YARN TENSION WHILE KNITTING TEXTILE FABRIC

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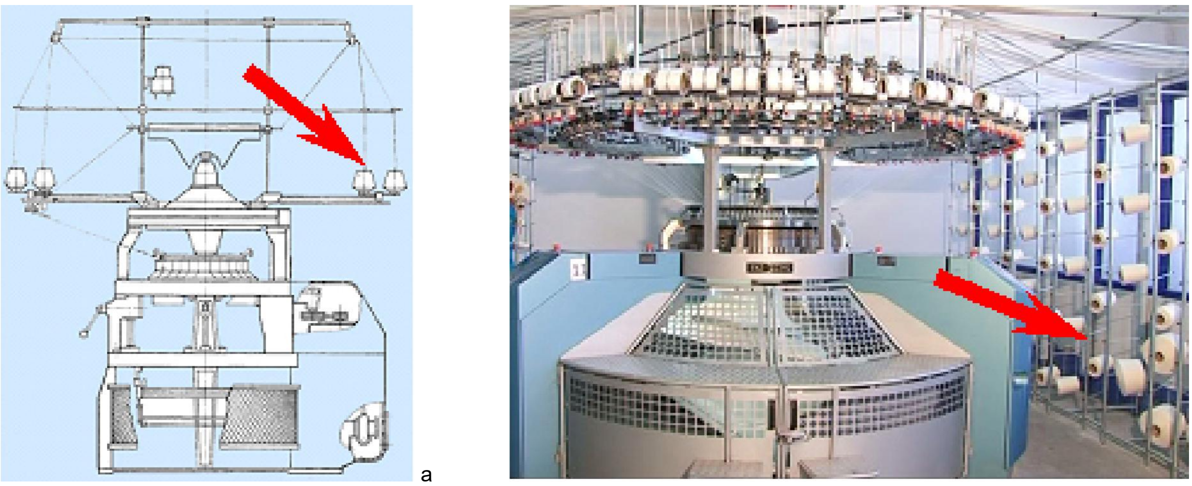
***Abstract:** Yarn tension in looms is a value defining intensity of formation process, structure of knitted fabric. Increased value of yarn tension before it enters knitting area causes a spiraling number of breaks and decreased value causes troubles for the process of lapping the yarn under the needle of the loom. Tension of yarns before they enter knitting area include its tension when going off the bobbin and additional tension arising by virtue of frictional forces between yarns and surfaces of guiding and working components of the loom having the torus form. It is very difficult to determine yarn tension in the loom within the area of textile fabric formation from experiments. It's appropriate to apply recursive approach and to determine tension within the threading areas in the loom from going off the bobbin to knitting area. Our work presents experimental research of interaction between different in their nature natural, synthetic and artificial yarns and spun yarn and surfaces in the form of torus, simulating surfaces of the yarn guides, yarn break detectors, needles and push downs of the looms with two types of tacking: an umbrella tacking, which is placed above knitting area; a tacking which is placed on the floor. As a result of the experiment the regression dependences were obtained between tension and guide curvature radius, contact angle and tension of yarn and spun yarn before the guide in the form of torus. Consistent application of regression dependences data allows determining tension of yarn and spun yarn within the knitting area for different types of natural yarns, for wide range of looms.*

***Keywords:** tension, warp yarns, weaving area, contact angle, curvature radius.*

1 INTRODUCTION

Simulation of the yarn processing using a (loom) knitting machines involves study of interaction between yarns and surfaces in the form of torus. These surfaces are dummies for surface of yarn guides, the yarn break detectors, needles and push downs of the looms with two types of tackings: an umbrella tacking, which is placed above knitting area; a tacking which is placed on the floor [1-3, 7]. When drafting the plan of the experiment, the direction connected to slip of rubbing surfaces [2, 10, 16, 17], yarn tension prior to guide [1, 2, 4, 6], yarn thickness and type of feedstock [5, 8, 9] should be considered. Flexural rigidity of the multifilaments and spun yarn with slight twist can be ignored while processing on the looms [1, 3, 13]. The above restrictions required development of all-new scheme of the experimental setup, which is different from previously developed [11, 12, 14, 15].

Figure 1 shows looms with tacking in different places.



a b

Figure 1 Looms: a - DL–4M; b - PaiLung

Figure 1a shows the loom DL–4M with umbrella tacking placed above the knitting area. The loom DL–4M is intended for knitting rib fabric to produce underwear and sportswear. Figure 1b shows the loom PaiLung with tacking placed on the floor. It is intended for knitting fabric with stockinette structure [7].

Figure 2 shows structural schemes of threading on the looms DL–4M and PaiLung. For the loom DL–4M (I – Figure 2) threading line may be divided into 11 sections (Figure 2 shows in red):

1r – from bobbin to guiding yarn; 2r – from guiding yarn to break detector; 3r – from break detector to guiding yarn; 4r – from guiding yarn to guiding yarn; 5r – from guiding yarn to cylindrical tensioner; 6r – from cylindrical tensioner to break detector; 7r – from break detector to vertical thread storage in the form of cylinder; 8r – from vertical thread storage in the form of cylinder to break detector; 9r – from break detector to inlet of yarn thread guide; 10 (Figure 2 shows in brown) – from inlet of yarn thread guide to knitting area; 11 (Figure 2 shows in yellow) – from knitting area to formed textile fabric.

