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Influence of the artificial defect on the flexible pipeline twist angle

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ABSTRACT

Purpose: To establish the dependence of the change in the values of the twisting angle of the flexible pipeline on the internal water pressure and the defect length, which is directed along and across the axis of the sleeve.

Design/methodology/approach: Experimental studies were conducted in two stages. At the first stage, the methodology and plan of the experiment were developed, the factors and their values were determined, and experimental studies were conducted. The limits of variation in the area of factor spaces were established based on the basic analysis of a priori information. The length of the defect was 0, 50 and 100 mm. The pressure values in the sleeve were 0.2, 0.4 and 0.6 MPa. Adequacy of the obtained regression equations was checked using Fisher's test. At the second stage, the analysis of the research results was carried out and the numerical values of the factors that most affect the change in the value of the twisting angle of the sleeve were established.

Findings: According to the results of experimental studies, the dependences of the change in the twisting angle of the flexible pipeline on the internal water pressure and the length of the defect were obtained. It was established that the dependence of the previously mentioned factors is close to linear. The largest discrepancy in the maximum sleeve twist angle – 21% was observed at pressure values of 0.4 MPa.

Research limitations/implications: The research was limited to only two factors: the defect length and the pressure in the middle of the sleeve. Such factors as the degree of wear of the sleeve, the type of sleeve and the number of defects on the test sample were not taken into account.

Practical implications: The obtained results can be used during the development of a new method of testing flexible pipelines, which will allow to establish hidden defects in them.

Originality/value: For the first time, the dependence of the influence of the size and direction of the defect on the reinforcing frame of the pressure fire hose on the value of its twist angle at constant internal pressure indicators was established.

Keywords: Flexible piping test process, Pressure hose, Twist angle, Defect, Operating pressure

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PROPERTIES

1. Introduction

The development and growth of various industrial enterprises is associated with the growth of the number of emergencies (ES) of man-made nature. The causes of man-made emergencies are mainly fires and explosions, as well as spills and emissions of hazardous chemicals (HC). Adverse effects on the environment are associated with emissions of HC and combustion products. Accordingly, their concentration may become higher than the maximum allowable, which will cause toxic effects and chronic intoxication in people who are in the danger zone [1]. In addition, these substances may enter soils and groundwater. Elimination of such emergencies requires operational work related to firefighting, localization and elimination of spills and emissions, as well as the collection of HC. In order to eliminate them, emergency rescue formations (ERF) are involved. The success of the unit work process depends on many factors, including their proper technical support and training. Not the least role in this process is played by the peculiarities of the territorial location of units, as well as their numerical composition, which certainly affects such an important factor as response time [2]. The condition of ERF readiness to perform the assigned actions is to equip them with the required number and types of technically serviceable equipment, as well as its trouble-free operation during operational work [3]. ERF equipment includes fire engines and emergency rescue equipment, as well as fire equipment and emergency rescue tools. Fire-fighting equipment includes: fire equipment, portable fire tools, fire rescue devices, personal protective equipment and more. It is worth noting the important role of various types of flexible pipelines, such as pressure fire hoses (PFH), which are used both for extinguishing fires and during the collection of spilled HC. PFHs are also used in the supply of a solution of water with a foaming agent, which is necessary for the formation of air-mechanical foam in the supply devices and covering the surface of the HC spill area to reduce their evaporation. It is believed that this type of firefighting equipment has the lowest reliability among others. Their sudden failure can cause an increase in the duration of operational work and spillage of HC in places of destruction, which will increase the scale of the negative consequences. In order to prevent this, PFH maintenance is performed, which also includes testing. The tests are reduced to a simplified assessment of the technical condition of the sleeve, ie, tests under excess pressure during which only the integrity and tightness of the sleeve is determined.

These tests do not allow to diagnose the technical condition of the sleeve at an early stage of its damage (before rupture). Therefore, it is important to develop and improve test methods to determine the presence of a latent defect before the onset of the limit state (rupture), the detection of which during firefighting can lead to a significant increase in the time of its elimination

2. Literature data analysis and problem statement

The failure of flexible pipes can occur for various reasons. Types of damage include breakage of the integrity of the material from which the flexible pipe is made, as well as the destruction of the connecting fittings.

