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Control of the stability circular knitting process with passive yarn feeding

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1. Introduction

One of the problems for producers of knitted garments is to decrease the amount of faults (defects), which occur when needle's hook or heel breaks off, and to stop machine as soon as possible. The existing defect detecting devices could be divided into two main categories. Those which react to production defects (holes) and those which react to elements (needle, sinker) shape. These systems are very specific and do not give information about knitting process. Usually these are optical or capacitive sensors, but they do not give further information about knitting process and the cause of defect.

An effective monitoring of the knitting process is required in order to avoid defects. It is very important to locate a defect and its cause as soon as possible, in order to avoid productivity and quality losses. The new method for knitting process control was proposed [1, 2]. According to this method the yarn tension during knitting process is measured. Deviation of yarn tension with defect could be used to stop the knitting machine, when the yarn input tension falls below some limits. The new achievements in mechatronics let to stop the machine quickly and exactly [3]. Parameters, which influence tension variations, may be initial yarn, threads input tension, speed of knitting, linear density of the yarns, dynamic rigidity and viscosity characteristics of the yarns.

In the above mentioned paper there were examined only polyester yarn. The influence of knitting process parameters, linear density of threads [4] and mechanical characteristics of yarns was not investigated.

The aim of this research was to study deviation of tension during knitting with needle defect for different threads with passive threads feeder unit.

2. Determination of main factors, having the greatest influence on the thread tension with defect of needle

During the knitting process yarn tension varies because of yarn sinking to the loop. When the needle‘s hook or heel breaks off, yarn guide doesn't lay the yarn on the needle and tension decreases.

Experiments were carried out using sock knitting machine "BABY" (14 gauge, 156 needles, diameter 3.5 inches) with passive yarn input device. Defects of the needles were simulated by taking out one needle, then after twenty more needles taking out two more needles, and, after twenty more needles, having one needle with broken needle hook. So we hoped to find three points of tension decrease during every turn of knitting machine cylinder.

The polyamide PA (29.4 *tex*), polyester PES (9.4 *tex*), textured PES (11 *tex* x 2) and Cotton (15.4 *tex* x 2) yarns were investigated.

Experiments were carried out using the orthogonal plan for three factors changing them on two levels (is shown in Table 1). Maximum level of factors is plus, minimum is minus.

Table 1

Experimental plan

N	X_0	X_1	X_2	X_3	X_1X_2	X_1X_3	X_2X_3	$\bar{y}_i$
1.	+	+	+	+	+	+	+	$\bar{y}_1$
2.	+	+	+	-	+	-	-	$\bar{y}_2$
3.	+	+	-	+	-	+	-	$\bar{y}_3$
4.	+	+	-	-	-	-	+	$\bar{y}_4$
5.	+	-	+	+	-	-	+	$\bar{y}_5$
6.	+	-	+	-	-	+	-	$\bar{y}_6$
7.	+	-	-	+	+	-	-	$\bar{y}_7$
8.	+	-	-	-	+	+	+	$\bar{y}_8$

This plan is good due to the fact, that the low number of tests (N=8) lets to determine a factor, having the main influence on yarn tension decrease. The presented plan lets to get the regression equation

$$y = b_0X_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3 \quad (1)$$

The coefficients were calculated as follows

$$b_0 = \frac{\sum \bar{y}_i}{N};\ N=8 \quad (2)$$

$$b_i = \frac{\sum X_i \bar{y}_i}{N} \quad (3)$$

$$b_{ij} = \frac{\sum X_i X_j \bar{y}_i}{N} \quad (4)$$

where $\bar{y}_i$ is the average value of drop off of thread input tension with the plus or minus sign in reliance on factors X_i or X_iX_j signs in columns. The coefficients b values show the influence of factors.

First factor X_1 was input tension T (changing spring pressure of tensiometer).

Second factor X_2 was a speed v of knitting machine cylinder revolution (max, as it is used for knitting leg and min speed was two times lower – as it is used for knitting the heel of socks).

The third factor was linear density of yarns.