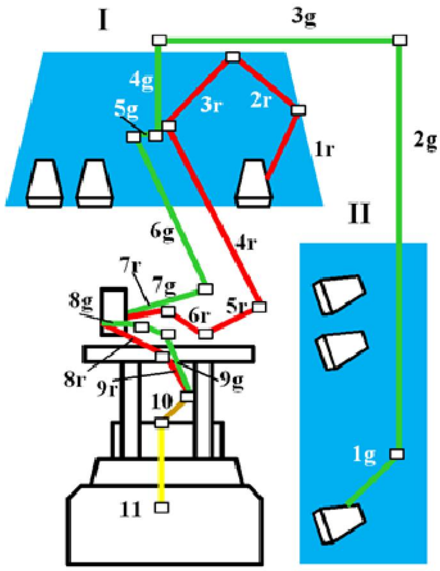


Figure 2 Structural scheme of threading on the looms DL–4M and PaiLung

For the loom PaiLung (II – Figure 2) threading line may be divided into 11 sections (Figure 2 shows in green):

1g – from bobbin to inlet of vertical cylindrical guide tube; 2g – from vertical cylindrical guide tube to rectangular connecting element; 3g – horizontal cylindrical guide tube between rectangular connecting elements; 4g – from rectangular connecting element to yarn tensioner in the form of two washers; 5g – from tensioner in the form of two washers to guiding yarn; 6g – from guiding yarn to vertical yarn storage in the form of cylinder; 7g – from vertical yarn storage in the form of cylinder to guiding yarn; 8g – from guiding yarn to break detector; 9g – from break detector to inlet of yarn thread guide; 10 (Figure 2 shows in brown) – from inlet of yarn thread guide to knitting area; 11 (Figure 2 shows in yellow) – from knitting area to formed textile fabric. Sections 10 and 11 for looms DL–4M and PaiLung are identical, that is why in Figure 2 they are shown in one colour. Yarn tension in the sections 1r and 1g will be equal to tension of the yarn when going off the bobbin.

Threading line has the form of spatial zigzag line. Table 1 shows elements of yarn supply system on the knitting machines DL–4M and PaiLung, which divide threading line into corresponding sections (Figure 2). Analysis of the structural scheme of the threading line shows its very complicated geometrical configuration both in plane and in space. In threading line inflection point the yarn or spun yarn are contacting with guide eyes in form of torus, tension devices, and control devices.

Figure 3 shows yarn thread guides and working components of the looms with which the yarn or the spun yarn interacts during its entry into the area of knitting the textile fabric.

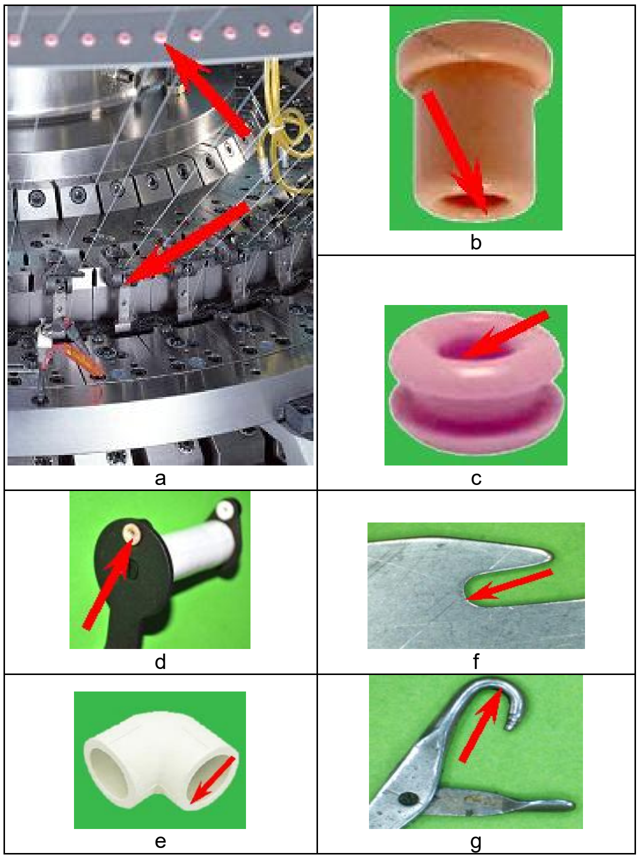
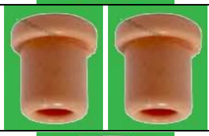
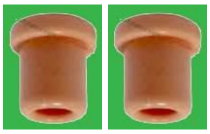
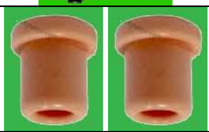
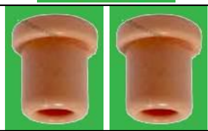
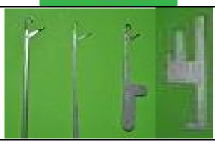
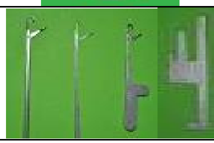


Figure 3 Structural elements in the form of torus of the threading system on the looms: a, c - yarn thread guides; b - components of break detectors; d - cylindrical yarn tensioner; e – rectangular connecting component; g – needles; f - push downs

