DEVELOPMENT OF RESEARCH METHODICS OF CONTACT ZONES BETWEEN THREADS IN WOVEN FRAMES OF FIRE FIGHTING SLEEVES

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ABSTRACT

In previous studies, the authors showed that the magnitude of the internal burst pressure in fire pressure hoses is influenced, among other parameters, by parameters such as vertical buckling coefficients, coefficients characterizing the lengths of contact zones between the threads in fractions of the diameters of the warp and weft threads. Accounting for these parameters is necessary for a more accurate determination of the bursting internal hydraulic pressure in fire pressure hoses, which is one of the most important strength parameters of the latter. Fabrics reinforcing frames of fire pressure hoses are technical fabrics, working in very tense conditions. The method of experimental studies of the contact zones between the threads in woven reinforcing frames of fire pressure hoses using a JSM-6490LV scanning electron microscope and statistical methods on the base of which coefficients of vertical thread crushing, coefficient characterizing length of contact zones between the threads in fractions of the diameters of the warp and weft threads.

Key words: fire pressure hose, woven reinforcing frame, bursting internal hydraulic pressure, experimental research methods of the contact zones between the threads.

INTRODUCTION

In [1], a theoretical study of the dependence of the bursting internal hydraulic pressure in fire pressure hoses (FPH) on the parameters of their woven reinforcing frame was performed.

It is shown that for a more accurate determination of the bursting internal hydraulic pressure in the FPH using the formula (1) [1, 2], it is necessary to take into account, among other parameters, such parameters as vertical buckling factors, coefficients characterizing the lengths of contact zones between the threads in fractions of diameters of warp yarn and weft.

The magnitude of the burst pressure for all types of commissioning, produced in the Russian Federation and used for the purpose in the Republic of Kazakhstan, are regulated by GOST R 51049-97 [3] (Russian Federation).

MATERIALS AND METHODS

The lengths of the arcs of contact between the main and weft threads and coefficients calculated based on them, characterizing the lengths of the contact zones between the threads in fractions of the diameters of the warp and weft threads, the values of the coefficients of vertical crumpling of the warp η_{bv} and weft η_{wv} threads based on the study of the contact zones between the threads in woven reinforcing frames FPH of various diameters of production of “BEREG” Scientific Production Association (Russian Federation) at their section.

The JSM-6490LV scanning electron microscope was used to investigate the microstructure and analyze the surface of various materials, as well as measure the scale factor of the video image by acquiring an image of the surface of an object with a high spatial resolution. The principle of operation of a microscope is based on the interaction of the electron beam with the object under study.

The resulting zones along the warp and weft threads of contact between the threads of the woven reinforcing frames of the various diameters FPH were scanned with the electron beam of the microscope, and the backscattered electrons that were generated carried the information about the surface topography. The video signal obtained on the basis of this information formed a topographical image of the contact zone between the threads, which made it possible to study this zone. The composition of the microscope includes:

- system of energy dispersive microanalysis INCA Energi 450;
- electron-optical system;
- five-axis motorized object table and object camera;
- electronic detector;
- display, operating and vacuum systems.

All operations with a microscope were carried out with the help of a personal computer on which the autonomous computer software was installed.

The microscope allows making an increase in the object under study with the multiplicity from 8 to 300000.

The processing of experimental data was carried out using statistical methods.

As examples in fig. 1–10 present photographs of the contact zones between the threads in the reinforcing woven frameworks of the FPH produced by the “Bereg” SPA with diameters of 51 mm, 66 mm, 77 mm, 89 mm, 150 mm with sections along the warp and weft at 50, 40 and 37 times magnification after their rupture at a sufficient distance from the local zone of rupture.

We present the methodology of experimental studies of the contact zones between the threads in the woven reinforcing frames of the FPH using a JSM-6490LV scanning electron microscope, on the basis of which the coefficients η_{bv}, η_{wv}, β_b, β_w were determined.

Employees of the department of certification and metrological support of the federal state budgetary institution of the All-Russian Fire Protection Research Institute of the Ministry of Emergency Situations of the Russian Federation (FSBI ARFPRI MES RF) (Balashikha, Moscow oblast) carried out experiments in accordance with GOST R 51049-2008 (Russia) (Method for determining the rupture pressure of the sleeve) by breaking the latexed FPH produced by “BEREG” SPA with diameters from 51 mm to 150 mm in order to determine an experimental values of the internal data burst pressures sleeves at their certification.

From the FSBI ARFPRI MES RF of RF we obtained data on the bursting pressure of latexed FPH produced by “BEREG” SPA diameters from 51 mm to 150 mm, as well as pieces of these sleeves after conducting an experiment on their rupture, which we investigated using a JSM-6490LV microscope. These segments were cut from the FPH, subjected to the tensile test, at a sufficient distance from the local zone of the sleeve destroyed at break.

