IMPROVEMENT OF STRUCTURE AND TECHNOLOGY OF MANUFACTURE OF MULTILAYER TECHNICAL FABRIC

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***Abstract:** At present during construction and operational commissioning of main oil and gas lines pipes with external factory polyethylene coating are used. Comparing to field coating of pipelines with insulation material introduction of factory insulation of pipes technology allowed for both getting a boost of pipes construction and significantly improve efficiency of its anticorrosive protection. In both, the first and the second, cases for backing up and laying pipes with external factory insulation coating the chains and cords cannot be used. Extreme pressure in the contact area leads to damage of insulation coating, inducing metal corrosion where sections with damaged insulation contact with water and soil.*

Woven power grips are used for laying pipes with factory insulation coating. These grips are manufactured of multilayer technical fabrics. Structure of multilayer technical fabrics and conditions of its formation on a loom determine effectiveness of the woven power grips manufacturing process.

In this work the improvement of multilayer technical fabric was conducted and experimental researches of its formation on the loom were carried out. The influence was determined of warp yarn input tension, value of different tension of shed and value of spade on value of beat-up force, main technological parameter determining intensity of fabric formation process.

The researches that were carried out allowed to improve the structure of the multilayer technical fabric. Comparative analysis of conditions of prototype formation and formation of proposed multilayer technical fabric on the loom was carried out. Resulting from the experiment beat-up force value regression dependences on value of input tension of warp yarns, different tension of shed and value of spade were obtained. Analysis of regression dependences allowed to determine optimal parameters of loom threading.

***Keywords:** woven power grips, multilayer technical fabric, beat-up force, warp yarns tension, fabric tension, fabric breaking force.*

1 INTRODUCTION

At present during construction and operational commissioning of main oil and gas lines pipes with external factory polyethylene coating are used (Figure 1a). Factory insulation of pipes is the reliable protection against corrosion. Polymer coating prevents from rust formation and early wear of steel utilities. Corrosion protection is applied to steel pipelines, which are laid under ground or in high humidity. Constant contact with wet ground, air and water may lead to rapid damage of metalware. Polymeric factory insulation protects metal against contact with aggressive external environments and by several times extends the service life of pipelines. Comparing to field coating of pipelines with insulation material introduction of factory insulation of pipes technology allowed for both getting a boost of pipes construction and significantly improve efficiency of its anticorrosive protection. In both, the first and the second, cases for backing up and laying pipes with external factory insulation coating the chains and cords cannot be used [1]. Extreme pressure in the contact area leads to damage of insulation coating, inducing metal corrosion where sections when damaged insulation contacts with water and soil.

Woven power grips (Figure 1b) are used for laying pipes with factory insulation coating. These grips are manufactured of multilayer technical fabrics [1-3]. Structure of multilayer technical fabrics and conditions of its formation on a loom determine effectiveness of the woven power grips manufacturing process [1-4].

Design of woven power grips is presented on the Figure 2. Woven power grip represents locked loop from 20 cm multilayer technical fabric, ends of which are joined in the H area. Surface of grip A is in contact with ground surface. Surface of grip B is in contact with insulation coating of the pipe. In the areas C and D the grip is in contact with rollers of the lifting machine. These four areas provide for maximum wear of the surface of multilayer technical fabric. Process of friction between the surface of the woven power grip and indicated areas is of great importance [5-7]. Should gravitation force of the pipe G increase, width of the grip may be extended by means of adding another strip of 20 cm multilayer technical fabric (Figure 1b).

a) b)

Figure 1 Components and way of laying oil and gas pipelines: a) pipes with external factory insulation coating; b) woven power grips

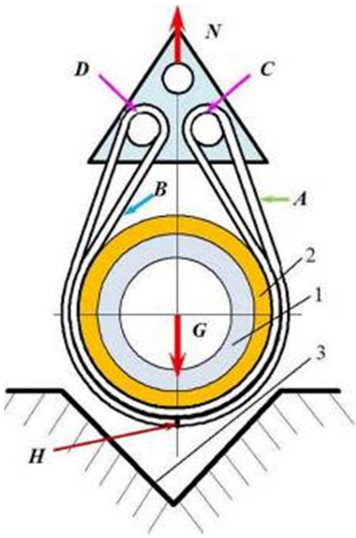
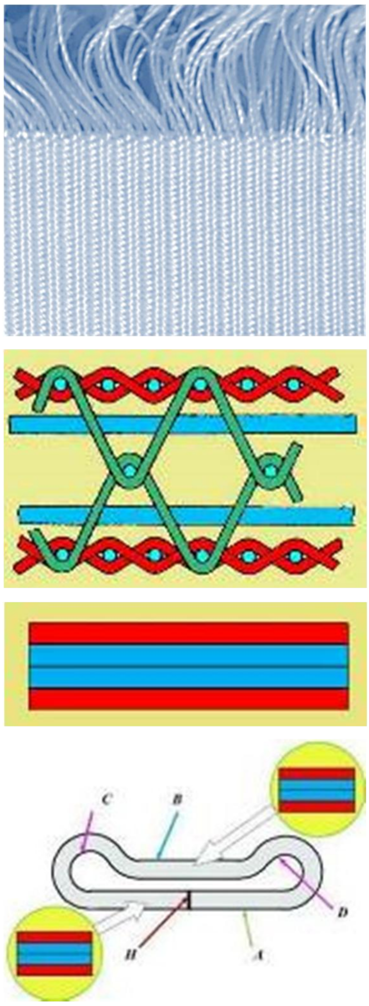