Table 1 Elements of yarn supply system

No.	Umbrella tacking (loom DL-4M)		A tacking on the floor (loom PaiLung)	
	Area	***Guide***	***Area***	***Guide***
1	1r-2r		1g-2g	
2	2r-3r		2g-3g	
3	3r-4r		3g-4g	
4	4r-5r		4g-5g	
5	5r-6r		5g-6g	
6	6r-7r		6g-7g	
7	7r-8r		7g-8g	
8	8r-9r		8g-9g	
9	9r-10		9g-10	
10	10-11		10-11	

Curvature radius of these surfaces having the form of torus both significantly exceeds yarn cross-section radius and commensurable with it. Such type of interaction also occurs in implementation of similar technological processes [4, 6, 8, 9]. Figure 4 shows scheme of interaction between the yarn or spun yarn and cylindrical surface (Figure 4a) and surface in the form of torus (Figure 4b). Analysis shows that in the second case the forces of normal pressure in the section of the yarn, act not along a straight line, but along a curved surface in the form of a torus. In this case, frictional forces do not obey the friction laws known [1, 3].

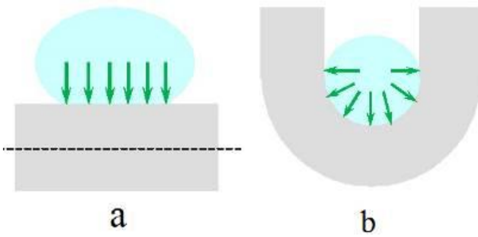


Figure 4 Scheme of interaction between the yarn and guiding surfaces: a – cylindrical; b - form of torus

2 EXPERIMENT

For the experiment, five types of yarns and spun yarns were chosen:

Series A: cotton yarn 29 Tex

Series B: wool 28 Tex

Series C: flax 30 Tex

Series D: viscose yarn 29 Tex

Series E: caprone multifilament 15.2x2 Tex.

The following yarn guides were chosen:

I – ceramic yarn guide (Figure 3c);

II – ceramic yarn guide at input and output in break detector (Figure 3b) and cylindrical yarn tensioner (Figure 3d);

III – rectangular connecting element (Figure 3e);

IV – needles and push downs of the loom (Figures 3f, 3g).

For each structural element I-IV (Figure 3) of the treading system on the loom, to determine joint influence of input tension of the yarn, radius of guide in the form of torus and calculated value of contact angle on output tension of yarn *P*.

In our work we planned and implemented orthogonal design of the second order for three factors. Standard form of regression equation shall be as follows [2]:

$$P = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_{12} x_1 x_2 + \\ + b_{13} x_1 x_3 + b_{23} x_2 x_3 + b_{11} x_1^2 + b_{22} x_2^2 + b_{33} x_3^2 \quad (1)$$

The range of factors variability in equation (1) is determined by real conditions of yarns and spun yarn processing on looms.

Factor x_1 - value of yarn or spun yarn tension up to structural element I-IV of the threading system of the loom:

- for guide of the yarn I changed within the range from P_{0I} = 3 cN to P_{0I} =33 cN;
- for ceramic guide of the yarn II at the entry and output in the break detector and cylindrical tensioner of the yarn changed from P_{0II} = 4 cN to P_{0II} = 16 cN;
- for rectangular connecting element III changed from P_{0III} = 4 cN to P_{0III} = 10 cN;
- for needles and push downs IV of the loom changed from P_{0IV} = 5 cN to P_{0IV} = 11 cN.

The range of tension change is determined by position of the structural element I-IV in threading line on the loom (Figure 2).

Factor x_2 – curvature radius of the guide:

- for ceramic guide of the yarn I in the form of torus within the range from R_I = 2 mm to R_I = 4 mm;
- for ceramic guide of the yarn II in the form of torus at the entry and output in the break detector and cylindrical tensioner of the yarn within the range from R_{II} = 1 mm to R_{II} = 3 mm;
- for rectangular connecting element III of the yarn within the range from R_{III} = 1 mm to R_{III} = 3 mm;
- for needles and push downs IV of the loom within the range from R_{IV} = 2 mm to R_{IV} = 4mm.

The value of radii was determined using digital microscope (USB Digital microscope Sigeta).

Factor x_3 – calculated value of the contact angle:

- for ceramic guide I of the yarn in the form of torus within the range from φ_I = 190 to φ_I = 920;
- for ceramic guide of the yarn II in the form of torus at the input and output in the break detector and cylindrical yarn tensioner within the range from φ_{II} = 170 to φ_{II} = 900;
- for rectangular connecting element III of the yarn calculated value of contact angle remained unchanged φ_{III} = 900;
- for needles and push downs IV of the loom within the range from φ_{IV} = 600 to φ_{IV} = 1800.

The value of the calculated contact angle is determined by the form of threading line and position of the structural element I-IV in the threading system.

At the first stage tension after the structural element I is determined. Table 2 shows matrix of orthogonal design of the second order for ceramic yarn guide I.

