EXPERIMENTAL DETERMINATION OF THE TENSILE FORCE IN EMBROIDERY THREADS KNITTING

Peter Hadzhidobrev, Andreas Charalambus

College in Sliven
Bourgassko shausee 59, 8800 Sliven, Bulgaria
Email: Peter_HD@mail.bg
Charalambus@mail.bg

Abstract

In this work, a method for indirectly determining the tensile force in yarn of twisted units is propounded on a tensile force-elongation diagram. The elongation occurs in the change of the screw line step of the twisted units. The screw-line step is calculated after multiple measurements of short-length areas in the work zone of the knitting needles. The measuring is possible for knitting in producing conditions and in real time.

Key words:

yarn, yarn stress, diagram, tensile force, elongation, load intensity measuring methods

1. Introduction

The valuation of the tensile force in the yarn during knitting has a great significance for the choice of yarn and for optimising the technological parameters of the knitting process. It is impossible to directly determine the tensile force in the place of the working organs action without constructive changes to the knitting machine. In the literature, works aimed at solving that problem are few in number. That is why it still stands as a challenge for experimental and theoretical development.

Valuing the yarn's tensile force in the knitting process is possible when the loading force of the knitting needle is known. Experimental determination of the force on the knitting needle is carried out according to Simin's method [5] through needle cutting and further the two parts connecting by an elastic element with a tension sensor. The signal $P(\tau)$ received from the tension sensor gives the loading P in the time τ, and it is shown on Figure 1. From the needle loading the tensile force applied on the yarn is established.

Tsitovich [6] has devised other experimental developments for determining tensile forceby moving the knitting needle. A tension sensor is assembled on the knitting machine carriage. The elastic wafer is bent when it is moving, and the tension sensor gives the signal, as shown on Figure 2. This is the loading $P(\tau)$ on the needle, and the tensile force applied on the yarn can be specified on this basis. The experiment also yields a numerical value of the tensile force, which reaches about 7 N. The duration of the force's action is about 5 ms.

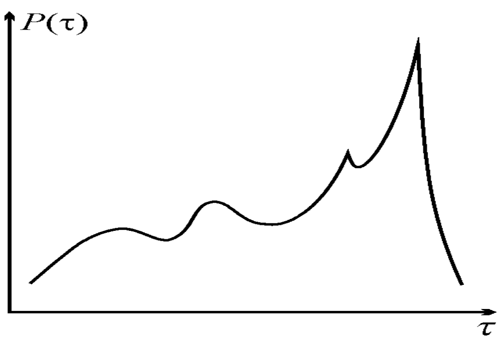

Figure 1. Loading P in the time τ from tension sensor on needle

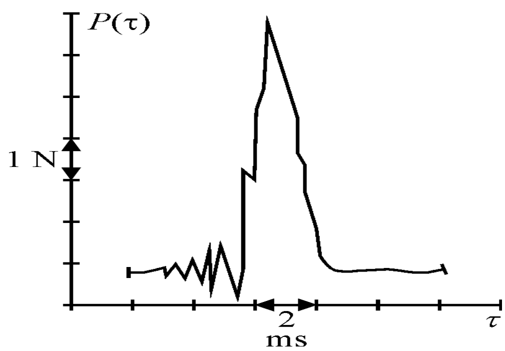

Figure 2. Loading P in the time τ from tension sensor on knitting machine carriage

Charalambus [2] has made a quality determination of the tensile force on the yarn through its deformation during knitting work. The loading is specified by the change of the yarn cross size. Coloured markers are used for the change examination in the stitch length.

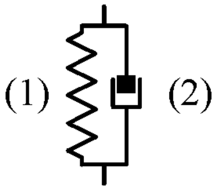

Figure 3.
Mechanical model of Kelvin

Recently attention has been focused on different mechanical and mathematical models for the strain force determination in the working zone of the knitting needles. Such models are those put forward by Budulan [1], Pusch [4] etc. This should be an opportunity to compare the results produced by the model to the real characteristics of the process researched.