Consider the method of research on the example of determining the coefficients of vertical crumpling of the main thread of the FPH with a diameter of 51 mm. A segment of the FPH with a diameter of 51 mm was cut into ten samples from 50 to 70 mm each. Then each of these samples was cut with a sharp blade along the weft and warp yarn.

Thus, ten samples were obtained for the study of contact zones with a cut along the base and ten samples for the study of contact zones with a cut along the weft for a panorama of 51 mm in diameter, which were examined using a JSM-6490LV microscope.

The area of contact between the threads was studied with the help of a microscope using the built-in microscope equipment and ten photographs were taken of the area of contact between the threads in a woven reinforcing frame of FPH of 51 mm in diameter when cut along the weft thread at 50 time magnification (one of these photographs is shown in Fig. 2). The photograph clearly shows the crumpled cross section of the main thread, similar in shape to the ellipse. For all ten photographs, using the measuring unit of the microscope, we measured the crumpled section of the warp thread vertically - the minor axis of the ellipse.

RESULTS AND DISCUSSION

The results were processed by statistical methods: the results of a test sample (10 samples) were used to calculate the variance and determine the number of representative (reliable) samples (number of photos of contact areas to determine the vertical collapse) with a confidence level of 0.954 and a marginal error not exceeding 5%.

The variance of the test sample was calculated by the formula:

$$\sigma^2 = \frac{\sum_{i=1}^{n}\left(x_i - \overline{x}_{test}\right)}{n_{test} - 1} \qquad (1)$$

where: x_i - the current value of the crumpled section of the thread;

$\overline{x}_{test}$ - the average value in the test sample of the crumpled section of the thread;

n_{test} - the number of sample.

The number of a representative sample was determined by the formula:

$$n_x = \frac{t^2\sigma^2}{\Delta_{\overline{x}}^{\,2}}, \qquad (2)$$

where: t is the confidence coefficient (selected from the tables depending on the value of the confidence probability; in our case, when $P(x) = 0.954 \cdot t = 2$;

$\Delta_{\overline{x}}$ - marginal sampling error (5% of the average value of the thread crease).

For example, for the FPH with a diameter of 51 mm, the required number of experiments turned out to be 12. Therefore, to the ten experiments already conducted (10 photographs) we added another 2. For each of the 12 photographs, we measured the crumpled section of the warp thread vertically using a measuring microscope unit (the minor axis of the ellipse), then the results were summed, and the number obtained was divided by 12 to obtain the average value of the crumpled cross section of the thread, taking into account the increase.

This average value was divided by the increase coefficient (see in accordance with Fig. 2 with a fifty-time increase), i.e. fifty and received the average actual size of the main thread crumpling vertically. So, for example, the average size of a crumpled section of a thread on vertical along 12 photos, similar to that shown in fig. 2, was 33.18 mm.

This value was divided by 50 (because the photo with a fifty-time increase) and received the actual average size of the crumpled cross section of the warp on the vertical 0.6636 mm with a confidence level of 0.954 and the value of the marginal error not exceeding 5%.

This number was divided by the initial diameter of the warp yarn 1.20 mm. (See [4], table 1. - Baseline data for the calculation of burst pressure in the FPH of "BEREG" SPA) and obtained the coefficient of vertical collapse of the warp: 0.6636: 1.2 = 0.553. This value was entered into table 1. In a similar way, the determination of the coefficients of crushing of the warp and weft of the FPH of other diameters was done.

A similar technique was used in determining the coefficients β_b, β_w. The difference was that in this case the average actual value of the length of the contact zone was determined, which was then divided by the initial value of the corresponding thread diameter.

The values of the coefficients η_{bv}, η_{wv}, β_b, β_w are shown in Table 1.

Table 1 – coefficients η_{bv}, η_{wv}, β_b, β_w of the zone of contact of the threads in the woven reinforcing frameworks of latexed FPH produced by the "Bereg" SPA

Diameter latex PNR, mm	Coefficient of the main thread vertical collapse	Coefficient of the weft thread vertical collapse	Coefficient of contact zone β_O	Coefficient contact area β_Y
150	0.558	0.559	1.13	1.11
89	0.545	0.549	1.16	1.13
77	0.532	0.528	1.18	1.14
66	0.543	0.540	1.17	1.13
51	0.553	0.545	1.16	1.12

Analysis of the obtained crumpling coefficients indicates a relatively small range of their change from 0.528 to 0.559. The values of these coefficients indicate that both the warp and weft threads in the woven reinforcing frames of the FPH produced by the "Bereg" SPA of different diameters are creased slightly less than half. In [5] the author was forced to ask the coefficients of the vertical crumpling of the warp and weft threads, taking them to be 0.55, since their precise experimental determination at the time of rupture of the FPH at the current level of measuring equipment development is extremely difficult, if it possible. The same opinion is shared by the authors of work [6].

