. 7. Parameters of PFH loading-unloading cycles during experiments

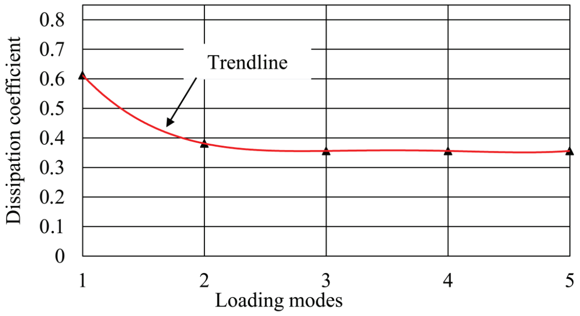

Fig. 8. Dependence of dissipative properties of material of the PFH of «T» type with an inner diameter of 66 mm on a loading mode

The dependence obtained by using the Microsoft Excel 2007 tabular processor was approximated by a polynomial trendline. The trendline type was selected based on the calculated value of determination coefficient, which characterizes the degree of proximity of the specified line to the original data. Exponential, linear, logarithmic, and power trendlines were considered among the possible types of trendlines. Accordingly, the highest value equal to 1 was obtained for the power trendline. The obtained trendline describes the corresponding equation (3).

$$Y_i = 0.0065 \cdot X_i^4 - 0.0952 \cdot X_i^3 + \\ + 0.5115 \cdot X_i^2 - 1.1968 \cdot X_i + 1.386, \qquad (3)$$

where Y_i is the prediction value of the dissipation coefficient of the pressure fire hose of the i-th sample; X_i is the loading modes of the i-th sample.

Table 3

Summary table of results from calculation of some mechanical properties of a fire hose

Characteristic	Designation	Cycle 1	Cycle 2	Cycles 3–5
Maximum loading	$F_i^{\max}$, N	1128	1080	1064
Maximum deformation of the fragment	$\Delta\ell_i^{\max}$, mm	9.5	4.5	3.5
Residual deformation of the fragment	$\Delta\ell_i^{res}$, mm	5.0	1.0	0
Elasticity module of material	E_i, MPa	60.7	117	148
Coefficient of dissipation of hose material	β_i	0.612	0.381	0.356

Generalization of the conducted complex of experimental tests is shown in Table 3, which summarizes the averaged estimates of strength and elasticity for the material of the PFH of «T» type with the inner diameter of 66 mm.

5. Discussion of results of research into elastic and dissipative properties of pressure fire hoses

The results of a series of experimental determining the elastic and dissipative properties of the PFH revealed that significant initial hysteresis of the fragment of fire hose of cycle 1 (Fig. 4) considerably decreases during repeated tests of cycle 2 (Fig. 5), cycles 3–5 (Fig. 6). Along with a decrease in residual deformations and stabilization of elastic properties (Table 3), this approximates the behavior of the material of the PFH in the longitudinal direction to elastic.

Reliable and safe application of the PFH, which is caused by hydraulic tests for tightness at overpressure during scheduled inspections, is determined only by integrity and tightness of pressure fire hoses.

These tests are aimed only at a simplified assessment of the PFH reliability. Their task does not include determining physical and mechanical properties of the PFH. This limits the possibilities of theoretical research using the method of finite elements.

The performed tests were limited to the study of only one type of hoses, while their wear was not taken into consideration.

These shortcomings can be eliminated by the study of different types of hoses with arbitrary term of operation and statistical processing of results.

The further development of appropriate research involves the experimental analysis of the influence of cyclic deformation, as well as the influence of high temperatures on physical-mechanical properties of the material of the PFH.

These studies require development of both a new methodology for experiments and the production of appropriate equipment.

6. Conclusions

1. Experimental research into determining the elastic properties of the PFH revealed that elasticity module of the material of the hose in the longitudinal direction was stabilized at the level of 148 MPa. In this case, the magnitude of elasticity module in almost identical range of loading (1,064÷1,128 N) greatly depends on the load «history», that is, the corresponding rigidities and elasticity modules increased in the first two or three test modes and got stabilized in the next modes at a significant decrease in residual deformations (5÷0 mm).

2. Experimental research into determining the dissipative properties of the PFH revealed that dissipation coefficient of the hose material was stabilized at the level of 0.356. In this case, its magnitude in almost the same range of load (1,064÷1,128 N), decreased steadily and was stabilized only in the following modes.

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