Input yarn tension T was registered by tensiometer ELTENS FY-23 (resonance frequency – 205 Hz). A graph of yarn tension was drawn by recorder H 339, which is able to register 150 Hz frequency signal. As we can see, the values of zero thread tension is on height of one cm in all tenzogrammes.

Some results of tests are shown in Fig. 1. These are the real tenzogrammes, where the thread tension during knitting with needle defects is recorded. In all Figures is shown, what were the values of initial thread tension, yarn feeding speed and linear density during this test. Scale of tension for all graphs is 2 cN/mm. Scale of time for all graphs is 0.02 s/mm.

The experiments were made with three pairs of threads PES 9.4 *tex* and PA 29.4 *tex*, PES 9.4 *tex* and PES 11 *tex* x 2 and PES 9.4 *tex* and Cotton 15.4 *tex* x 2. The results show, that in the all graphs there are observable three defects. The calculated values of coefficients b are shown in Table 2.

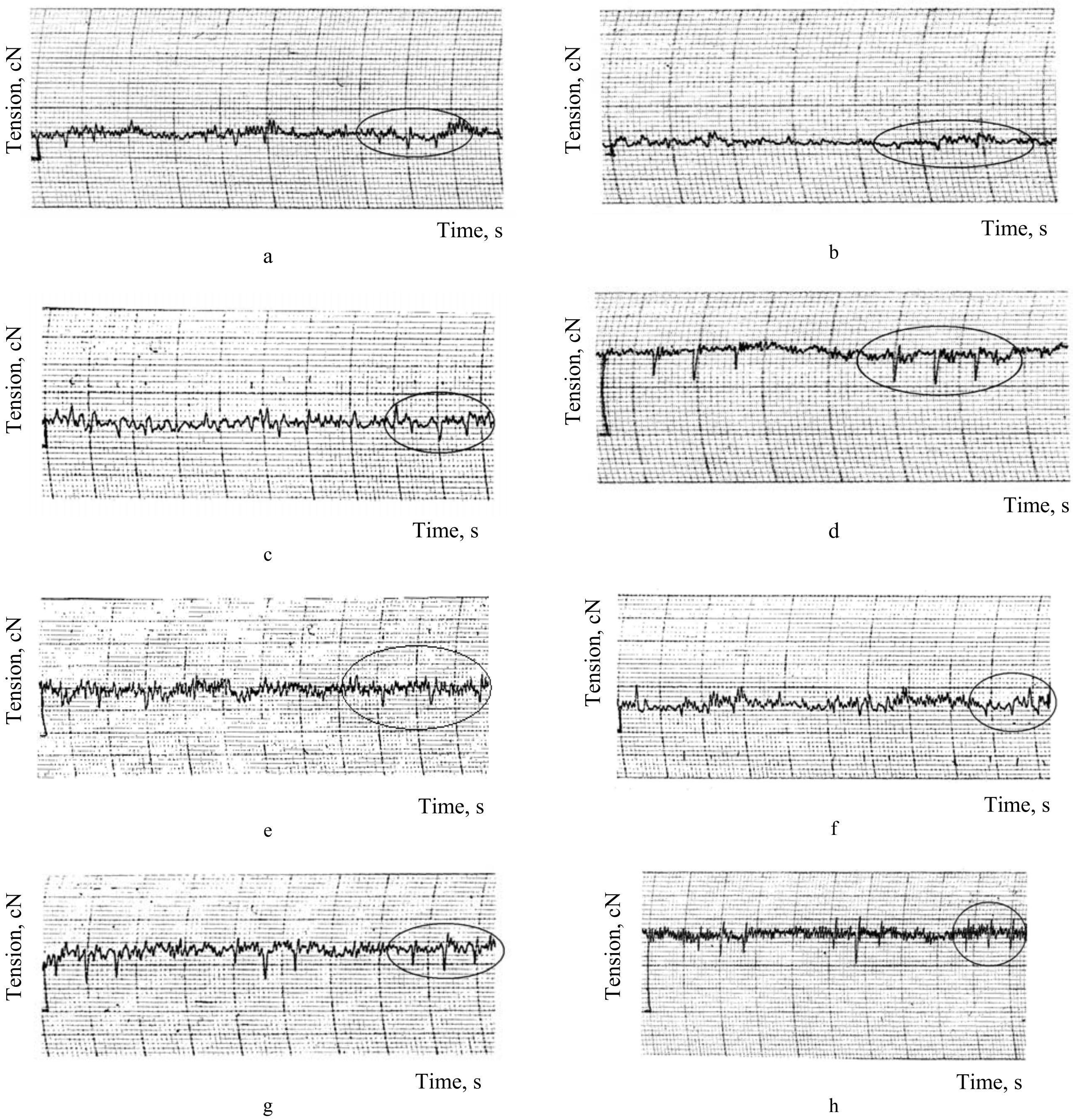

Fig. 1 The drop off of threads tension during knitting with needle defects reliance on initial tension, yarn feeding speed and linear density: a - T = min; v = max; PA 29.4 *tex;* b - T = min; v = max; PES 9.4 *tex ;* c - T = min; v = max; PES 11 *tex* x 2 ; d - T = max; v = max; PES 9.4 *tex ;* e - T = max; v =min; PES 11 *tex* x 2 ; f - T = min; v = max; Cotton 15.4 *tex* x 2 ; g - T = = max; v = max; PES 11 *tex* x 2 ; h - T = max; v = max; Cotton 15.4 *tex* x 2

Table 2

Values of the regression coefficients

	PES 9.4 *tex* PA 29.4 *tex*	PES 9.4 *tex* PES 11 *tex* x 2	PES 9.4 *tex* Cotton 15.4 *tex* x 2
b_0	5.87	5.75	5.87
b_1	3.62	3.25	3.12
b_2	0.12	0.50	0.62
b_3	0.36	0.25	0.37
b_{12}	- 0.62	- 0.25	- 0.37
b_{13}	- 0.37	- 1.00	- 1.37
b_{23}	- 0.37	- 0.12	- 0.12

From Table 2 we can state, that the main factor, having the biggest influence, is X_1 – thread tension; because results show, that the coefficient b_1 has higher value than b_2 and b_3. The interaction coefficient b_{13} has some influence, because it is related with main X_1 factor. Knitting speed and linear density have a smaller influence on decrease of the yarn input tension.