Table 2 Matrix of orthogonal design of the second order for ceramic yarn guide I

No.	Factors					
	Input tension		Curvature radius		Contact angle	
	χ_1	P_{0I} [cN]	χ_2	R_I [mm]	χ_3	φ_{IP} [°]
1	+1	30	+1	4	+1	85
2	-1	6	+1	4	+1	85
3	+1	30	-1	2	+1	85
4	-1	6	-1	2	+1	85
5	+1	30	+1	4	-1	25
6	-1	6	+1	4	-1	25
7	+1	30	-1	2	-1	25
8	-1	6	-1	2	-1	25
9	-1.215	3	0	3	0	55
10	+1.215	33	0	3	0	55
11	0	18	-1.215	1.8	0	55
12	0	18	+1.215	4.2	0	55
13	0	18	0	3	-1.215	19
14	0	18	0	3	+1.215	92
15	0	18	0	3	0	55

Connection between natural and encoded values for ceramic yarn guide I shall be as follows:

$$x1 = \frac{P_{0I} - 18}{12}, \quad x2 = \frac{R_I - 3}{1}, \quad x3 = \frac{\varphi_I - 55}{30}. \quad (2)$$

At the second stage tension after the structural element II is determined. Table 3 shows matrix of orthogonal design of the second order for ceramic yarn guide II at the input and output: in the break detector and cylindrical tensioner.

Table 3 Matrix of orthogonal design of the second order for ceramic yarn guide II

No.	Factors					
	Input tension		Curvature radius		Contact angle	
	χ_1	P_{0II} [cN]	χ_2	R_{II} [mm]	χ_3	φ_{IIP} [°]
1	+1	15	+1	3	+1	83
2	-1	5	+1	3	+1	83
3	+1	15	-1	1	+1	83
4	-1	5	-1	1	+1	83
5	+1	15	+1	3	-1	23
6	-1	5	+1	3	-1	23
7	+1	15	-1	1	-1	23
8	-1	5	-1	1	-1	23
9	-1.215	4	0	2	0	53
10	+1.215	16	0	2	0	53
11	0	10	-1.215	0.8	0	53
12	0	10	+1.215	3.2	0	53
13	0	10	0	2	-1.215	17
14	0	10	0	2	+1.215	90
15	0	10	0	2	0	53

Connection between natural and encoded values for ceramic yarn guide II shall be as follows:

$$x1 = \frac{P_{0II} - 10}{5}, \quad x2 = \frac{R_{II} - 2}{1}, \quad x3 = \frac{\varphi_{II} - 53}{30} \tag{3}$$

At the third stage the tension after the structural element III is determined. Table 4 shows matrix of orthogonal design of the second order for rectangular connecting element III.

Table 4 Matrix of orthogonal design of the second order for rectangular connecting element III

No.	Input tension		Curvature radius	
	χ_1	P_{0III} [cN]	χ_2	R_{III} [mm]
1	+1	10	+1	20
2	-1	4	+1	20
3	+1	10	-1	10
4	-1	4	-1	10
5	-1	4	0	15
6	+1	10	0	15
7	0	7	-1	10
8	0	7	+1	20
9	0	7	0	15

Connection between natural and encoded values for rectangular connecting element III shall be as follows:

$$x1 = \frac{P_{0III} - 7}{3}, \quad x2 = \frac{R_{III} - 15}{5} \tag{4}$$

At the fourth stage tension after the structural elements IV is determined. Table 5 shows matrix of orthogonal design of the second order for needles and push downs of the loom IV.

Connection between natural and encoded values for needles and push downs of the loom IV shall be as follows:

$$x1 = \frac{P_{0IV} - 8}{2}, \quad x2 = \frac{R_{IV} - 0.7}{0.2}, \quad x3 = \frac{\varphi_{IV} - 120}{50} \tag{5}$$

Figure 5 shows the scheme of experimental setup. Its assembly detailed in the work [2]. Distinctive feature is that unit 4 of the simulated conditions of interaction with surface in the form of torus included such structural elements as I – IV of the threading system of the loom (Figure 3)

Table 5 Matrix of orthogonal design of the second order for needles and push downs of the loom IV

No.	Factors					
	Input tension		Curvature radius		Contact angle	
	χ_1	P_{0I} [cN]	χ_2	R_I [mm]	χ_3	φ_{IP} [°]
1	+1	10	+1	0.9	+1	170
2	-1	6	+1	0.9	+1	170
3	+1	10	-1	0.5	+1	170
4	-1	6	-1	0.5	+1	170
5	+1	10	+1	0.9	-1	70
6	-1	6	+1	0.9	-1	70
7	+1	10	-1	0.5	-1	70
8	-1	6	-1	0.5	-1	70
9	-1.215	5.6	0	0.7	0	120
10	+1.215	10.4	0	0.7	0	120
11	0	8	-1.215	0.45	0	120
12	0	8	+1.215	0.94	0	120
13	0	8	0	0.7	-1.215	60
14	0	8	0	0.7	+1.215	180
15	0	8	0	0.7	0	120

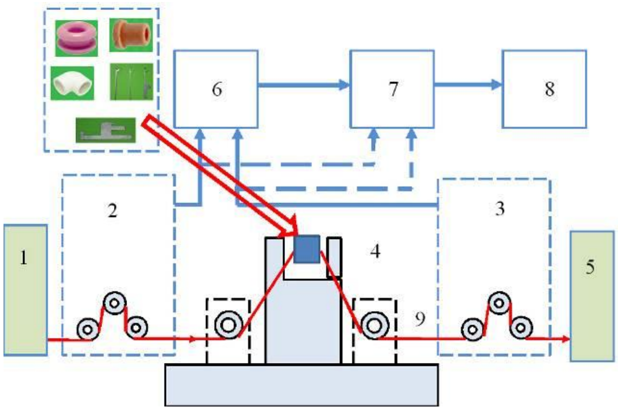


Figure 5 Scheme of the experimental setup:
1 – yarn threading unit; 2 – metering unit for yarn input tension; 3 – metering unit for yarn output tension; 4 – environment modelling unit for surface in the form of torus; 5 – yarn take up unit; 6 – amplifier; 7 – analogue to digital converter ADC; 8 – personal computer; 9 – yarn

The value of radii was determined using digital microscope (USB Digital microscope Sigeta) (Figure 6).