Figure 2 Design of woven power grip: 1 - pipe; 2 - insulation coating; 3 - ground surface; A - surface of the woven power grip, which is in contact with ground; B - surface of the woven power grip, which is in contact with insulation coating; C, D - surface of the woven power grip, which is in contact with rollers of the lifting machine; H - area of edge-joint of multilayer technical fabric; G - gravitation force of the pipe; N - lifting force

2 MATERIALS

Multilayer technical fabric MTF-1 (Figure 3a) was used for woven power grip. This fabric consists of 5 layers. Figure 3b shows cross-section of fabric along warp yarns. Warp yarns of external protective layers (PL) are shown in red colour, warp yarns of force layers (FL) are shown in blue colour. Warp yarns for binding external protective layers and force layers (BIN) are shown in green colour. Main element of woven power grip is warp yarns of the force layers.



a) b) c) d)

Figure 3 Multilayer technical fabric MTF-1: a) general view; b) cross-section of fabric along warp yarns; c) conventional design of cross-section of fabric along warp yarns represented as layers; d) woven power grip represented as locked loop from multilayer technical fabric MTF-1

External protective layers are meant for protection of the force layers (Figure 3c). For fabric MTF-1 (width 20 cm) 816 hard-twisted caprone multifilaments 29 tex S110x2 S300 Z 180 were used as warp yarns of external protective layers (PL) [8]. 544 caprone multifilaments 93.5 tex S 30 Z 60 were used as warp yarns of force layers (FL).

136 caprone multifilaments 29 tex S110x2 S300 Z 180 were used as warp yarns for binding of external protective layers and force layers (BIN).

Analysis of woven power grip as locked loop from multilayer technical fabric MTF-1 (Figure 3d) shows that top protective layer is inside the loop and does not protect force layers. It is formed of hard-twisted caprone multifilaments, which are significantly more expensive in manufacturing comparing to manufacture of warp yarns of the force layers. This layer is virtually extra one in the structure of the multilayer technical fabric. This condition should be considered while improving the structure of the multilayer technical fabric.

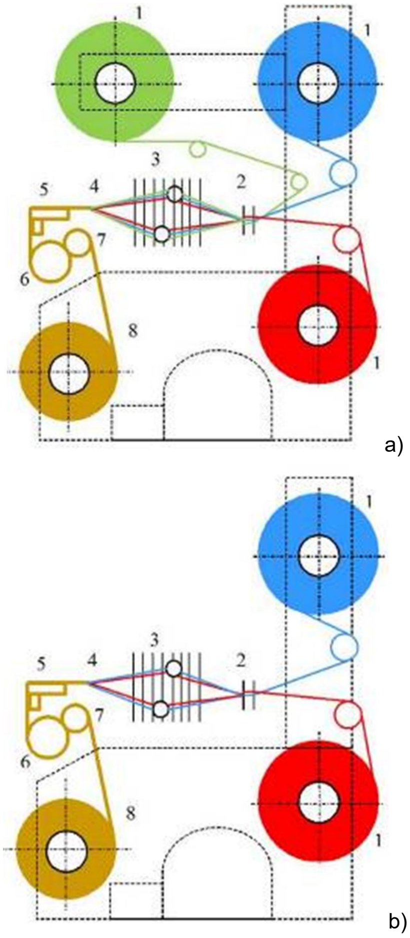


Figure 4 Elastic system of threading for warp yarns on looms:
a) during manufacture of multilayer technical fabric MTF-1;
b) during manufacture of multilayer technical fabric MTF-9;
1 - weaver beam; 2 - warp yarn break detector; 3 - heddle frames of shed development mechanism; 4 - area of multilayer technical fabric formation; 5 - breast beam; 6 - roller; 7 - roller for fabric pressing; 8 - shaft for winding of fabric; ■ - warp yarns for binding external protective layers and force layers (BIN); ■ - warp yarns of force layers (FL); ■ - warp yarns of protective layers (PL); ■ - multilayer technical fabric

Figure 4a shows elastic system of warp yarns threading while manufacturing of multilayer technical fabric MTF-1. Automatic loom with center-shed dobby for 8 heddle frame was used to manufacture the fabric. Warp yarns are arranged on three beams. It significantly aggravates servicing of the loom [2, 3]. Different contraction of warp yarns (Figure 3b) involves creation of different input tension for each type of warp yarns [4, 8-10].