2. Theoretical premises

The tensile force in knitting is specified according to the yarn elongation. In the first approximation, the acting tensile force P is proportional to the absolute elongation of the yarn $\Delta L = (L - L_0)$, which is the difference between the final length L of a certain area measured under the force action in the knitting process, and the starting length L_o under an applied standard strain force of 0.5 cN/tex. In the simplest case, this connection is described by Hook's Law, which gives the linear dependency between the force and elongation:

$$P = k.\Delta L \tag{1}$$

where k is the elasticity coefficient of the yarn.
For yarns in knitting production, this dependency is not justified. The mechanical model of Kelvin, because of its simplicity and good accordance, makes the theoretical description of the yarn behaviour under strain loading ??[[**]] to the real properties. The model contains two parallel-connected elements; the first (1) gives the elasticity properties and the second (2) gives the rayon properties of the yarn (Figure 3). The properties of the model for the linear area are given by the following formula:

$$P(\varepsilon, v) = E.S_f.\varepsilon + \beta.S_f.v \tag{2}$$

where the strain force P (ε,v) is a function of the relative elongation $\varepsilon = \Delta L/L_0$, and the elongation speed $v = \Delta L/\Delta \tau$. S_f is the area of the theoretical tubular section, E is the module of linear deformation (Young's module), β is a coefficient of rayon resistance.

3. Experimental results

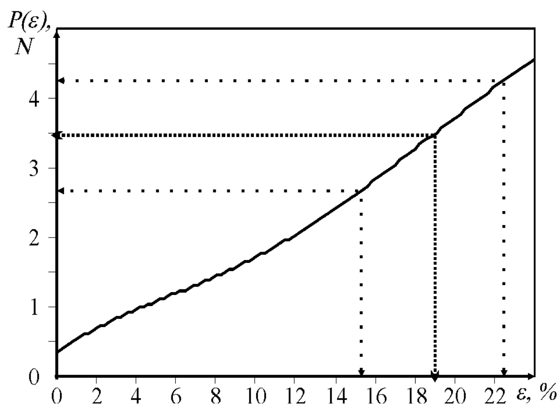

Figure 4.
Tensile force-elongation diagram for yarn of standard linear density 32x2 tex, 100% polyacrylnitrile

The graphic dependency type (2) is obtained experimentally for a certain type of yarn in dynamic researches for determining yarn toughness, and it is described in the form of a tensile force-elongation diagram $P(\varepsilon)$ at a standard defined speed of the elongation, as the right ??[[addend]] in (2) is constant. On Figure 4. such a diagram is given for yarn of standard linear density 32x2 tex, 100% polyacrylnitrile (PAN), performed by Hadzhidobrev and Petrova [3].
The elongation can be defined through marked equal intervals on the yarn length. Such approximately equal intervals are obtained technologically in the yarns containing two twisted units, whose alternation gives the necessary marks. They are best seen in an embroidery thread type of different colours of the twisted units. The step s_0, which is related to the initial length L_o and is defined under the applied standard initial tensile force, is compared to the step s (Figure 5), which is related to the final length L and is defined under the action of the work tensile force. In that case, the absolute elongation is $\Delta s = (s - s_0)$, and for the relative elongation the result is $\varepsilon_s = \Delta s/s_0$. The relative elongation is specified by the measuring results, and on this basis the tensile force P is defined.

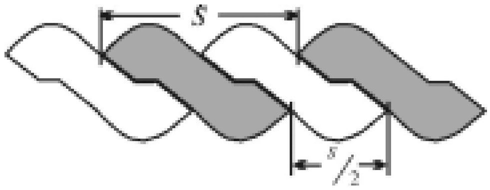

Figure 5.
Step of the screw line

The step of the screw line is measured repeatedly from the image taken by the PC-camera, and the values obtained are mediated. This method is suitable for the observation of multiple straight areas of short length (for example 1 cm), where some steps from the screw line are inserted. For example, the dimensions of the photographed area should be 1.5×1.5 cm at a distance to the object of 1–to 1.5 cm in order to obtain a quality picture of the the camera image of 800×600 pixel dimensions. The resolution in these conditions is approximately 1200 dots per inch.