The causes of failure of flexible pipes, which are associated with the destruction of the connecting fittings can be either damage to the attachment of the flexible pipe to the sleeve [4] or destruction directly on the fittings [5].

In [4] it was found that one of the factors of failure of the sleeves is the external damage formed by the action of sharp metal bushings. Thanks to the finite element method, the distribution and concentration of stresses on the sleeve surface were analyzed.

In addition, with time, there is a loss of elasticity of elastomers, which are part of the material from which the flexible pipes are made, which causes leaks at the points of connection to the valve. The second reason is related to possible manufacturing defects of the connecting fittings, which as a result of the appearance of hydraulic pressure inside the flexible pipeline causes its destruction [5]. Accordingly, these faults in the flexible fittings are mainly due to the low quality of their manufacture and manufacturing defects. Diagnosis of the technical condition of the connecting fittings during operation is mainly during hydraulic tests.

Violation of the integrity of the material from which the flexible pipes are made can occur for many reasons. The process of assessing the ultimate strength of flexible pipelines is complex. This is due to the fact that they are made of composite materials and may consist of several layers, which are combined in different ways [6]. When assessing the ultimate strength of flexible pipes, it is necessary to take into account their internal structure and many other factors, which explains the complexity of the mathematical models used for this purpose.

One of the methods of diagnosing the technical condition of flexible pipelines is the method of industrial computed tomography. According to [7], this method allows you to get fairly accurate results, but the diagnosis must have information on the material from which the sleeve is made. For some composite sleeves, this method of diagnosis is not effective, which limits its use.

In [8], the change in the physical properties of the material of flexible pipelines, namely elastomers as a result of exposure to liquid fuel, was studied. This effect can occur either from the inside, which is possible when pumping liquid fuel through flexible pipes or even from the outside, if it was spilled. Physical properties such as weight and volume, as well as hardness and tensile strength, were studied. It is established that different elastomers from which flexible pipelines are made interact differently, some actively, and some show insignificant interaction with liquid fuel.

Fracture due to the occurrence of cyclic deformations and stresses occurring in the sleeve was also detected [9]. The process of predicting the service life of a flexible pipeline before damage occurs is complicated by the fact that the sleeves are made mainly of composite material. The complexity of the internal structure from which the pipelines are made necessitates the adoption of certain simplifications in the process of their research, which causes significant errors. In studies [9], the process of fatigue of only the elastomers of the sleeve material is evaluated, and the condition of the fabric reinforcing layer was not considered. In [10], a system of nonlinear equations was proposed, which allows estimating the probable deformations and loads that occur in the reinforcing layer of flexible pipelines and setting pressure limits. Elastomer fatigue was not taken into account.

According to [11], when setting the maximum pressure of flexible pipelines, and in particular the PFH, it is necessary to take into account many different factors. These factors include: breaking force of weft threads, sleeve radius, geometric densities at the warp and weft, diameters of warp and weft threads, vertical folding coefficients of warp and weft threads. In [11], a mathematical model was proposed, which, taking into account the previously mentioned factors, allows to estimate the maximum pressure of the PFH. In this case, the properties of elastomers that are part of the material from which the PFH is made, this mathematical model does not take into account.

In [12], a mathematical model was proposed that allows to estimate the process of fatigue damage in rubber-like materials. This mathematical model was developed on the basis of experimental studies of the process of accumulation of fatigue in different samples of rubber. In [13], a computational and experimental study of self-heating of a rubber-cord composite during cyclic deformation is considered, which contributes to the change in the mechanical properties of the material. A comparison of the results of experimental studies, which are given in [12] and calculated, using numerical simulations. In the course of work qualitative and quantitative dependences of a hysteresis loop on time at cyclic deformation of a rubber cord composite were received. Pictures of temperature distribution on a sample are received. The dependence of the self-heating temperature on the deformation amplitude and the load frequency is established.

Homogenization and interpolation methods can be used to perform numerical analysis of probable deformations of the flexible pipeline [14]. The use of these methods leads to the adoption of some simplifications when considering the structure of the material and certain average values of the parameters, which also can not provide the necessary reliability of the results.