From graphics it was noticed, that the deviation of tension reduction is not very big in comparison with the average value of maximum tension. In Table 3 for this reason is shown the average thread stress reduction value, calculated in percentage of the average maximum thread tension value.

Table 3

Reduction of tension in percentage of average maximum thread tension

Threads	Values at tension *T*	Decreasing, % v = min	Decreasing, % v = max
PA 29.4 *tex*	T_{min}	43	40
PA 29.4 *tex*	T_{max}	36	25
PES 11.4 *tex* x 2	T_{min}	57	40
PES 11.4 *tex* x 2	T_{max}	40	31
PES 9.4 *tex*	T_{min}	50	33
PES 9.4 *tex*	T_{max}	38	29
Cotton 15.4 *tex* x 2	T_{min}	31	28
Cotton 15.4 *tex* x 2	T_{max}	22	23

The results show, that reduction of tension in percents is higher, when the input tension has min level T_{min}, and lower, when the input tension has max level T_{max} in all cases. The small influence of knitting speed on reduction of tension also can be observed. The min influence of speed can be explained by the process having longer time for the decrease of tension.

Cotton yarn had the smallest reduction of input tension. This case shows, that the reaction of Cotton differs from PA and PES yarn.

Further the experiments were made to determine dynamic rigidity and viscosity characteristics for threads, having good (PES) and bad (Cotton) reaction to the needle defect.

3. Dynamic experiments

Results of the past experiments show, that different yarns had particular yarn input tension under the same knitting machine parameters. It means, that yarn behavior during loop formation process depends on the yarn mechanical properties. For this investigation, yarn dynamic experiments were made with the frequency as in the knitting machine, small stretching adequate the loop length and different initial yarn tension value P_0 [5 - 8].