Figure 6.
Photographed material frame at elongation 24% of the yarn

In Figure 6. a photographed material frame is shown at elongation 24% of the yarn with a tensile force–elongation diagram, shown in Figure 4. The black lines A, which are perpendicular to the longitudinal axis of the yarn, are marks made at intervals of 1 cm, where the length measuring line is inserted. The distance between several narrowed parts of the yarn is measured by this line, which is mediated to find the screw line step. The step of the screw line is 6.44 mm on this frame.

The accordance between setting the elongation of area at a size of 0.5 m and elongation, specified through the screw line step, is examined. At twisted yarn of initial length L_0 = 0,5 m, stretched under a standard initial tensile force loadi of 0.5 cN/tex, the absolute elongation is set at intervals of 1 cm, responding to 2% relative elongation, until the yarn is torn. For each setting value of the elongation, the screw line step s_i is measured by a scanned image and the results are statistically processed.

4. Mathematical processing and discussion of results.

The following calculations are made for the sample:

- the average value $\bar{s}$ of the found results;

$$\bar{s} = \frac{\sum_{i=1}^{n} s_i}{n}; \quad (3)$$

- the standard deviation σ of the average value;

$$\sigma = \sqrt{\frac{n.\sum_{i=1}^{n}(s_i)^2 - \left(\sum_{i=1}^{n} s_i\right)^2}{n.(n-1)}}; \quad (4)$$

- the variation coefficient of the average value in percent;

$$C = \frac{\sigma}{\bar{s}}.100\%, \quad (5)$$

where n is the number of measurements.

The aim of the processing is to calculate the average value of the elongation and its statistical characteristics, and to select optimal conditions for measuring and testing the accordance between the real elongation and that determined through the step of the screw line. In Table 1, for the certain setting elongation $\bar{s}$ the average values of the screw line step s, the standard diviation σ and the variation coefficient C for n = 20 measuring are given. In the last two rows, they are calculated as follows:

- the relative elongation ε_s. by the screw line step:

$$\varepsilon_s = \frac{\bar{s}}{\bar{s}_0} - 1 \qquad (6)$$

- the absolute error $\Delta\varepsilon_s$, established according to (6):

$$\Delta\varepsilon_s = \left(\frac{\sigma}{\bar{s}} + \frac{\sigma_0}{\bar{s}_0} \right) . \varepsilon_s \, . \qquad (7)$$

Table 1. Set elongation $\bar{s}$ average values of the screw line step s, standard deviation σ and variation coefficient C

Set relative elongation ε,%	0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0
Elongation ΔL, cm for L_0 = 50 cm and P_0 = 0,5 cN/tex	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
Screw line step $\bar{s}$, mm	4.72	5.11	5.02	5.11	5.33	5.23	5.32	5.51	5.66	5.86	5.91	6.15	6.30
Standard deviation of the step σ, mm	0.45	0.55	0.53	0.42	0.47	0.56	0.35	0.46	0.45	0.39	0.46	0.60	0.45
Variation coefficient C,%	9.53	10.8	10.6	8.22	8.82	10.7	6.58	8.35	7.95	6.54	7.78	9.76	7.14
Relative elongation ε_s, %, specified by the step $\bar{s}$	0.0	8.26	6.36	8.26	12.9	10.8	12.7	16.7	19.9	24.1	25.2	30.3	33.5
Absolute error $\Delta\varepsilon_s$, % of relative elongation ε_s	-	1.68	1.28	1.47	2.4	2.2	2.0	3.0	3.5	3.9	4.4	5.8	5.6