According to [15] under the action of cyclic loads there is a change in the dissipative properties of rubber-composite composites, in particular, there is their self-heating. The prototypes were flat fragments that were made of rubber-composite composites and had all the same geometric dimensions. In the course of field experiments on the stretching of test specimens along the reinforcing fibers, it was possible to collect data on changes in their characteristics, which allowed to construct deformation curves, and to describe this process. Accordingly, it can be assumed that under the action of cyclic loads on a test specimen that has a latent defect, its dissipative properties will be different than in a similar sample in which there is no defect. This assumption was not tested in this study.

In [16,17] the mechanical properties in the conditions of static cycles of loading and unloading of the sleeve material were investigated. As a result of the performed experiments, the values of the modulus of elasticity and the dissipation coefficients of the sleeve material during cyclic deformations were established. It should also be noted that in [16] the tests were performed on the material of PFH of "T" type with an inner diameter of 66 mm in the longitudinal (along the base) direction. In [17], somewhat similar experimental studies were conducted on the material of PFH of "T" type with an inner diameter of 77 mm in the transverse direction, taking into account its heterogeneity. The research was carried out both on the outer fabric reinforcing frame and on the inner waterproofing rubber layer of the pressure hose. In the analysis of experimental studies, it was found that in the longitudinal and transverse directions of the sleeve material exhibits orthotropy.

It should also be noted in [18], the mechanical properties of the displacement of PFH material from torsion tests. The elastic and dissipative properties of the material of PFH of "T" type with an inner diameter of 77 mm, with varying values of internal hydraulic pressure. A number of field experiments on torsion of pressure hose samples with internal hydraulic pressure in the hose of 0.2 MPa, 0.4 MPa and 0.6 MPa in the conditions of static loading-unloading cycles were carried out.

The test specimens used in the studies [16-18] did not have any damage before the experiments.

Thus, after analyzing the literature [4-18], it was found that most studies are related to determining the causes of damage to flexible pipes [4-11]. In addition, a number of works [12,13, 15-18] are related to the study of changes in the properties of materials from which flexible pipelines are made under the influence of various influences. In some works, methods are presented that allow to establish [5-7, 14] or to predict [12,13,15] possible damages of flexible pipelines, in particular PFH. Due to the complex structure of flexible pipelines in a number of works [8-11, 18] the change of properties of only separate layers of which the material from which they are made is investigated is investigated.

Accordingly, it becomes clear that the damage that occurs in the materials from which the flexible pipes are made affect in general the change in their physical properties. This feature of the behavior of materials in the analyzed works is little studied.

Thus, in [19] the authors proposed a new method of testing the PFHs, which consists in the fact that the sample sleeve is filled with water, both edges of the sample sleeve are rigidly fixed with cylindrical clamps. A constant force is applied to its geometric center, the twisting angle is determined, and the condition of the sleeve, the presence and size of defects are judged by the deviation of its value. However, to date, no research has been conducted in this area, which allows us to formulate the problems of these studies.

3. Purpose and objectives of the study

The aim of the study is to establish the dependence of the change in the angle of twisting of the flexible pipe on the internal water pressure and the length of the defect, which is directed along and across the axis of the sleeve.

To achieve this goal, the following tasks were set:

- to develop a method and a plan for conducting an experiment to determine the effect of the defect and the water pressure in the sleeve on its twist angle,
- to carry out experimental researches and to establish dependences of influence of water pressure in a sleeve and defect on its twisting angle.

4. Materials and methods of pilot studies by definition of a corner of a twisting of the flexible pipeline

The purpose of the study is to establish the dependence of the values of the change in the twisting angle of the flexible pipeline on the internal water pressure and the defect length, which is directed along and across the axis of the sleeve in accordance with the proposed method [19].

In the form of a flexible pipeline, a pressure fire hose of "T" type with an inner diameter of 77 mm was used, which had a test length L = 0.8 m, which is determined by the size of the experimental installation. The design of the PFH was considered in detail in [16], which consists of a power frame and an inner elastic waterproofing layer. Part of the new sleeve was separated for relevant research. Given the fact that the power frame fully absorbs the forces due to the presence of hydraulic action of the internal pressure of the fluid inside the sleeve [11], it was decided to cause a defect on the power frame.