Figure 4b shows elastic system of warp yarns threading while manufacturing of multilayer technical fabric MTF-9. Warp yarns are located on two beams. It makes servicing of the loom much easier while manufacturing of fabric comparing to multilayer technical fabric MTF-1.

In result of researches carried out for woven power grip the multilayer technical fabric MTF-9 (Figure 5a) was offered. This fabric includes 6 layers. Figure 5b shows cross-section of fabric along warp yarns. Warp yarns of external protective layers (PL) are shown in red colour, warp yarns of force layers (FL) are shown in blue colour. Main element of the woven power grip is warp yarns of the force layers (FL).

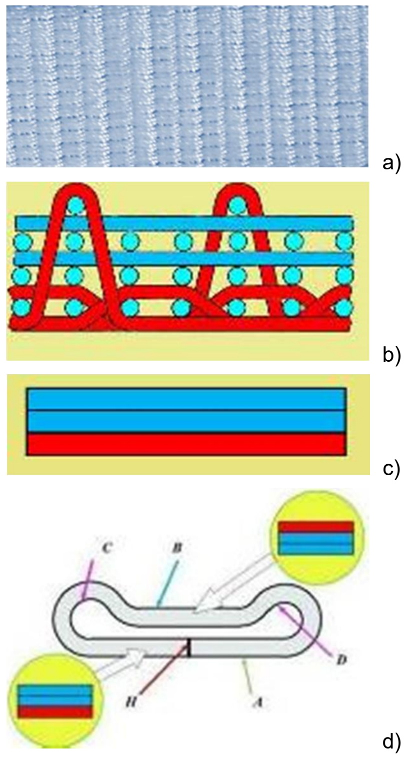


Figure 5 Multilayer technical fabric MTF-9:
a) general appearance; b) cross-section of fabric along warp yarns; c) conventional representation of cross-section of fabric along warp yarns in the form of layers; d) woven power grip in the form of locked loop made of multilayer technical fabric MTF-9

External protective layers are intended for protection of the force layers (Figure 5c). For fabric MTF-9 (width 20 cm) 488 caprone multifilaments 29 tex S110x2 S300 Z 180 were used as warp yarns of the external protective layers (PL). 952 caprone multifilaments 93.5 tex S 30 Z 60 were used as warp yarns of force layers (FL). In this structure connection between the layers is due to warp yarns of the external protective layers (PL). Hard-twisted caprone multifilaments 29 tex S110x2 S300 Z 180 were used as weft yarns.

Analysis of the woven power grip in the form of locked loop made of multilayer technical fiber MTF-9 (Figure 5d) shows that warp yarns of the two force layers (FL) will be placed inside the woven power grip. While using the woven power grip, force layers will not contact with ground surface, pipe surface, and rollers of the lifting device (Figure 2). It will allow to avoid damage to the force layers. Exclusion of upper protective layer allowed to increase number of warp yarns in the two force layers (FL).

3 EXPERIMENT

Four plans of experimental researches were implemented to determine the influence of the structure of the multilayer technical fabric for power grips on conditions of its formation on the loom [5-7, 9-14]. Two multilayer technical fabrics MTF-1 and MTF-9 were chosen for experiment. Tables 1 and 3 represent matrixes of the experimental researches that were carried out to determine influence of the input tension of warp yarns of the protective layers on beat-up force value for multilayer technical fabric MTF-1 and MTF-9. Position of the backrest over the middle level and value of spade corresponded to the center of the experiment that was carried out to determine joint influence of the spade and different tension of shed on the beat-up force value. For multilayer technical fabric MTF-1 the input tension of warp yarns of the protective layers changed within the limits from 164.7 to 223.4 cN. For multilayer technical fabric MTF-9 the input tension of warp yarns of the protective layers changed within the limits from 125.8 to 175.4 cN.