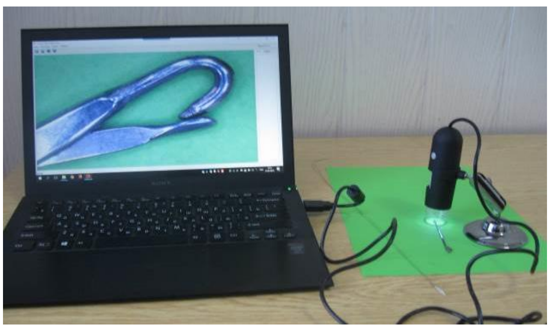


Figure 6 Setup for determining geometric dimensions of the structural elements I – IV of the threading system of the loom

3 RESULTS AND DISCUSSION

As a result of implementation of orthogonal design of the second order for three factors (Tables 2-5) for each of the series A, B, C, D, E (for five types of natural, synthetic and artificial spun yarn and yarns) for four types **I**, **II**, **III** and IV of yarns and spun yarn guides, 10 concurrent metering were conducted. Their average values represented in the Tables 6-10.

Table 6 Tension values – series A: cotton spun yarn 29 Tex

Experiment No.	Tension of natural spun yarn [cN] Series A (Cotton spun yarn 29 Tex)			
	I	II	III	IV
1	44.82	22.31	14.78	33.05
2	8.79	7.31	5.93	18.28
3	48.79	27.36	14.79	51.98
4	9.07	8.13	5.93	25.67
5	34.62	17.22	5.93	18.77
6	6.79	5.15	14.78	10.53
7	37.18	20.51	10.36	27.48
8	6.99	6.21	10.36	14.01
9	3.87	5.22	10.36	14.18
10	44.47	21.75		30.05
11	25.22	16.23		30.83
12	23.38	12.93		18.92
13	20.38	11.41		15.32
14	27.96	15.69		30.74
15	23.82	13.35		21.72

Table 7 Tension values – series B: wool 28 Tex

Experiment No.	Tension of natural spun yarn [cN] Series B (Wool 28 Tex)			
	I	II	III	IV
1	41.51	20.70	13.85	26.96
2	8.21	6.83	5.57	15.19
3	44.29	24.26	13.83	38.88
4	8.41	7.41	5.55	19.95
5	33.68	16.77	5.56	16.87
6	6.64	5.52	13.83	9.59
7	35.62	19.26	9.69	23.09
8	6.79	5.96	9.71	12.12
9	3.7	4.97	9.70	12.13
10	41.95	20.49		25.02
11	23.61	14.74		24.39
12	22.26	12.33		16.38
13	19.91	11.13		13.71
14	25.71	14.41		24.39
15	22.59	12.64		18.31

Table 8 Tension values – series C: flax spun yarn 30 Tex

Experiment No.	Tension of natural spun yarn [cN] Series C (Flax spun yarn 30 Tex)			
	I	II	III	IV
1	43.23	21.53	14.32	29.77
2	8.51	7.08	5.75	16.65
3	46.48	25.64	14.33	44.25
4	8.74	7.75	5.74	22.38
5	34.13	16.98	5.74	17.68
6	6.71	5.58	14.32	10.01
7	36.29	19.73	10.04	24.71
8	6.89	6.06	10.04	12.85
9	3.79	5.09	10.03	13.04
10	43.20	21.09		27.17
11	24.37	15.36		26.93
12	22.84	12.63		17.55
13	20.12	11.25		14.35
14	26.87	15.05		27.24
15	23.21	12.99		19.79

Table 9 Tension values – series D: viscose yarn 29 Tex

Experiment No.	Tension of natural spun yarn [cN] Series D (Viscose yarn 29 Tex)			
	I	II	III	IV
1	41.82	20.83	14.04	25.79
2	8.31	6.89	5.64	14.83
3	43.75	23.27	14.02	33.38
4	8.44	7.31	5.63	17.97
5	33.57	16.70	5.63	16.03
6	6.65	5.52	14.03	9.27
7	34.95	18.44	9.83	19.97
8	6.76	5.83	9.84	10.97
9	3.72	4.98	9.84	11.23
10	41.79	20.34		22.99
11	23.32	14.04		20.92
12	22.37	12.37		15.81
13	19.79	11.02		12.79
14	25.89	14.44		22.85
15	22.59	12.59		17.09

Table 10 Tension values – series B: caprone multifilament 15.2x2 Tex

Experiment No.	Tension of natural spun yarn [cN] Series E (Caprone multifilament 15.2x2 Tex)			
	I	II	III	IV
1	47.18	23.45	15.37	38.67
2	9.17	7.63	6.15	20.95
3	52.45	30.17	15.42	66.83
4	9.54	8.71	6.16	31.67
5	35.31	17.55	6.15	20.53
6	6.89	5.73	15.38	11.35
7	38.53	21.71	10.79	32.36
8	7.14	6.43	10.76	15.97
9	3.98	5.39	10.77	16.05
10	46.38	22.73		35.05
11	26.51	17.63		38.03
12	24.14	13.34		21.15
13	20.75	11.63		16.88
14	29.57	16.63		36.93
15	24.71	13.88		24.99