The most frequent defects of the material from which PFH are made are: cut, puncture, rubbing and burn. The size and nature of these defects can vary greatly, and therefore it is quite a difficult task to fully cover everything in one work, so in this study it was decided to limit ourselves to the study of the change in the mechanical properties of PFH due to their cut.

As it was mentioned earlier, the size of the defects can vary quite widely, so in this study the size of the defect was chosen arbitrarily. The defect on the test samples of the sleeves was artificially applied by means of a longitudinal and transverse cut (along the base and along the weft) of the power frame with a depth of 0.3-0.5 mm, and the width of the cut was 0.1-0.2 mm. This type of defect can occur during operational deployment, when fire-extinguishing substances are not supplied through the PFH, but when they are unrolled due to contact with sharp objects, a cut may occur. In addition, a cut due to contact with sharp objects can occur during the process of maneuvering a firefighter with a barrel, when a hose filled with water is attached to it.

The planned experiment is aimed at identifying the nature of the change in PFH mechanical properties, which have a defect in the form of a cut, compared to sleeves without a cut, which is difficult to detect visually, but which may later cause their sudden failure.

The experiment was conducted on an experimental installation, which was developed and manufactured at the Department of Engineering and Rescue Machinery of the National University of Civil Defence of Ukraine.

The schematic diagram of the device is presented in Figure 1. Two cylindrical clamps (6) with rubber pads are attached to the installation frame (1), which keep the right and left edges of the investigated part of the flexible pipeline (3) from scrolling.

The active housing (2) located in the central part of the device is designed to load and, accordingly, rotate the middle of the investigated part of the flexible pipe with a fixed torque by means of a clamp (11) with rubber pads, which is fixed on the active housing and clamps the movable central part of the sleeve by means of fixators (9).

Torque loading occurs by means of a load (5), through a cable (4) on the guide (8). Deformation measurement (electric protractor) (10) is mounted on the active housing.

One rolling support (7) for the cable is attached to the installation frame (1), which is made in the form of a roller, the axis of which is perpendicular to the direction of the cable. Bearings prevent deflection of the investigated central part of the PFH.