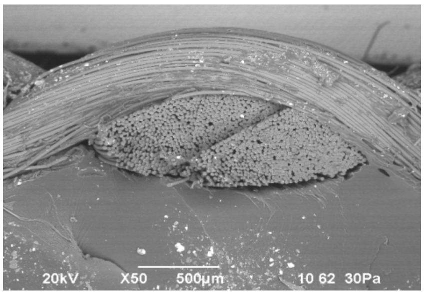

Fig. 1 - Photograph of the contact zone between the threads in the woven reinforcing frame of the FPH with a diameter of 51 mm when cut along the main thread at a 50-time increase after its rupture

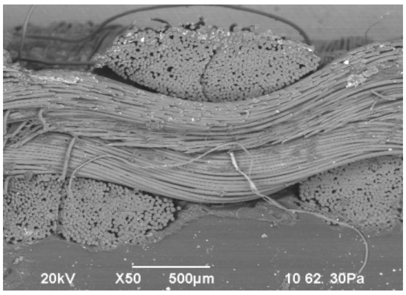

Fig. 2 - Photograph of the contact zone between the threads in the woven reinforcing frame of the FPH with a diameter of 51 mm with a cut along the weft yarn at a 50-time increase after its rupture

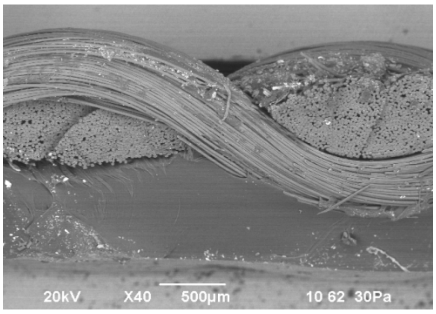

Fig. 3 - Photograph of the zone of contact between the threads in a woven reinforcing frame FPH 66 mm in diameter when cut along the main thread at a 40-time increase after its rupture

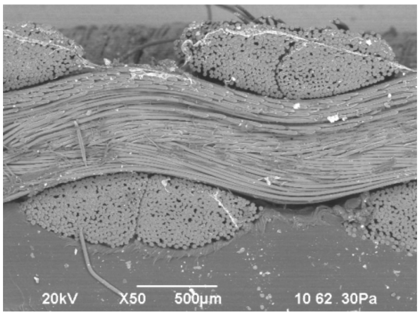

Fig. 4 - Photograph of the contact zone between the threads in the woven reinforcing frame of the FPH with a diameter of 66 mm with a cut along the weft yarn at a 50-time increase after its rupture

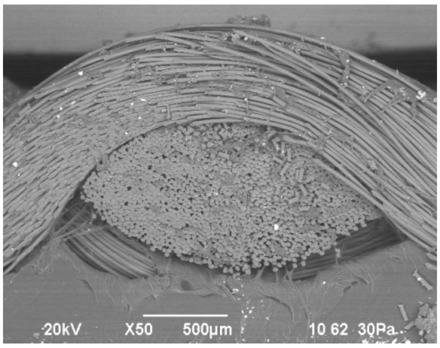

Fig. 5 - Photograph of the contact zone between the threads in the woven reinforcing frame of the FPH with a diameter of 77 mm when cut along the main thread at a 50-time increase after its rupture

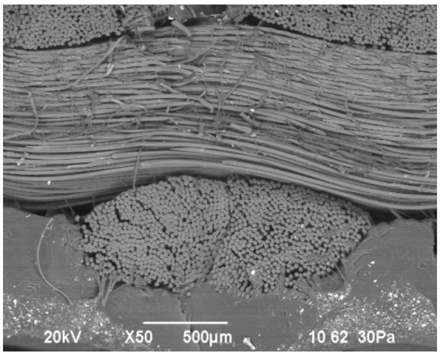

Fig. 6 - Photograph of the contact zone between the threads in the woven reinforcing frame of the FPH with a diameter of 77 mm with a cut along the weft yarn at a 50-time increase after its rupture

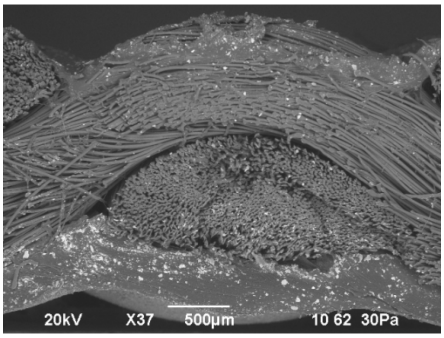

Fig. 7 - Photograph of the contact zone between the threads in the woven reinforcing frame of the FPH with a diameter of 89 mm with a cut along the main thread at a 37-time increase after its rupture