Applying well-known methods to determine coefficient in the regression equation (1) for orthogonal design of the second order [1-2], considering dependences (2-10), the following regression dependences are obtained:

Series A (Cotton yarn 29 Tex):

for yarn guide **I**

$$P_{IA} = 1.22P_{0I} - 0.86R_I - 0.01\varphi_I + 0.33R_I^2 - \\ - 0.06P_{0I}R_I + 0.006P_{0I}\varphi_I - 0.98, \quad (6)$$

for yarn guide **II**

$$P_{IIA} = 1.42P_{0II} + 0.51R_{II} - 0.01\varphi_{II} - \\ - 0.17P_{0II}R_{II} + 0.01P_{0II}\varphi_{II} - 1.65 \quad (7)$$

for yarn guide **III**

$$P_{IIIA} = 0.31 + 1.44P_{0III}, \quad (8)$$

for yarn guide IV

$$P_{IVA} = 4.44P_{0IV} - 32.07R_{IV} + 0.07\varphi_{IV} + 50.99R_{IV}^2 - \\ - 5.24P_{0IV}R_{IV} + 0.02P_{0IV}\varphi_{IV} - 0.18R_{IV}\varphi_{IV} - 3.68 \quad (9)$$

Series B (wool 28 Tex):

for yarn guide I

$$P_{IB} = 0.59P_{0I} + 0.04R_I + 0.01\varphi_I - 0.05P_{0I}R_I + 0.002P_{0I}\varphi_I + 2.39 \quad (10)$$

for yarn guide II

$$P_{IIB} = 1.31P_{0II} + 0.36R_{II} - 0.004\varphi_{II} - 0.13P_{0II}R_{II} + 0.01P_{0II}\varphi_{II} - 0.81 \quad (11)$$

for yarn guide III

$$P_{IIIB} = 0.29 + 1.34P_{0III} \quad (12)$$

for yarn guide IV

$$P_{IVB} = 3.4P_{0IV} - 22.92R_{IV} + 0.04\varphi_{IV} + 33R_{IV}^2 - 3.4P_{0IV}R_{IV} + 0.02P_{0IV}\varphi_{IV} - 0.09R_{IV}\varphi_{IV} - 1.33 \quad (13)$$

Series C (Flax 30 Tex):

for yarn guide I

$$P_{IC} = 1.03P_{0I} - 0.69R_I - 0.01\varphi_I + 0.005P_{0I}\varphi_I + 1.66 \quad (14)$$

for yarn guide II

$$P_{IIC} = 1.34P_{0II} + 0.4R_{II} - 0.006\varphi_{II} - 0.14P_{0II}R_{II} + 0.01P_{0II}\varphi_{II} - 1.29 \quad (15)$$

for yarn guide III

$$P_{IIIC} = 0.28 + 1.39P_{0III} \quad (16)$$

for yarn guide IV

$$P_{IVC} = 3.73P_{0IV} - 25.72R_{IV} + 0.05\varphi_{IV} + 39.25R_{IV}^2 - 4.05P_{0IV}R_{IV} + 0.02P_{0IV}\varphi_{IV} - 0.13R_{IV}\varphi_{IV} - 2.38 \quad (17)$$

Series D (Viscose yarn 29 Tex):

for yarn guide I

$$P_{ID} = 1.01P_{0I} - 0.003\varphi_I + 0.005P_{0I}\varphi_I - 0.22 \quad (18)$$

for yarn guide II

$$P_{IID} = 1.03P_{0II} - 0.62R_{II} - 0.003\varphi_{II} + 0.005P_{0II}\varphi_{II} + 1.01 \quad (19)$$

for yarn guide III

$$P_{IIID} = 0.29 + 1.36P_{0III} \quad (20)$$

for yarn guide IV

$$P_{IVD} = 2.4P_{0IV} + 6.65R_{IV} - 0.02\varphi_{IV} - 2.1P_{0IV}R_{IV} + 0.01P_{0IV}\varphi_{IV} - 5.45 \quad (21)$$

Series E (Caprone multifilament 15.2x2 Tex):

for yarn guide I

$$P_{IE} = 1.28P_{0I} + 0.39R_I - 0.009\varphi_I - 0.08P_{0I}R_I + 0.01P_{0I}\varphi_I - 1.92 \quad (22)$$

for yarn guide II

$$P_{IIE} = 1.54P_{0II} + 0.67R_{II} - 0.01\varphi_{II} - 0.23P_{0II}R_{II} + 0.01P_{0II}\varphi_{II} - 2.23 \quad (23)$$

for yarn guide III

$$P_{IIIE} = 0.29 + 1.49P_{0III} \quad (24)$$

for yarn guide IV

$$P_{IVE} = 5.84P_{0IV} - 43.85R_{IV} + 0.11\varphi_{IV} + 75R_{IV}^2 - 7.7P_{0IV}R_{IV} + 0.03P_{0IV}\varphi_{IV} - 0.28R_{IV}\varphi_{IV} - 6.92 \quad (25)$$

Figures 7-11 show the response surfaces of the regression dependences (6-25). Tension dependences after the yarn guide from input tension and curvature radius of the surface guide in the form of torus were constructed at a fixed value of the calculated contact angle of the cylinder. This value corresponded to the centre of the experiment (Tables 1-4).