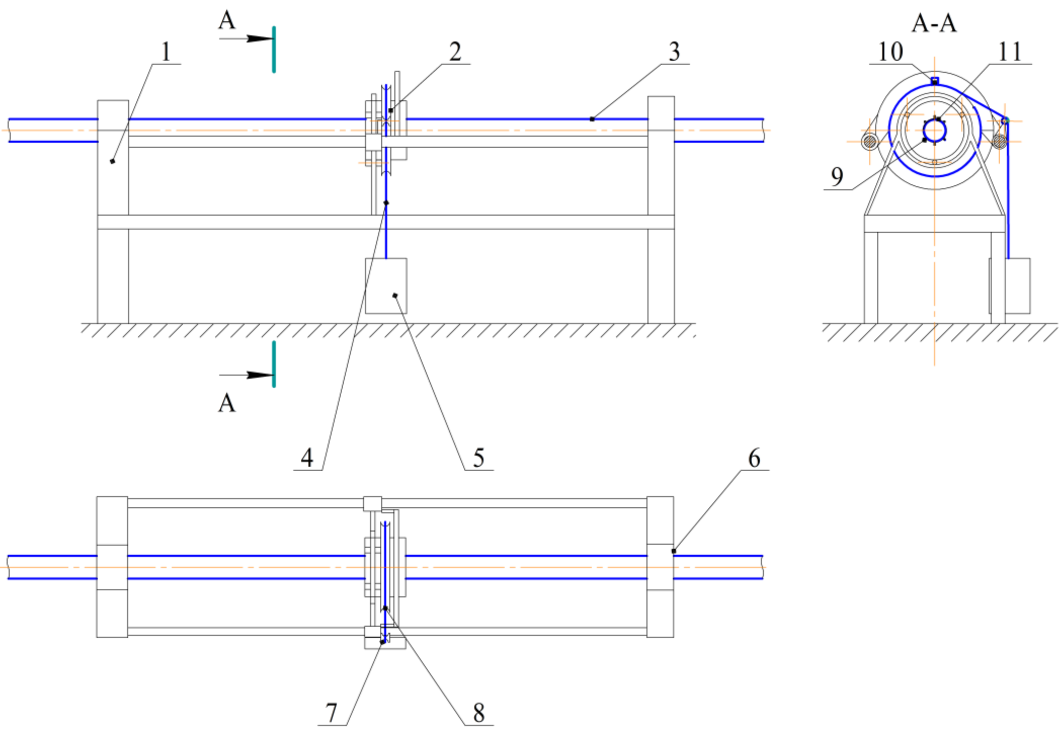

Fig. 1. Scheme of the experimental installation to determine the flexible pipeline twisting angle: 1 – installation frame; 2 – active housing; 3 – sample of the flexible pipeline; 4 – cable; 5 – cargo; 6 – cylindrical clamps; 7 – rolling support; 8 – cable guide; 9 – fixators; 10 – deformation meter; 11 – clamp

The study was conducted on the experimental setup of Figure 1, in the following sequence. The clamp (12) is fixed on the investigated part of the flexible pipe (3) and installed in the active housing (2), by means of a pump (not shown in the figure) the sample is filled with water to the pressure program (P) defined by the program. Both edges of the pipeline are fixed with cylindrical clamps (6). The load (5) is suspended from the cable (4) of the torsional load unit – the active body (2), after which the twisting angle of the sample is fixed.

The torque M_k for each experiment is equal to the product of the force load F (the action of a load weighing 21.66 kg) on the length R = 0.08 m of the lever. That is, the torque was constant and was $M_k = 16.992$ Nm.

When planning the experiment, second-order orthogonal planning was used [20]. When the number of factors k = 2.

A full-factor experiment (FFE) of type 2k with a permissible accuracy of the 5% model was planned for research and realization of the goal, in which the pressure in the sleeve P (x_1) and the size of the defect L_d (x_2) were chosen as factors, and the angle twisting φ (y).

Based on the analysis of information, the choice of the experimental area of the factor space was made. The center of the interval in which the study is planned was chosen as the zero level of the factor. The interval of variation, the values of the upper and lower levels of factors in natural and coded expression are also selected. Values of factor levels and intervals of variation are given in Table 1.

The value of the pressure in the sleeve varied from 0.2 MPa – the lowest pressure in the PFH to 0.6 MPa – the highest pressure.

The lower level of the defect length was 0 mm, which is due to the need to trace the change in the angle of twist on the new sleeve. The maximum length of the defect is 100 mm.

Next, on the basis of the FFE plan, a working matrix was compiled and experiments were performed to measure the

Table 1.
Levels of factors variation

Interval of variation and level of factors	Sleeve pressure P, MPa	Defect length L_d, mm
Zero level $x_i = 0$	0.4	50
Interval of variation	0.2	50
The lower level $x_i = -1$	0.2	0
Upper level $x_i = +1$	0.6	100
Code designation	x_1	x_2

Table 2.
Working matrix of planning and results of experimental researches with defect on a base and weft

Study	P, MPa	L_d, mm	Results on a base/weft					
	x_1	x_2	y_1	y_2	y_3	y_4	y_5	$\bar{y}$
1	0.6	100	33/34	35/37	32/36	34/37	33/37	33.4/36.2
2	0.6	0	29/29	30/30	29/29	31/31	32/32	30.2/30.2
3	0.2	100	54/54	56/56	56/59	57/58	57/58	56/57
4	0.2	0	52/52	53/53	52/52	51/51	55/55	52.6/52.6
5	0.4	50	38/40	38/41	40/40	39/42	40/40	39/40.6
6	0.6	50	30/33	33/34	32/32	33/33	32/33	32/33
7	0.2	50	51/54	55/55	55/56	53/54	56/56	54/55
8	0.4	100	46/46	45/49	47/48	44/49	45/48	45.4/48
9	0.4	0	35/35	36/39	35/35	37/37	36/36	35.8/35.8
10	0.4	50	41/41	40/41	40/43	39/42	40/43	40/42
11	0.4	50	41/40	40/39	41/40	42/40	41/40	41/39.8
12	0.4	50	38/41	38/40	37/42	39/42	39/41	38.2/41.2
13	0.4	50	38/41	38/38	37/39	37/38	39/40	38/39

Table 3.
Regression ratio for experimental studies with defect on the base and on the weft

Defect direction	Regression ratio					
	b_0	b_1	b_2	b_1^2	b_2^2	b_{12}
Basis	41.12	-10.87	3.77	2.57	0.47	0.4
Weft	43.06	-10.86	3.76	2.81	0.71	0.4

torsion angle. The working matrix of planning and the results of the experiment, performed in five repetitions, with a defect in the base and weft (Tab. 2).

