Study of the stretching force of the needle's thread in the work with woollen textiles

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Abstract. The presented paper deals with examining the thread tension force while working with woolen textile materials. The thread's tension force is a main characteristic of a quality stitch. Its analysis and definition is characterized by the creation of a computer-integrated measuring system to determine the thread's tension force. A statistical method (double-factor disperse analysis) is used to analyze and evaluate the fact how the factors:
- F1 – surface mass of processed woolen textile materials,
- F2 –the number of layers on the thread's
influence the deviation from the maximal value of the thread's tension force.

1. Introduction

The stretching force of the needle thread is a major factor affecting the quality of the stitch line in the sewing industry.

The analysis of the nature and technological features of the process of stitching formation [6,8,9,11] shows that there are numerous factors influencing the stretching force of the needle thread.

The impact of some of them on the stretching of the upper thread has been the subject of study by several elite world famous companies [8,11].

In our country, on the stretching force of the needle thread, the influence of the factors has been studied: number of concatenated layers of under dynamic operating conditions [1] and the fibrous composition of the textile material under static operating conditions [3] through the application of two – factors and multi – factors dispersion analysis for linen fabrics under dynamic operating conditions [2, 4], etc.

The increasing variety of textile requires continuous experimentation to establish the optimal values of the tension of the needle thread for the textile material in question, which will be treated according to the specific characteristics of the sewing process.

More thorough study of this problem is further motivated by the created computer-integrated measuring system for determining the stretching force of the needle thread [10].

In modern sewing companies the maximum force of the upper thread stretching is adjusted manually from the disc brake, based on experience and the insight of the machine operator or the technician.

Thus in the factories were created conditions for the influence of the subjective factor on the quality and the productivity in the process of stitching formation.

The application of the statistical methods for research and analysis at the study of the stretching force of the needle thread places on a scientific basis these studies and it is essential for ignoring the influence of the subjective factors.

Overall, the sewing industry, especially in large-scale production, it is necessary to carry out many preliminary studies to refine the nature and the size of the stretching force of the upper thread in the specific technological conditions of work, which will be processed the textiles.

Of particular interest is the study of the attribute stretching force of the needle thread in the variation of two or more factors under dynamic operating conditions of the sewing machine, and by applying a variance analysis.

For this purpose, in the preliminary studies [1, 4] two-factor analysis of variance has been applied, as were examined respectively - cotton type fabrics (97% Cotton + 3% elastane) and linen fabrics, and in the research [2] a multi-factor dispersion analysis has been applied for linen fabrics.

By several observations on the fashion trends in terms of the fibrous composition of textile materials that were hot for the season autumn-winter 2016-17, we can summarize that prevailed the fabrics with wool and woolen type fibrous compositions.

2. Discussion and analysis

In light of the above, the objective of this work is by using of the statistical method of analysis and evaluation (two-factor disperse analysis), to establish whether it is essential, individually and jointly, the impact of factors:

- F_A – surface mass of the textile material;
- F_B - number of layers in the treated package of textile materials

on the variation of the stretching force of the needle thread for woven woolen fabrics.

2.1. Conditions to execute the experiment

The total stretching force of the needle thread during the conducting of the experiments is reported by means of a computer-integrated information measuring system [10].

The system includes the following modules:

- Modified capacitive sensor Rothschild, with integrated transformer capacity in pulse-width modulation, created on the basis of specialized integrated circuit UTI (Universal transducer interface) – Smartek;
- Converter UTI thresholds the signal with an interval of ~ 3 m Sec;
- Controller based on microprocessors Microchip - PIC 16F628. Created a program that uses the measurement results of pulse-width modulation them transferred to a package of data for communication protocol. Protocol for communication with the PC is built through communication interface - rs 232 at a frequency of exchange 19,200 bod/Sec;
- PC – saves the received data automatically, and created software is able to configure the duration of the measurement;
- By means of MS-Office, Excel is carried out the further processing of the obtained results.