Adequacy of the obtained regression dependences was verified using SPSS software application for statistical processing of experimental findings [2]. Analysis of significance of the coefficient of the regression equations (6-25) allowed to discard insignificant ones [1, 7-8].

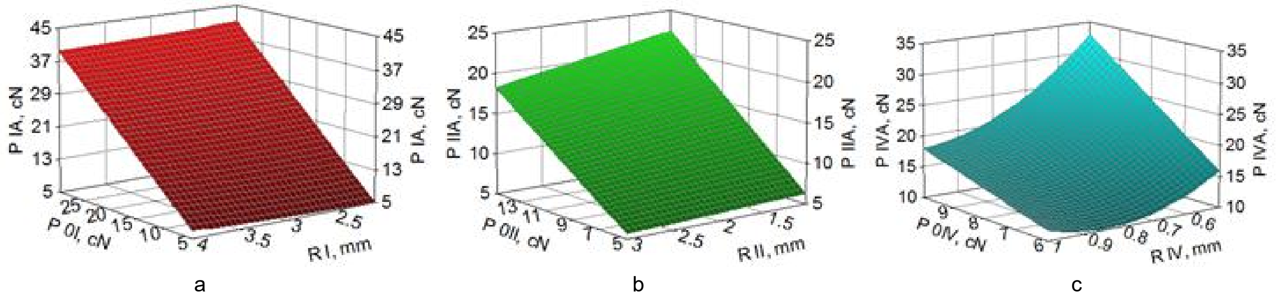


Figure 7 Response surfaces of the series A: a - for yarn guide I; b - for yarn guide II; c - for yarn guide IV

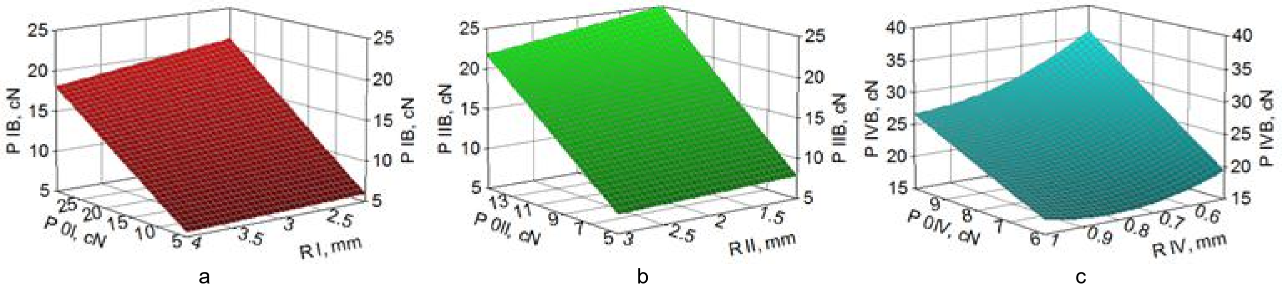


Figure 8 Response surfaces of the series B: a - for yarn guide I; b - for yarn guide II; c - for yarn guide IV

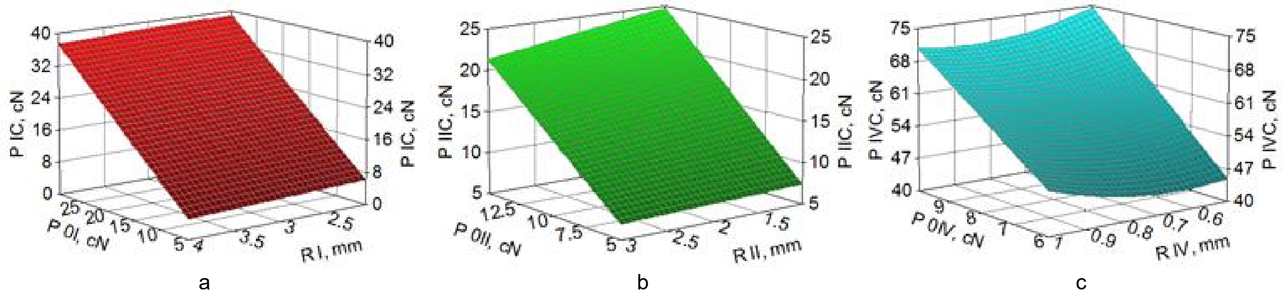


Figure 9 Response surfaces of the series C: a - for yarn guide I; b - for yarn guide II; c - for yarn guide IV