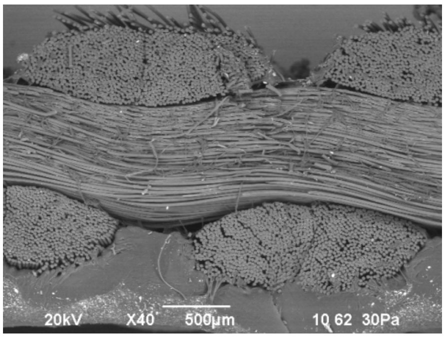

Fig. 8 - Photograph of the contact zone between the threads in the woven reinforcing frame of the FPH with a diameter of 89 mm with a cut along the weft yarn at a 40-time increase after its rupture

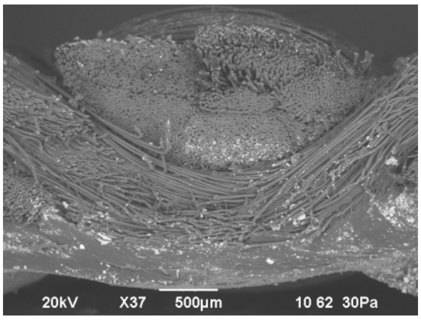

Fig. 9 - Photograph of the contact zone between the threads in the woven frame of the FPH 150 mm in diameter when cut along the main thread at a 37-time increase after its rupture

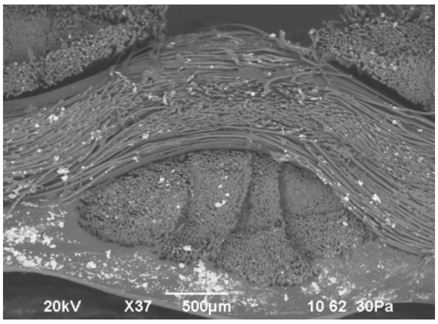

Fig. 10 - Photograph of the zone of contact between the threads in the woven frame of the FPH 150 mm in diameter when cut along the weft yarn at 37-time magnification after its rupture

Our studies show slightly lower values of these coefficients, and, consequently, a greater actual crumpling of the threads of the sleeves woven reinforcing frame.

In [5, p. 59] the author accepts the assumption that the length of the contact arcs between the warp and weft threads in the design model for a weft is equal to the diameter of the main thread, and the length of the contact arc between the weft and the warp thread in the design model for the warp section is equal to the diameter of the weft thread. The latter is equivalent to the adoption of coefficients β_b, β_w equal to one.

Our studies show that the coefficients of the contact zones are higher in value and range from 1.11 to 1.18.

It should also be noted that there may be a question about the unjustified use of data on coefficients η_{bv}, η_{wv}, β_b, β_w obtained for a sleeve that has already undergone rupture to calculate the burst pressure using formula (1) [1], since their values at the moment of rupture will differ from those obtained.

However, we believe that at high forces of mutual pressure between the threads and a strong crumpling of the threads in the radial direction for a long time, the residual deformations become dominant, and the role of the elastic component, which disappears after the load is removed, is not significant in the share of total deformation. Therefore, we believe that due to the dominant residual deformation and relatively small elastic component, such factors as η_{bv}, η_{wv}, β_b, β_w after the experience of breaking the sleeves will be close enough to the values of these coefficients during the break.

The validity of the assumption of the dominant role of the residual deformation is confirmed by the fact that both the visual study and the JSM-6490LV microscope of the warp and weft sections, extracted from the FPH woven reinforcing cages of different diameters after the tensile stress and removal of the load, indicates a strong residual curvature and strong residual vertical crumbling of these threads, and the presence of thin layers of rubber or latex has virtually no effect on these residual deformations.

The validity and justification of using the found coefficients η_{bv}, η_{wv}, β_b, β_w to calculate the burst pressure using formula (1) [1] and, therefore, the conclusion that residual deformation dominates, is well confirmed by comparing the calculated and available experimental data on bursting pressures. This, in our opinion, is the main criterion. The use of the coefficients η_{bv}, η_{wv}, β_b, β_w found by the above method is justified and justifies itself, since it leads to a significant increase in the accuracy of calculations (see [4], table 2 - Calculated and experimental data on rupture pressures in the FPH of “BEREG” SPA).

CONCLUSION

1. A set of experimental studies of contact zones between threads in FPH with use of modern measuring equipment and statistical methods was carried out, as a result of which the values of the coefficients of threads vertical crumbling, the lengths of contact zones between threads in woven reinforcing frames of FPH of different diameters were determined.

2. Calculations taking into account the experimentally obtained values of the lengths of the contact arcs between the warp and weft threads, the values of the coefficients of the vertical crumpling of the warp and weft threads give significantly more accurate results on bursting pressures in FPH which confirms the need to take them into account.

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