Threads tension during knitting is varying till 10 cN, but at the moment of the loop formation it can be as much as three times bigger. For this reason the dynamic characteristics were investigated using 10 cN, 20 cN and 30 cN initial tension P_0.

Experiments were carried out using the cyclic tension device (Figs. 2 and 3) which jaw moves by sine law. The yarns affect power sensor which was modified from ELTENS power sensor head. This enabled to get yarn tension signal F with different amplitude F_a and phase δ. This information can be found from experimental graph.

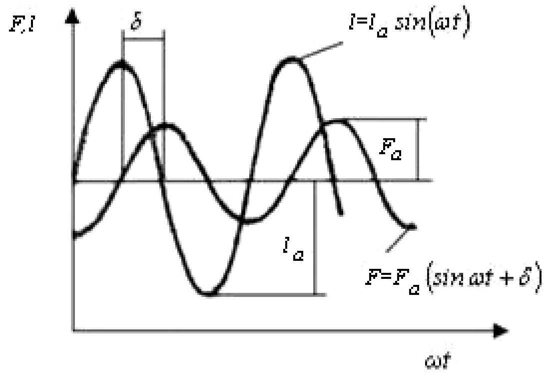

Fig. 2 Curves of yarn tension

Experiments were made in these conditions:
Maximum amplitude $2l_a$ - 4 mm;
Specimen initial length l_m – 0,5 m;
Cyclic frequency w – 1,4 s^{-1};
A_0 - cross-section area of yarn, mm^2;
T – linear density of yarn, tex.

Dynamic rigidity modulus for 0.5 *m* length of the yarn was calculated using this formula

$$C_d = F_a / l_a, \text{ cN/mm} \qquad (5)$$

Dynamic viscosity modulus was calculated using this formula

$$\eta = F_a l_m sin\delta / (l_a A_0 w), \text{ Ns/mm}^2 \qquad (6)$$

Dynamic viscosity modulus formula for mass unit

$$\eta = F_a l_m sin \ / (l_a wT), \text{ Ns/tex} \qquad (7)$$

The aim of these experiments was to investigate dynamic rigidity and viscosity modulus for threads with the same linear density. The tests were made with polyester PES thread, having linear density 13.3 tex and Cotton yarn with linear density of 13.1 tex. This enabled to compare results which are shown in Figs. 4 and 5.

The results of dynamic experiments show, that rigidity and viscosity modulus for polyester threads were higher, when the initial tension was small (10 cN) and lower, when initial tension was 20 cN. For cotton yarns rigidity and viscosity modulus were lower, when the initial tension was small (10 cN) and higher, when initial tension was 20 cN.