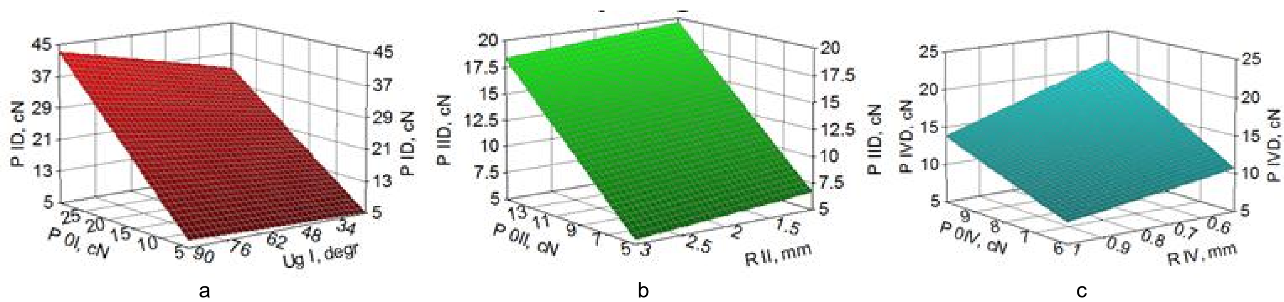


Figure 10 Response surfaces of the series D: a - for yarn guide I; b - for yarn guide II; c - for yarn guide IV

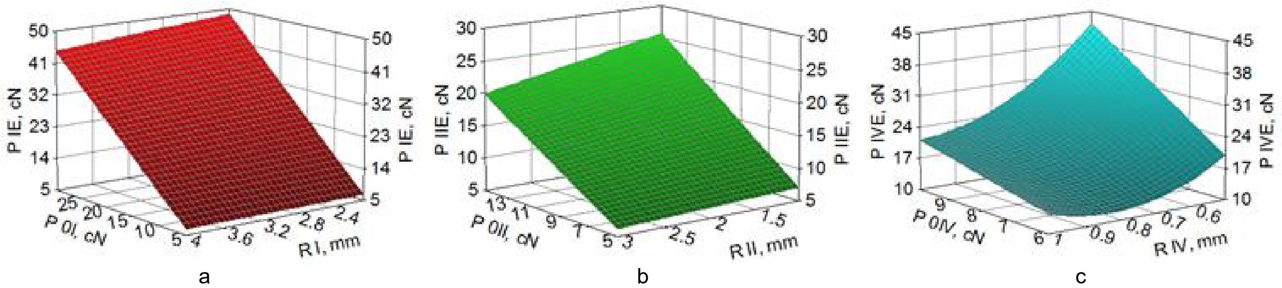
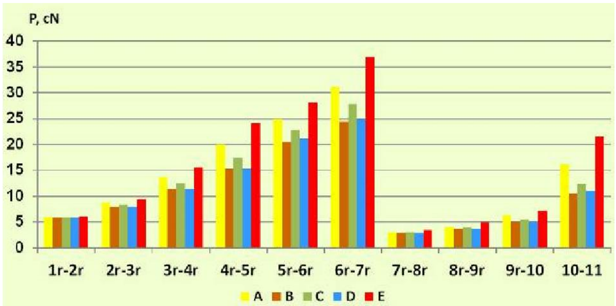


Figure 11 Response surfaces of the series E: a - for yarn guide I; b - for yarn guide II; c - for yarn guide IV

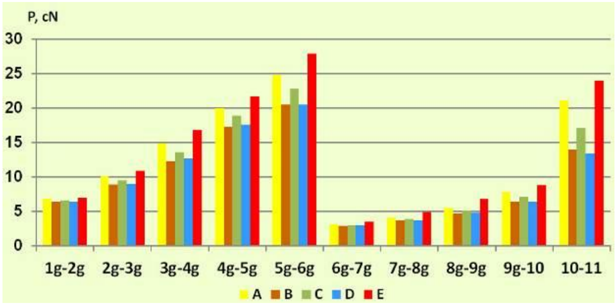
Using regression dependencies (6-25) the values of yarn and spun yarn tension were determined in the knitting area on the looms DL–4M and PaiLung. The value of the yarn and spun yarn tension when going off the bobbin was considered constant and such as not depending on its diameter.

Having been analysed, graphical dependences (Figure 12) allowed to determine that yarn tension is increasing from area to area an reaches its maximum before the mechanism of active yarn supply: area 6r-7r for loom DL–4M; area 5g-6g for loom PaiLung. After the mechanism of active supply the yarn will have the minimum tension. Its tension will gradually increase before knitting area at the expense of its interaction with structural elements I-IV. It should be noted that, loom PaiLung will have for different yarns and spun yarns (series A-E), the tension varied within 14-24 cN.

Received results may be used to optimize technological process of knitting of the textile fabric, when yet at the initial stage the intensity of the yarn and spun yarn processing on the looms may be determined.



a



b

Figure 12 Yarns tension change histogram according to areas of yarn threading: a – loom DL–4M; b – loom PaiLung; ■ – Series A (cotton spun yarn 29 Tex); ■ – Series B (wool 28 Tex); ■ – Series C (flax 30 Tex); ■ – Series D (viscose spun yarn 29 Tex); ■ – Series E (caprone multifilament 15.2x2 Tex)

4 CONCLUSION

Resulting from conducted comprehensive experimental research of the process of interaction between yarns and surfaces in the form of torus, simulating surfaces of the yarn guides, elements of break detector devices, needles and push downs of looms, the regression dependencies were obtained. These dependencies allow to determine changes in yarn tension from the bobbin to the area of textile fabric knitting. Dependencies were obtained considering types of feedstock processed and constructions of the specific looms. Obtained results may be used to optimize technological process of knitting in terms of optimizing of geometrical form of yarn threading line on the loom, decreasing breaks, and increasing quality of the produced textile fabrics.

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