Table 1 Matrix of the plan that determines influence of the input tension of the warp yarns of the protective layers on the beat-up force value for multilayer technical fabric MTF-1

№.	Position of the backrest over the middle level		Value of spade		Input tension of the warp yarns of the protective layers
	x_1	h [mm]	x_2	φ_Z [°]	P_S [cN]
I-1	0	0	0	45	192.2
I-2	0	0	0	45	164.7
I-3	0	0	0	45	178.3
I-4	0	0	0	45	208.3
I-5	0	0	0	45	223.4

In Table 1 x_1 coded representation h - values of vertical shift of backrest. When backrest is higher than average level then value h = 10 mm (Table 2 for fabric MTF-1) in coded representation it appears as +1, when backrest is lower than average level then value h = -10 mm (Table 2 for fabric MTF-1) in coded representation it appears as -1. When backrest is at the average level then value h = 0 mm (Table 2 for fabric MTF-1) in coded representation it appears as 0. Value φ_Z shows the value of spade - angle, created by the warp yarns during beat-up. In coded representation it appears as x_2. For multilayer fabric MTF-1 if x_2=0 φ_Z=45°, if x_2=1 φ_Z=55°, x_2=-1 φ_Z=35°. All abovementioned is true for fabric MTF-9. Numeric values shall be taken from Tables 2 and 4.

Tables 2 and 4 show matrixes of orthogonal design of the second order for two factors that determine joint influence of spade and different tension of shed on the beat-up force value for multilayer technical fabric MTF-1 and MTF-9.

Table 2 Matrix of orthogonal design of the second order for two factors that determine joint influence of spade and different tension of shed on beat-up force value for multilayer technical fabric MTF-1

№.	Position of the backrest over the middle level		Value of spade	
	x_1	h [mm]	x_2	φ_Z [°]
I-6	-1	-10	-1	35
I-7	-1	-10	+1	55
I-8	+1	10	-1	35
I-9	+1	10	+1	55
I-10	0	0	-1	35
I-11	0	0	+1	55
I-12	-1	-10	0	45
I-13	+1	10	0	45
I-14	0	0	0	45

Tension of shed is influenced by the value h. If value h = -10 mm branches of the upper part of shed will be more tight. If value h = 10 mm branches of the lower part of shed will be more tight. Increase or decrease of the said parameters lead to change of contact angles between warp yarns and guides and conditions of relative movement of the weft yarn towards warp yarns in the multilayer fabric formation area [9, 11, 15, 16]. For multilayer technical fabric MTF-1 the value of spade changed within limits from 35 to 55°. This value of spade is explained by the formation of external protective layers of this fabric with plain weave (Figure 3b). Different tension of shed was created by means of vertical displacement of the top point of backrest in reference to middle position. This value was changing within limits from 10 to -10 mm. Minus indicates that backrest descended below middle position. For multilayer technical fabric MTF-9 the value of spade changed within limits from 6 to 22°. This value of spade allows to realize normal formation of external protective layer. Different tension of shed was changing within limits from 10 to -10 mm.

Connection between denominated and coded values for multilayer technical fabric MTF-1 shall be as follows:

$$x1 = \frac{h}{10}, \quad x2 = \frac{\varphi_Z - 45}{10}, \tag{1}$$

for multilayer technical fabric MTF-9 shall be as follows:

$$x1 = \frac{h}{10}, \quad x2 = \frac{\varphi_Z - 14}{8}. \tag{2}$$

Table 3 Matrix of the plan that determines the influence of the input tension of warp yarns of protective layers on the beat-up force value for multilayer technical fabric MTF-9

№.	Position of the backrest over the middle level		Value of spade		Input tension of the warp yarns of the protective layers
	x_1	*h* [mm]	x_2	φ_Z [°]	P_S [cN]
II-1	0	0	0	14	150.6
II-2	0	0	0	14	125.8
II-3	0	0	0	14	143.2
II-4	0	0	0	14	162.0
II-5	0	0	0	14	175.4

Table 4 Matrix of orthogonal design of the second order for two factors that determine joint influence of spade and different tension of shed on beat-up force value for multilayer technical fabric MTF-1

№.	Position of the backrest over the middle level		Value of spade	
	x_1	*h* [mm]	x_2	φ_Z [°]
II-6	-1	-10	-1	6
II-7	-1	-10	+1	22
II-8	+1	10	-1	6
II-9	+1	10	+1	22
II-10	0	0	-1	6
II-11	0	0	+1	22
II-12	-1	-10	0	14
II-13	+1	10	0	14
II-14	0	0	0	14

Experimental setup for determining technological efforts during formation of multilayer technical fabrics is described in the work in reasonable details [2-4, 11]. It included eight-channel amplifier 8АНЧ-7М, oscillograph H-700, power modules for them. Separate measuring tensometric units were intended to determine tension of warp yarns, beat-up force, and tension of fabric. Time records after 0.2 seconds were recorded by the oscillograph H-700 itself. Figure 6 shows an example of oscillogram. Three repetitive oscillograms were done for each series. Calibration charts were obtained for each measuring tensometric unit for determining tension of warp yarns, beat-up force and tension of fabric. These charts were used for interpretation of oscillograms.