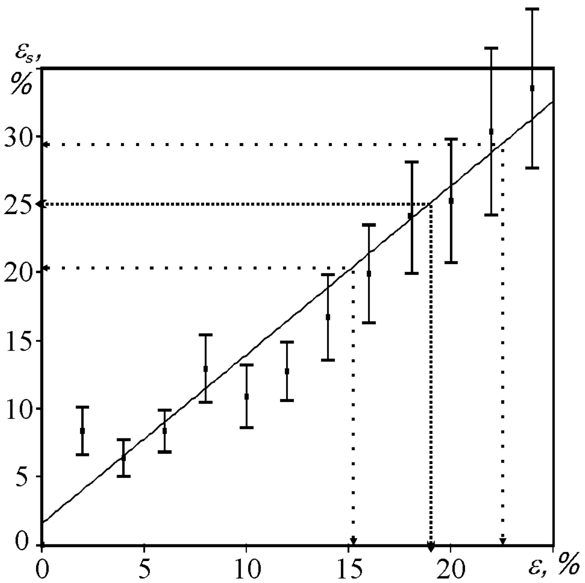

Figure 7.
Experimental results of measuring with the absolute errors

$$\varepsilon = \frac{\varepsilon_s - 1{,}44}{1{,}24} \qquad (9)$$

It is seen from the Table 1 that for low values the elongation obtained through the screw line step is not justified. The results are stabilised for higher values of ε_s, but they are increased towards those of the setting elongation ε. On Figure 7. the experimental results of measuring are entered with absolute errors. The dependency $\varepsilon_s(\varepsilon)$ is found by the method of the smallest squares, and a linear link is stated:

$$\varepsilon_s = 1{,}44 + 1{,}24.\varepsilon \qquad (8)$$

Formula (8) enables drawing the direct line on Figure 7., where it is seen that the experimental points have good accordance to the linear dependency established. Comparing the found experimental values for the relative elongation specified by the screw line *s* to the setting relative elongation, the difference in the results defines the systematic error of the method. In linear dependency, the regularity between the real and experimental specified elongation with short areas sets the systematic error. This allows for each experimental certain relative elongation ε_s the relevant real elongation ε, to be calculated:

5. Methods for determining tensile force

The tensile force of the yarn can be defined graphically through the diagrams $P(\varepsilon)$ –(Figure 4) and $\varepsilon_s(\varepsilon)$ (Figure 7) in the following sequence:

- Experimental elongation is accepted, for example ε_s = 25%;
- Through the graphic $\varepsilon_s(\varepsilon)$ (Figure 7), it is defined $\varepsilon \approx$ 18,9% for ε_s = 25%;
- Through the graphic $P(\varepsilon)$ (Figure 4), it is defined $P \approx$ 3.5 N for $\varepsilon \approx$ 18.9%;
- It is seen from Table 1 that ε_s = (25.2 $\pm$ 4.4)% and 20.8% < ε_s < 29.6%;

- From Figure 7. it is defined 15.3% < ε < 22.5% and ε = (18.9 $\pm$ 3.6)%;
- From Figure 7. for ε = (18.9 $\pm$ 3.6)% it is defined 2.7 < P < 4.3 N.

Then P = (3.5 $\pm$ 0.8) N or in percent P = 3.5 N $\pm$ 23% . When the error is performed by standard deviation, the confidence coefficient of probability of the found average values is 0.68.

6. Conclusions

A method for evaluating the tensile force in some types of special yarns is proposed.

The tensile force is found on the tensile force-elongation diagram after elongation, being specified as a change of the screw line step in the twisted units.

The step of the screw line is calculated after multiple scanning and measuring of short length areas in the working zone of the knitting needles. Scanning is possible both during knitting in producing conditions and in real time.

The method developed is designed for the experimental testing of the mathematical models created in order to specify the tensile force loading of the yarn in knitting.

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