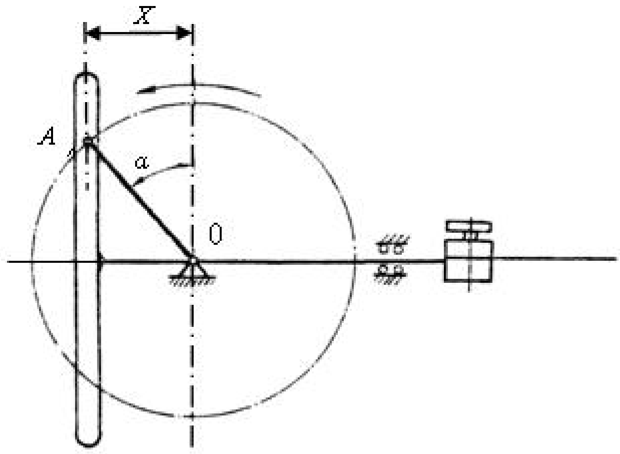

Fig. 3 Cyclic tension device

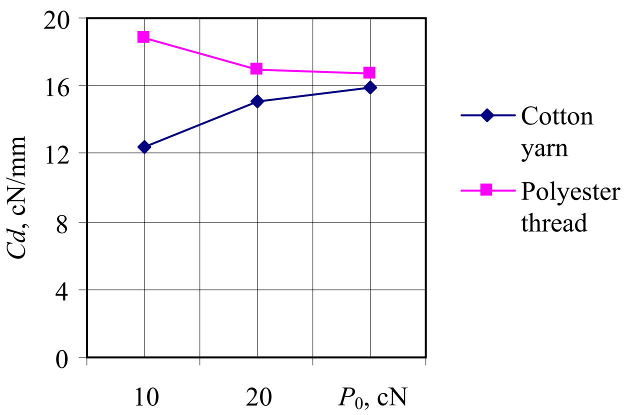

Fig. 4 Dynamic rigidity modulus range

The results show, that dynamic rigidity and viscosity modulus of cotton yarn and polyester thread are different, when initial yarn tension is 10 cN and similar, when initial yarn tension is above 20 cN. It explained, why Cotton yarns had not observable reduction at tension T during knitting.

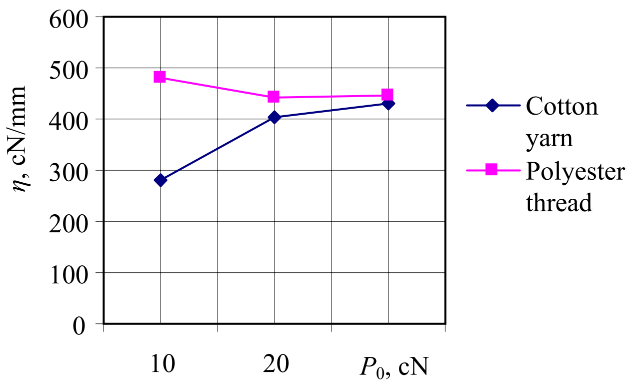

Fig. 5 Range of dynamic viscosity modulus for mass unit

In the socks knitting machines with passive yarn input devices yarn tension is not very high. So, behavior of different type yarns will be different in these machines.

4. Conclusions

1. The coefficients of regression equations, calculated from the results of experiments plan, which were obtained by measuring thread tension reduction, showed, that the thread tension during knitting has the biggest influence when reacting to needle defect. Speed of the thread has less influence and linear density of the thread has fractional influence, when reacting to needle defect.

2. It was determined, that the average reduction of thread stress in percentage is higher, when given knitting speed and thread tension is low. Low value of tension reduction in percentage shows weak reaction of threads to the needle defect. Cotton yarn had the smallest reduction of thread tension, than PES yarn.

3. Decreasing of the input tension depends on mechanical characteristics of threads–dynamic rigidity and viscosity.

4. The results of experiments show, that reaction to a defect of the needle for the investigated threads can be well observable with increasing knitting tension over 10 cN till 20 cN, because the rigidity and viscosity in that case is similar for synthetic PES thread and Cotton yarn.

5. Passive input feeding did not guarantee, that for all threads during knitting with needle defect the reaction of tension will be noticed.

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MEZGIMO PROCESO STABILUMO KONTROLĖ APSKRITOJE MAŠINOJE SU PASYVIU SIŪLO TIEKIMU

R e z i u m ė

Mezgant būtina kontroliuoti ir pašalinti mezgimo defektus. Esantys optiniai, mechaniniai įtaisai reaguoja į siūlo trūkimus, adatų kulniukų, kabliukų, liežuvėlių lūžius, mezginiuose atsiradusias skyles, tačiau jie neteikia jokios informacijos apie mezgimo procesą, todėl tuo tikslu buvo pasiūlyta matuoti įmezgamo siūlo įrąžą.

Mezgimo metu lūžus adatos kabliukui, kulneliui siūlas kilpos nesudaro, todėl siūlo įtempis sumažėja. Įtempio sumažėjimas priklauso nuo siūlo tiekimo būdo, siūlo statinio įtempimo, mezgimo greičio, ilginio tankio bei siūlų mechaninių charakteristikų. Šiame darbe imituojant adatos defektus buvo nustatyta, kad didžiausią įtaką siūlo įtempio sumažėjimui, esant pasyviam siūlo tiekimui, turi įmezgamo siūlo įtempis. Mezgimo greitis bei siūlų ilginis tankis žymios įtakos siūlo įtempio sumažėjimui neturėjo. Nagrinėjant siūlų įtempio sumažėjimą procentais nuo vidutinės maksimalios įrąžos gauta, kad įtempio sumažėjimas didesnis esant mažam mezgimo greičiui ir mažai siūlo įrąžai tirtiems poliesteriniams, poliamidiniams siūlams ir medvilniniams verpalams. Medvilninių verpalų įtempio sumažėjimas į adatos defektą visais atvejais buvo mažesnis už kitų tirtų siūlų.