The work contains a series of experimental researches that determines influence of the structure of the multilayer technical fabric and conditions of its manufacturing on the loom on the breaking load value of 20 cm strip. This series of experiments was carried out in the Institute of strength problems of the Academy of Sciences of Ukraine. Experiments were carried out using INSTRON 8802 tensile-testing machine (breaking force up to 250 kN). Ten replicated experiments were carried out for each series.

To fasten 20 cm strip of the multilayer technical fabric shaped clamps with movable axles (70 mm in diameter) were inserted into the upper and lower grips of INSTRON 8802 tensile-testing machines [17]. Loose ends of fabric wrapping around these axles and were joined. To fix the joint the area of joining was clamped on both sides with metal plates, fixed by 5 screws with nuts on each end of the sample. Such a fastening scheme made it possible to exclude slippage of the loaded branch of the fabric against the unloaded end of the fabric during tensile tests.

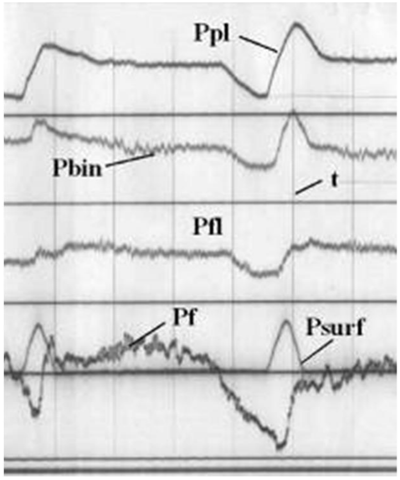


Figure 6 Example of oscillography record of technological efforts during formation of multilayer technical fabrics: PSURF - beat-up force; PPL - tension of the warp yarns of the external protective layers (PL); PBIN - tension of warp yarns for binding of external protective and force layers (BIN); PFL - tension of warp yarns of the force layers (FL); PF - tension of fabric; t - time

4 RESULTS AND DISCUSSION

Figure 7 shows results of tensile test for 20 cm strips of multilayer technical fabrics MTF-1 and MTF-9.

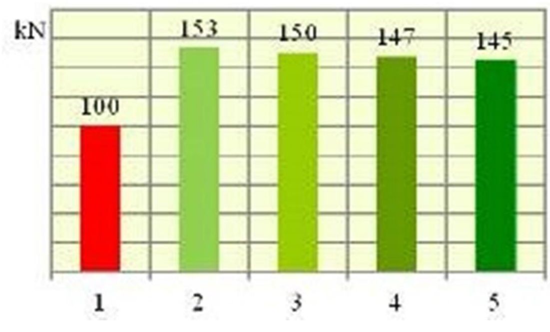


Figure 7 Breaking force values of the multilayer technical fabrics: 1) MTF-1 (density of weft yarns 100 yarns/dm); 2) MTF-9 (density of weft yarns 100 yarns/dm); 3) MTF-9 (density of weft yarns 120 yarns/dm); 4) MTF-9 (density of weft yarns 130 yarns/dm); 5) MTF-9 (density of weft yarns 140 yarns/dm)

Where the same density of fabric along the weft yarns breaking strength of the multilayer technical fabric MTF-9 is higher by 53% comparing to its prototype. The influence of density along the weft yarns of the multilayer technical fabric MTF-9 on the breaking force value was determined separately. It was established that the higher the density along the weft yarns the lower breaking force value. It is explained by more strained conditions of fabric formation on the machine.

Figure 7 represents results of experimental researches determining breaking load processed in terms of math statistics methods. They reflect the process with the 95% confidence probability.

According to experiment plans the data were obtained that determined the influence of threading tension of the warp yarns on the conditions of multilayer technical fabric formation MTF-1 (Table 5) and MTF-9 (Table 6).

For multilayer technical fabrics MTF-1 if threading tension of the ground/back warp yarns increases from 164.7 cN (variant I-2) to 223.4 cN (variant I-5) the beat-up force increases from 139.3 to 152.5 cN by one yarn. At the same time the value of the beat strip decreases from 22.3 to 12.6 mm. Where threading tension increases, warp tension at the fell of the fabric in the moment of beat increases as follows: ground/back warp yarns from 239.0 cN (variant I-2) to 289.6 cN (variant I-5) and weft warp yarns from 168.7 cN (variant I-2) to 244.2 cN (variant I-5).

For multilayer technical fabrics MTF-9 if threading tension of the ground/back warp yarns increases from 125.8 cN (variant II-2) to 175.4 cN (variant II-5) the beat-up force increases from 72.5 to 118.7 cN by one yarn. At the same time the value of the beat strip decreases from 18.2 to 7.2 mm. Where threading tension increases, warp tension at the fell of the fabric in the moment of beat increases as follows: ground/back warp yarns from 217.7 cN (variant II-2) to 261.4 cN (variant II-5) and weft warp yarns from 124.1 cN (variant II-2) to 206.3 cN (variant II-5).