As a model of the object of study, was used polynomial of the 2nd degree [21]:

$$y = b_0 + b_1x_1 + b_2x_2 + b_1^2x_1^2 + b_2^2x_2^2 + b_{12}x_1x_2 \quad (1)$$

where b_1, b_2 – regression ratio.

The following formula is used to determine the regression coefficients in orthogonal planning:

$$b_i = \frac{\sum_{u=1}^{n} x_{\text{iu}} y_u}{\sum_{u=1}^{n} x_{\text{iu}}^2} \quad (2)$$

where
u=13 – the number of studies in the experiment; – column number in the planning matrix; – the average value of the criterion in each study obtained during the experiment (Tab. 2); x_{iu} – coded factor values.

Values of $\sum_{u=1}^{n} x_{iu}^2$ with the kernel type 2^2 : $x_0 = 9$, $x_i = 6$, $x_{\text{ij}} = 4$, $x_i^{2\text{-}\varphi} = 2$.

After substituting the values of the coefficients and the data of the scheduling matrix of expression (2), the regression coefficients for the defect on the basis and on the weft are given in Table 3.

After substituting the numerical values of the coefficients in expression (1) we obtain the equation in the coded numbers in the case of a defect on the basis of (3) and (4) in the case of a defect on the weft:

$$y^b = 41.12\text{-}10.87x_1 + 3.77x_2 + 2.57x_1^2 + 0.47x_2^2 + 0.4x_1x_2 \quad (3)$$

$$y^w = 43.06\text{-}10.86x_1 + 3.76x_2 + 2.81x_1^2 + 0.71x_2^2 + 0.4x_1x_2 \quad (4)$$

The hypothesis about the adequacy of the regression equation will be tested using Fisher test [22]:

$$F_{\text{esti}} = \frac{S_{\text{ad}}^2}{S_{\{y\}}^2} \quad (5)$$

where

$S_{ad}^2 = \frac{\sum_{u=1}^{N}(\overline{y_u} - y_u)^2}{n\frac{(k+2)(k+1)}{2}}$ – adequacy dispersion;

$S_{\{y\}}^2 = \frac{\sum_1^N \sum_1^n (y_{uj} - \overline{y_u})^2}{N(n-1)}$ – reproducibility variance.

Given the previously obtained values of the variance of adequacy and reproducibility of the value of the Fisher criterion will be in the case of a defect based on $F_{\text{esti}}^b = 1.903$, in case of weft defect $F_{\text{esti}}^w = 4.61$.

Depending on the calculated degrees of freedom of greater and lesser variance, we determine the tabular value of the Fisher test $F_{(0.05;f_{\text{ad}};f_y)}$ F_{tab} with $f_{\text{ad}} = 7$, and $f_y = 3$, $F_{\text{tab}} = 8.88$.

Since $F_{esti} < F_{tab}$ з 95 – % probability we can consider the regression equations (3) and (4) adequate to the process under study.

In practice, it is not convenient to use the mathematical dependence in the coded quantities, after obtaining an adequate regression equation, we convert it by replacing the coded quantities with named (actual) for this we use equations (6) and (7), which characterize the relationship.

$$x_1 = \frac{P - x_1}{\Delta x_1}; \quad (6)$$

$$x_2 = \frac{L_d - x_2}{\Delta x_2}, \quad (7)$$

where x_1 and x_2 – the value of the corresponding factor at zero level (Tab. 1), Δx_1 and Δx_2 – their variation intervals according to the same table.

Converting the regression equations (3) and (4) to the nominal form and after the reduction we have the expression:

$$\varphi^b = 64.14P^2 + 0.00019\text{L}_d^2\text{-}107.64\text{P} + 0.041\text{L}_d + 0.04\text{PL}_d + 70.62 \quad (8)$$

$$\varphi^w = 70.34P^2 + 0.00028\text{L}_d^2\text{-}112.61\text{P} + 0.03\text{L}_d + 0.04\text{PL}_d + 73.8 \quad (9)$$

The obtained expression allows us to investigate the effect of an artificial defect on the angle of twist of the sleeve depending on the pressure in the sleeve and the length of the defect.