Stende atlikti dinaminiai bandymai nustatant poliesterinių ir medvilninių siūlų standumą bei klampumą parodė, kad medvilninių verpalų moduliai mažesni už poliesterinių siūlų esant 10 cN siūlo įrąžai ir susilygino esant įrąžai nuo 20 cN iki 30 cN.

Tai leido paaiškinti, kodėl medvilniniai verpalai turi mažiausią reakciją į adatos defektą esant mažam tiekimo įtempiui.

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CONTROL OF THE STABILITY CIRCULAR KNITTING PROCESS WITH PASSIVE YARN FEEDING

S u m m a r y

During the knitting process it is important to control and detect defects and quickly remove them. Existent optical and mechanical devices react to broken threads, hook, butt, latch of needles, holes of fabrics, but they do not give any information about knitting process.

For this aim the method of measuring threads tension during knitting was proposed. When the needle hook, heel, latch are broken, the yarn tension decreases. This reaction depends on yarn feeding method, static thread tension, knitting speed, linear density and mechanical characteristics of threads.

In this paper, the research of needle defects during knitting with passive yarns input was made and it was determined, that the biggest influence on reducing threads tension to defect had input tension. The influence of knitting speed and linear density was small. Reducing yarn tension in percentage of average maximum tension showed, that the decrease of yarn tension is higher when the speed of knitting and tension is smaller for the investigated polyester, polyamide and cotton threads. Decrease of tension for cotton thread in all cases was less than for other investigated threads.

The results of experiments for the determination of dynamic rigidity modulus and dynamic viscosity modulus show, that both values of modulus for cotton yarns were lower than polyester threads, when the threads tension was 10 cN and were similar at tension values from 20 cN till 30 cN.

That enabled to explain, why the Cotton yarn have least reaction to the needle defect, when the yarn input tension during knitting was small.

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КОНТРОЛЬ ПРОЦЕССА СТАБИЛЬНОСТИ ВЯЗАНИЯ НА КРУГЛЫХ МАШИНАХ С УСТРОЙСТВОМ ПАССИВНОЙ НИТЕПОДАЧИ

Р е з ю м е

Во время вязания необходимо контролировать и устранять дефекты вязания. Существующие оптические, механические устройства реагируют на обрыв нити, поломки пяток, крючков, язычков игл, возникновение дыр, но они не дают информации о процессе вязания, поэтому было предложено измерять натяжение провязываемой нити.

При поломке крючка, пятки во время вязания нить петли не провязывает и тогда натяжение нити падает. Уменьшение натяжения нити зависит от метода подачи нити, статического натяжения, скорости вязания, линейной плотности, механических характеристик нити.

В представленной работе имитируя дефекты иглы было определено, что наибольшее влияние на уменьшение натяжения нити при пассивной нитеподаче оказывает натяжение нити. Скорость вязания и линейная плотность нити заметного влияния не имеет. Уменьшение натяжения нити в процентах от максимального натяжения больше при малой скорости вязания и меньшем натяжении для исследуемых полиэфирных, полиамидных и хлопчатобумажных нитей. Уменьшение натяжения хлопчатобумажной нити на дефект иглы во всех случаях было меньше чем других исследуемых нитей.

Динамические испытания проведены на стенде с целью определения модулей жесткости и текучести полиэфирной и хлопчатобумажной нитей показали, что модули хлоптобумажной пряжи меньше чем полиэфирной при натяжении в 10 cN и примерно равны с 20 cN до 30 cN.

Это позволило обяснить, почему хлопчатобумажная пряжа имеет наименьшую реакцию на дефект иглы при малом натяжении нити.

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