Tables 5 and 6 represent data determining influence of the feeding tension of warp yarns for conditions of formation of multilayer technical fabrics MTF-1(Table 5) and MTF-9 (Table 6). They represent results of measurings: P_S - feeding tension of warp yarn; P_{SURF} - beat-up force per one warp yarn being fed, being static and being dynamic; P_{FZ} - tension of warp yarn before the area of multilayer fabric formation; P_{RZ} - tension of warp yarn before shedding motion; t_P - time of beat-up; l_P - length of the beat strip; P_F - tension of fabric per one warp yarn.

Table 5 Results that determines influence of the input tension of warp yarns of the protective layers on the beat-up force value for multilayer technical fabric MTF-1

№.	Warp yarns	Branch of shed	P_S [cN]	P_{SURF} [cN] Statics	P_{SURF} [cN] Dynamics	P_{FZ} [cN]	P_{RZ} [cN]	$t_P \cdot 10^{-2}$ [s]	l_P [mm]	P_F [cN]
I-1	PL	1	192.2	61.2	142.8	264.0	249.6	2.5	15.9	73.4
		2	192.2			251.5	240.3			
		3	192.2			228.6	221.0			
	BIN	1	47.8			137.6	130.1			
		2	47.8			136.2				
	FL	3	102.1			213.7	199.1			
I-2	PL	1	164.7	42.8	139.3	239.0	226.7	3.08	22.3	56.3
		2	164.7			229.9	219.6			
		3	164.7			212.5	203.4			
	BIN	1	47.8			132.8	125.6			
		2	47.8			131.5				
	FL	3	42.2			168.7	97.2			
I-3	PL	1	178.3	52.9	140.0	253.7	239.8	2.53	16.7	71.1
		2	178.3			242.0	231.2			
		3	178.3			230.3	222.6			
	BIN	1	47.8			140.5	132.8			
		2	47.8			139.0				
	FL	3	69.5			203.1	149.2			
I-4	PL	1	208.3	67.8	147.8	277.9	262.7	2.35	15.0	93.0
		2	208.3			267.1	255.1			
		3	208.3			257.4	248.8			
	BIN	1	47.8			142.1	134.8			
		2	47.8			140.7				
	FL	3	125.4			231.1	245.3			
I-5	PL	1	223.4	72.3	152.5	289.6	273.8	2.09	12.6	94.2
		2	223.4			280.0	267.5			
		3	223.4			273.6	264.4			
	BIN	1	47.8			139.1	131.5			
		2	47.8			137.6				
	FL	3	150.3			244.2	287.5			

Table 6 Results that determines influence of the input tension of warp yarns of the protective layers on the beat-up force value for multilayer technical fabric MTF-9

№.	Warp yarns	Branch of shed	P_S [cN]	P_{SURF} [cN] Statics	P_{SURF} [cN] Dynamics	P_{FZ} [cN]	P_{RZ} [cN]	$t_P \cdot 10^{-2}$ [s]	l_P [mm]	P_F [cN]
II-1	PL	1	150.6	51.9	101.6	246.6	235.5	2.01	11.9	70.8
		2	150.6			256.7	241.0			
		3	150.6			172.8	169.5			
	FL	1	56.1			181.7	169.0			
		3	56.1			96.3	93.1			
II-2	PL	1	125.8	29.1	72.5	217.7	208.8	2.68	18.2	74.7
		2	125.8			225.7	211.9			
		3	125.8			145.8	143.1			
	FL	1	26.8			124.1	115.5			
		3	26.8			65.1	63.0			
II-3	PL	1	143.2	34.2	80.3	229.6	220.1	2.26	14.5	76.6
		2	143.2			239.7	225.0			
		3	143.2			157.9	154.9			
	FL	1	38.3			134.6	125.2			
		3	38.3			81.0	78.3			
II-4	PL	1	162.0	52.1	197.4	255.8	245.3	1.96	11.7	82.5
		2	162.0			272.3	255.7			
		3	162.0			176.4	173.1			
	FL	1	61.6			194.0	180.5			
		3	61.6			102.5	99.1			
II-5	PL	1	175.4	59.8	118.7	261.4	250.5	1.39	7.2	86.6
		2	175.4			275.1	258.3			
		3	175.4			188.5	185.0			
	FL	1	72.2			206.3	191.9			
		3	72.2			152.6	147.6			

Two plans of active carrying out of experiment (Tables 7, 8) were realized to determine joint influence of spade value φ_Z and different tension of shed h. For multilayer technical fabric MTF-1 the value of different tension of shed changed within limits from -10 to 10 mm with a step of 10 mm; the value of spade changed within limits from 350 to 550 with a step of 100. For multilayer technical fabric MTF-9 the value of different tension of shed changed within limits from -10 to 10 mm with a step of 10 mm; the value of spade changed within limits from 60 to 220 with a step of 80. Such decrease in value of spade comparing to multilayer technical fabric MTF-1 induces decrease in dynamic and static components of the warp yarns tension in the 3rd branch of the shed. The backrest shall be installed 10 mm lower with respect to neutral line; and that what corresponds to its optimal position.