5. Results experimental research on definition of a corner of a twisting of the flexible pipeline

In Figures 2 and 3 show the respective response surfaces of the dependence of the change of the twisting angle φ of the pressure fire hose with a diameter of 77 mm on the pressure in the hose P and the length of the defect L_d which is directed along (Fig. 2) and across the hose axis.

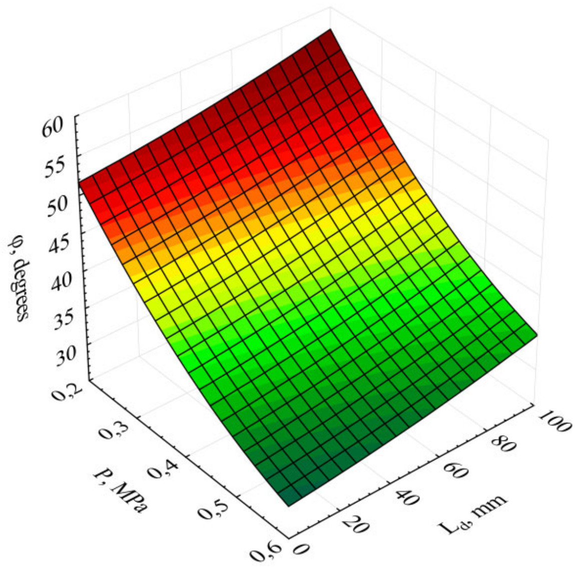

Fig. 2. Dependence of the twisting angle φ on the pressure in the sleeve and the length of the defect on the base

The response surfaces of the dependence of the change of the torsion angle φ of the PFH with a diameter of 77 mm on the length of the defect L_d and the pressure in the sleeve P are constructed.

Analyzing the obtained response surface of the dependence of the change of the twist angle of the sleeve on the pressure in the sleeve and the length of the defect (on the base and on the weft) we can conclude that the change in the twist angle on these parameters is the same. It can be seen that the effect of the defect length on the twist angle in the proposed range does not exceed 10°.

We can also conclude that for all values of pressure, the change in the angle of twist from the length of the defect is linear. It was found that the largest twist angle at different parameters of the defect is observed at a pressure value of 0.4 MPa.

Accordingly, it is advisable to consider the change in the torsion angle from the length of the defect at a given pressure P = 0.4 MPa. Given this, equations (8 and 9) can be simplified by recalculating at a constant pressure P = 0.4 MPa. After calculations, the equation will look like this:

$$\varphi^b = 40.106 + 0.00034L_d^2 + 0.02L_d \quad (10)$$

$$\varphi^w = 40.0104 + 0.00028L_d^2 + 0.046L_d \quad (11)$$

The dependence of the torsion angle on the length of the defect at a constant pressure P = 0.4 MPa, which is determined by equations (10 and 11), is shown in Figures 4 with a defect in the base and weft.

From the graph shown in Figure 4 there is an increase in the value of the twist angle from the length of the defect.

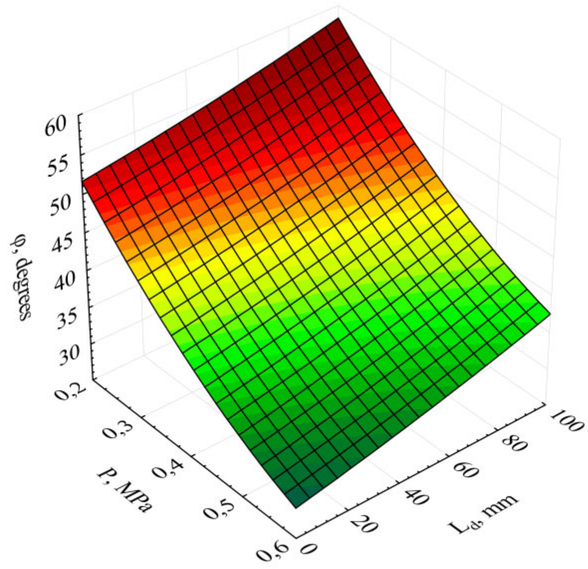

Fig. 3. Dependence of the twisting angle φ on the pressure in the sleeve P and the length of the defect L_d on the weft