The conditions for implementing the process stitching formation during the experiments are:

- Measurements for each experiment were performed under dynamic conditions;
- Sewing machine for stitch line of subclass 301 - JUKI (Japan);
- Step of stitch line - T = 3 mm;
- Selection of a sewing needle - BDS recommends ad for bonding of textile materials with the same fibrous content and structural features of double-layer package to use certain thicknesses of needles, and for three - and a multilayer package, respectively thicker needles. Therefore, attempts in which joining 2 layers of the textile materials a sewing needle № 75 was selected,

and for the experiments where 4 layers of textile material were jointed is selected sewing needle № 85;
- Sewing thread for the realization of experiments - thread with a composition 100% Cotton, trading № 50;
- For each experiment the thread stretching guide ha stop be adjusted in advance, so that the intertwining of the upper and lower thread to become the middle of the textile materials to be joined;
- Measurement starts from the upper dead point of the needle, maintaining a constant speed of rotation of the main shaft in 30 seconds;
- The nature of variation in the stretching force of the needle thread in time is given in Figure 1, it has been a representative sample of the recording of the measuring system of the tensile strength for 10 seconds;
- The rotational speed of the main shaft is determined by the number of amplitudes, Figure 1 by unit of time – second;
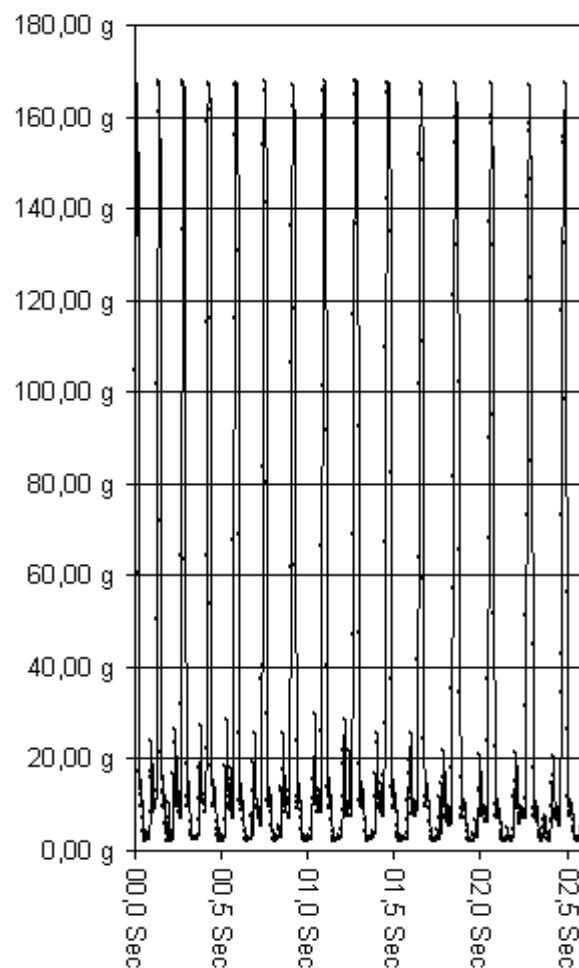

Figure 1. Variation of the stretching force of the needle thread in time

- The measuring system is calibrated so that the results of the measurement of the stretching force is in gram-force [gf]. This requires additional conversion of the research results as follows: 1 gf = 9.80665.10-3N = 0.98 cN;

- Textile materials with which the experiments were conducted are: Fabric One - 100% wool, surface mass 180 g/m^2, warp threads with Nm 52/2, weft threads Nm 52/2, warp density based on 127 threads/dm, weft density – 204 picks/dm; Fabric Two - 100% wool, surface mass 194 g/m^2, warp threads with Nm 52/2, weft threads Nm 37/1, warp density based on 175 threads/dm, weft density 263 picks/dm; Fabric Three - 100% wool, surface mass 207 g/m^2, warp threads with Nm 52/2, weft threads Nm 37/1, warp density based on 266 threads/dm, weft density 270 picks/dm.

When carrying out the two-factor analysis of variance, the values of variants of the factors F_A and F_B are: F_{A1} = 180 g/m2; F_{A2} = 194 g/m2; F_{A3} = 207 g/m2; F_{B1} = 2 layers; F_{B2} = 4 layers.

2.2. Experimental results

To assess the significant impact of both factors F_A and F_B (individually and jointly) on the stretching force of the needle thread is considered two-factor complex F_A - F_B where:

X [cN] - value of the maximum tensile force of the needle thread recorded in each trial /is determined as an average value of the maximum values of the tensile strength obtained for 30 seconds/;

m = 3 – repetitions number for each of the combinations of variations of factors;

a = 3 – factor F_A variants number;

b = 2 – factor F_B variants number;

$\overline{X}$ - general average, N – total number of tests, N = abm = 18

$$\overline{X} = (\sum_{i=1}^{N=abm} X_i)/N = 163.06 \text{ cN} \tag{1}$$

$$M_B = \frac{\sum X_B}{ma} \qquad \text{- mean values by factor } F_B \tag{2}$$

$$H_A = \frac{\sum X_A}{mb} \qquad \text{- mean values by factor } F_A \tag{3}$$

$$M_{AB} = \frac{\sum X_{AB}}{m} \qquad \text{- average for a subset} \tag{4}$$

After conducting the tests and the calculations by equations (1), (2), (3), (4) the following results are obtained:

$M_{A1B1} = 171.17 cN$; $M_{A2B1} = 168.3 cN$; $M_{A3B1} = 165.5 cN$

$M_{A1B2} = 161.5 cN$; $M_{A2B2} = 157.8 cN$ $M_{A3B2} = 154.7 cN$

$$Q_t = mb \sum \left(H_A - \overline{X} \right)^2 \tag{5}$$

$$Q_c = ma \sum \left(M_B - \overline{X} \right)^2 \tag{6}$$

$$Q_{tc} = m \sum \left[\left(M_{AB} - \overline{X} \right) - \left(H_A - \overline{X} \right) - \left(M_B - \overline{X} \right) \right]^2 \tag{7}$$

$$Q_z = \sum \left(X_{AB} - M_{AB} \right)^2 \qquad \text{- internal group variation} \tag{8}$$

The degrees of freedom are defined as follows:

$$f_A = a - 1; \; f_B = b - 1; \; f_{AB} = (a-1)(b-1) \tag{9}$$

$$f_Z = abm - ab; \; f = abm - 1 \tag{10}$$

2.3. Discussion of the experimental results .

Statistical processing of the experimental results on the algorithm of formulas (1 ÷ 10) gives the components of the dispersion, which are summarized in the Table. 1.

Table 1. Components of dispersion

Sum of squares of deviations	Degrees of freedom	Dispersion
Between the of groups factor F_A $Q_t = 104.43$	$f_1 = 2$	$S_A^2 = \dfrac{Q_t}{f_A} = 52.22$
Between the groups of factor F_B $Q_c = 496.17$	$f_2 = 1$	$S_B^2 = \dfrac{Q_c}{f_B} = 496.17$
Between the groups of interaction F_A and F_B $Q_{tc} = 1.893$	$f_3 = 2$	$S_{AB}^2 = \dfrac{Q_{tc}}{f_{AB}} = 0.947$
Internal group $Q_z = 3.67$	$f_4 = 12$	$S_Z^2 = \dfrac{Q_Z}{f_Z} = 0.307$

The resulting dispersions were evaluated using the criteria of Fisher. For this purpose, identify the relevant account and tabular values of F - criteria:

$$F_{RA} = \frac{S_A^2}{S_Z^2} = 170.1 \tag{11}$$

$$F_{RB} = \frac{S_B^2}{S_Z^2} = 1616.19 \tag{12}$$

$$F_{RAB} = \frac{S_{AB}^2}{S_Z^2} = 3.08 \tag{13}$$

$$F_{TA}\begin{cases} f_1 = a-1 \\ f_2 = abm - ab \\ r = 0.01 \end{cases} = 6.93 \tag{14}$$

$$F_{TB}\begin{cases} f_1 = b-1 \\ f_2 = abm - ab \\ r = 0.01 \end{cases} = 9.33 \tag{15}$$

$$F_{TAB}\begin{cases} f_1 = (a-1)(b-1) \\ f_2 = abm - ab \\ r = 0.01 \end{cases} = 6.93 \tag{16}$$

A comparison of expected values obtained with tabular values the criterion of Fisher at the chosen significance level r = 0.01 leads to the following conclusions:

- The surface mass of the joint woolen fabrics (F_A) substantially affects the results of the measured stretching force of the needle thread.

- The number of layers of processed fabrics package (F_B) also substantially affects the measured stretching force of the upper thread.
- Combined mutual influence of both factors (F_A and F_B) had no statistically significant impact on the stretching force of the needle thread at the selected level of significance.

3. Conclusion

- Experimental measurements of the stretching force of the needle thread under dynamic conditions of joining wool fabrics were made using advanced computer-integrated measuring system.
- The actual values of the stretching force of the needle thread X [cN] are obtained by varying the two factors.
- Two – factors analysis of variance establishes the importance of the factors: FA – surface mass of the textile materials to be joined and FB – number of layers of the processed package on the maximum value of the stretching force of the needle thread.
- The applied dispersion analysis proves that the individual effects of the factors FA and FB on the stretching force of the needle thread is statistically significant until their joint effect is negligible.
- The results are scientifically - applied character and can be used in making fast and accurate decisions in response to specific technological problems.

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