Using data from Tables 7 and 8 for multilayer technical fabric MTF-1 and MTF-9, using well-known method of coefficient determination in the regression equation for orthogonal design of the 2nd order the following regression dependencies were obtained: for MTF-1

$$P = 2488.2 + 46.3h - 14.8\varphi_Z - 0.68h\varphi_Z - 1.4h^2, \quad (3)$$

for MTF-9

$$P = 1511.2 + 16.7h - 31.4\varphi_Z - 0.7h\varphi_Z - 0.4h^2 + 0.7\varphi_Z^2. \quad (4)$$

Efficacy of obtained regression dependences were checked using SPSS program for statistical processing of experimental data [4-7, 10, 12-16]. Analysis of coefficient significance of regression dependences (3) and (4) allowed to drop insignificant [6, 11-14, 17]. In regression dependences (3) and (4) value of spade φ_Z shall be inserted in degrees [°], and h value that characterizes different tension of shed shall be inserted in mm.

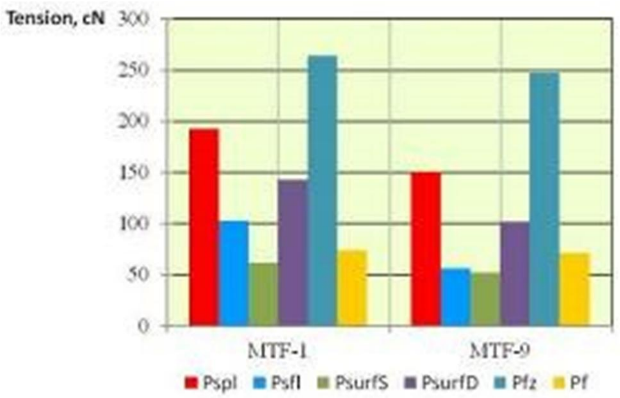


Figure 8 Comparative analysis of the manufacturing conditions for multilayer technical fabrics MTF-1 and MTF-9: ■ - tension of warp yarns of the external protective layers(PL) in static conditions P_{SPL}; ■ - tension of warp yarns of the force layers(FL) in static conditions P_{SFL}; ■ - beat-up force equivalent to one warp yarn in statics $P_{SURF}S$; ■ - beat-up force equivalent to one warp yarn in dynamics $P_{SURF}D$; ■ - tension of warp yarns of the external protective layers(PL) before the area of fabric formation P_{FZ}; ■ - tension of fabric equivalent to one warp yarn P_F

Table 7 Results that determines joint influence of spade and different tension of shed on beat-up force value for multilayer technical fabric MTF-1

№.	Warp yarns	Branch of shed	P_{SURF} [cN]		P_{FZ} [cN]	P_{RZ} [cN]	P_F [cN]
			Statics	Dynamics			
I-9	PL	1	39.1	117.7	229.6	217.3	67.2
		2			219.5	209.6	
		3			200.0	193.2	
	BIN	1			153.8	145.4	
		2			152.2		
	FL	3			145.9	135.9	
I-7	PL	1	33.7	98.5	226.1	213.7	76.9
		2			215.3	205.6	
		3			194.8	188.3	
	BIN	1			148.5	140.4	
		2			146.9		
	FL	3			139.3	129.7	
I-8	PL	1	49.1	139.7	243.9	230.5	64.3
		2			232.6	222.2	
		3			209.6	202.5	
	BIN	1			166.4	157.3	
		2			164.6		
	FL	3			186.8	174.0	
I-6	PL	1	38.6	108.4	229.5	216.9	75.1
		2			219.0	209.2	
		3			198.2	191.4	
	BIN	1			153.5	145.1	
		2			151.9		
	FL	3			145.7	135.7	
I-12	PL	1	36.4	102.1	226.6	214.1	69.8
		2			216.1	206.4	
		3			192.5	186.0	
	BIN	1			150.5	142.3	
		2			148.9		
	FL	3			140.5	130.9	
I-13	PL	1	42.2	120.9	236.2	223.3	73.1
		2			225.2	215.1	
		3			204.3	197.4	
	BIN	1			164.1	155.1	
		2			162.3		
	FL	3			165.5	154.1	
I-10	PL	1	48.1	133.0	239.8	226.7	67.0
		2			230.7	220.4	
		3			205.6	198.7	
	BIN	1			164.3	155.3	
		2			162.5		
	FL	3			174.8	162.8	
I-11	PL	1	40.8	111.6	234.3	221.4	71.8
		2			223.1	213.1	
		3			208.1	201.1	
	BIN	1			159.3	150.6	
		2			157.6		
	FL	3			146.2	136.2	
I-14	PL	1	42.8	119.6	236.0	223.1	66.9
		2			224.3	214.3	
		3			203.4	196.6	
	BIN	1			163.7	154.8	
		2			162.0		
	FL	3			164.4	153.1	