6. Discussion of results of research on definition of a corner of a twisting of the flexible pipeline

According to the results of experimental studies, the dependences of the change in the angle of twist of the sleeve on the internal pressure in it and the size of the existing defect, which is directed along and across the axis of the sleeve. The response surfaces of the change of the twisting angle φ of the pressure hose with a diameter of 77 mm from

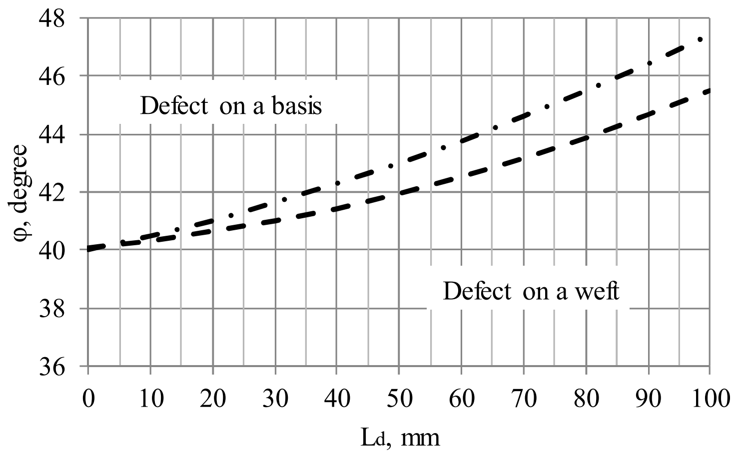

Fig. 4. Experimental dependence of the angle of twist of the sleeve on the length of the defect on the base and on the weft

the pressure in the hose P and the length of the defect L_d which is directed along (Fig. 2) and across (Fig. 3) the axis of the hose are obtained.

From Figures 2 and 3 it is established that the value of the pressure is linear and does not affect the nature of the change in the angle of twist of the sleeve. Experimental studies have shown that when the length of the defect (100 mm), during the variation of the pressure in the sleeve from 0.2 to 0.6 MPa, the maximum twist angle was observed at a pressure of 0.4 MPa.

These tests are aimed at establishing the relationship between the length of the defect and the pressure of the water in the sleeve on its twist angle during the tests.

The tests were limited to the study of only two factors, without taking into account the degree of wear, the type of sleeve and the effect of several defects on the test length. These limitations can be eliminated by examining the pressure hose with an arbitrary period of use, and conducting additional research with a new planning of the experiment.

A further development of the relevant research is the experimental analysis of the influence of different direction, shape and direction of the defect on the sleeve, as well as the influence of several defects on the test length of the PFHs.

These studies require the development of both a new plan for conducting experiments, methods of conducting experiments, and the manufacture of appropriate equipment.

7. Summary

1. A method of planning an experiment to determine the angle of twisting of a flexible pipeline on the example of a pressure fire hose of "T" type with an inner diameter of 77 mm. Due to the application of the multifactor experiment planning method, the quadratic regression equation is obtained. The levels of variation of factors and the working matrix of experiment planning and research results are established. The regression equation with coded and nominal values of factors is obtained. The reliability of the regression equations was checked using Fisher test, the estimated value of which was in the case of a defect on the basis of 1.903, and in the case of a defect on the weft – 4.61, which is less than the tabular value and confirms the adequacy of the described process.
2. By conducting a series of consecutive experiments, the dependences of the sleeve twist angle on the internal water pressure and the length of the defect, which is directed along (8) and across (9) the axis of the sleeve, were obtained.

It was found that when there is a defect on the sleeve from 0 to 100 mm, an increase in the twisting angle is observed in the damaged sections of the sleeve by 6-21%, depending on the pressure in the sleeve.

Depending on the length of the defect and the variation of the pressure in the sleeve in the range from 0.2 to 0.6 MPa, the maximum twisting angle was observed at a pressure of 0.4 MPa. At the specified numerical value of pressure in comparison with other indicators, the discrepancy on the maximum angle of twisting of a sleeve made 21%. It is established that the pressure in the sleeve does not affect the nature of the change in the angle of its twist depending on the length of the defect.

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