Figure 8 shows comparative analysis of the manufacturing conditions for multilayer technical fabrics MTF-1 and MTF-9. Threading tension of the warp yarns of the external protective layers (PL) decreased by 22% (from 192.2 to 150.6 cN), threading tension of the warp yarns of the force layers (FL) decreased by 45% (from 102.1 to 56.1 cN), beat-up force, equivalent to one yarn, in static conditions decreased by 15% (from 61.2 to 51.9 cN), beat-up force, equivalent to one yarn, in dynamic conditions decreased by 29% (from 142.8 to 101.6 cN), tension of the warp yarns of the external protective layers (PL) decreased by 7% (from 264.0 to 246.6 cN), tension of fabric at the moment of beat, equivalent to one yarn, decreased by 4%(from 73.4 to 70.8 cN). Value of beating strip decreased from 15.9 to 11.9 mm.

Table 8 Results that determines joint influence of spade and different tension of shed on beat-up force value for multilayer technical fabric MTF-9

№.	Warp yarns	Branch of shed	P_{SURF} [cN] Statics	Dynamics	P_{FZ} [cN]	P_{RZ} [cN]	P_F [cN]
II-9	PL	1	26.2	76.6	153.5	147.2	58.9
		2			161.3	151.4	
		3			135.9	132.9	
	FL	1			124.1	115.5	
		3			107.5	103.4	
II-7	PL	1	22.3	72.5	145.0	131.0	48.3
		2			152.2	143.5	
		3			128.7	125.8	
	FL	1			117.6	109/4	
		3			94.2	90.6	
II-8	PL	1	39.2	97.6	196.2	188.1	68.1
		2			205.5	192.9	
		3			169.0	166.7	
	FL	1			158.2	147.1	
		2			138.5	135.2	
II-6	PL	1	28.2	79.2	158.4	151.9	51.9
		2			166.8	155.6	
		3			137.9	136.0	
	FL	1			128.4	119.4	
		3			102.3	99.9	
II-12	PL	1	24.1	73.2	145.1	139.1	45.4
		2			154.2	144.8	
		3			126.6	124.2	
	FL	1			107.9	100.4	
		3			89.1	86.1	
II-13	PL	1	30.1	79.9	160.6	154.0	54.4
		2			168.3	158.0	
		3			141.1	138.5	
	FL	1			129.5	120.5	
		3			112.8	109.1	
II-10	PL	1	35.6	88.3	177.0	169.7	63.1
		2			186.0	174.6	
		3			154.1	152.0	
	FL	1			143.1	133.1	
		3			125.6	122.5	
II-11	PL	1	24.5	75.6	150.8	144.6	50.9
		2			159.2	149.4	
		3			135.7	132.6	
	FL	1			122.5	114.0	
		3			105.2	101.1	
II-14	PL	1	28.7	79.6	159.1	152.6	60.2
		2			167.6	157.4	
		3			140.8	138.1	
	FL	1			129.1	120.1	
		3			112.1	108.4	

Obtained results allow to state that multilayer technical fabric MTF-9 manufactured on the machine at smaller technological loads. It allows significantly cut yarn breakages, preserve their strength properties, and increase machine capacity.

5 CONCLUSIONS

Resulting from multi-method experimental researches in improvement of structure and technology of multilayer technical fabric manufacturing the new structure was obtained. Its use leads to 50% increase in strength of power grip for laying pipes with factory insulation coating of oil and gas pipelines. Realization of active planning of the experiment allowed to determine optimal parameters of threading for loom, at which beat-up force of the weft yarn will have minimum necessary value for obtaining multilayer technical fabric of the defined structure. At the same time threading tension of the warp yarns of the external protective layers (PL) decreased by 22%, threading tension of the warp yarns of the force layers (FL) decreased by 45%, beat-up force, equivalent to one yarn, in static conditions decreased by 15%, beat-up force, equivalent to one yarn, in dynamic conditions decreased by 29%, tension of the warp yarns of the external protective layers (PL) before the fabric formation area decreased by 7%, tension of fabric at the moment of beat, equivalent to one yarn, decreased by 4%.

Beat-up force value regression dependences on spade value and different tension of shed were obtained.

Obtained results may be used to improve the structure and technology of multilayer technical fabric manufacturing.

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