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Investigation of the Influence of Technological Knitting Parameters on the Unravelling of Structures

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Abstract. **The subject of this research is to study the influence of the technological parameters of knitting on the unravelling of structures, based on the features of the knitted structures, on the analyses made, the technological parameters of the machines as well as on the physical and mechanical properties of the raw materials. Tasks are determined depending on the need to achieve minimum disentanglement of the structures. To achieve complete optimization of the technological process, it is necessary to go through several successive stages: a general study of existing technological methods, development of technologies corresponding to modern norms and requirements, experimental determination of optimal technological parameters to achieve a minimum number of defects in the production of knitted structures, development of technical documentation based on the research done, generation of innovative methods while creating considered structures.**

Keywords: knitted structures, technological parameters, unravelling of the structures.

I. INTRODUCTION

Knitting has existed since ancient times. Knitwear in all its diversity is a challenge to make. Over time, knitting techniques have improved. With the development of technology, their mass production becomes possible. Jacquard structures are spectacular, but at the same time labor-intensive to implement. Their implementation in production takes place through multi-system cross-knitting and circular knitting machines. Modern software products offer an electronic visualization of the designed product. By means of it, a more accurate idea of the knitting process is obtained. In addition to the above, the choice of yarn and the appropriate knitting and finishing parameters are decisive for the quality of the product. One of the important tasks is to minimize the number of defects during the knitting process. In order to achieve this goal, it is necessary to know the forming details and how they are implemented on the machine [1,2,3].

One of the main problems that arise during entangling is thread tension. Based on the research done, modules have been developed that show ways to ease the stretching of the thread when crossing the loops [4,5].

The interlacing of threads, in both entangled and jacquard structures, determines their properties. Depending on the use of press and backing elements of equal or different degrees, these knits (jacquards) are classified as balanced and unbalanced. The degree of balance, depending on the use of different types and number of structural elements, determines the main parameters of the product. They predetermine its physical and mechanical properties and appearance, as well as the performance of the machine [6,7].

The considered knits are composed of basic loop elements. This is a prerequisite for the presence of properties close to the properties of the base structures. Their arrangement in a certain sequence suggests the appearance of defects. These shortcomings can be

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removed, both through appropriate technological parameters, and through the creation of structures with combined loop elements of different types and degrees. Knowing the properties of the raw materials from which the product is made helps in optimizing the technological process.

Formulation of the purpose of this research is based on the features of the considered structures, on the analyzes made and on the basis of the technological parameters of the machines and the physical and mechanical properties of the raw materials. Tasks are determined depending on the need to achieve minimum disentanglement of the structures. In order to achieve complete optimization of the technological process, it is appropriate to go through several successive stages: a general study of existing technological methods, development of technologies corresponding to modern norms and requirements, experimental determination of optimal technological parameters to achieve a minimum number of defects in the manufacture of structures with entangles and jacquard structures, development of technical documentation based on the research done, generating innovative methods while creating the considered structures.

II. MATERIALS AND METHODS

An important requirement in the knitting process is to minimize the number of defects during knitting. Therefore, the unraveling of the knitting is a main quality indicator. Many methods and techniques have been developed to ease the crossing of the loops of entangles. But so far, the dependencies between the change of technological parameters and the appearance of defects have not been investigated. One of the main technological indicators is the size of loop curling, knitting pulling force (rpm), sled movement speed (cm/sec).

To determine the optimal knitting parameters for conducting the study, an optimal composition plan (OCP) of the B_m type is selected. Plans of this type carry the most information at the star arm $\alpha = \pm 1$ and an observation in the center of the plan is made only at m=2. The advantage of these plans is that they have high information qualities with a small number of trials.

A complete factorial experiment 2^3 was conducted to determine the optimal knitting parameters of entanglements at which minimal unraveling of the knitting is observed. The process is carried out on a flat knitting machine "Steiger" E8.

After identifying the natural and coded values of the relevant factors at the different levels, the matrix for planning the experiment is drawn up.

The selected factors of influence are as follows:

X_1– weaving the thread, m/min;

X_2– fabric tension, m/s.

X_3 – machine speed, cm/s.

The selected optimization parameter is:

Y – unraveling of the product, pcs/area;

Optimization parameter is identified by the number of defects on predetermined fabric samples with dimensions of 300x200mm.

TABLE 1 RANGE OF FACTOR VARIATION

Factor levels	X_1	X_2	X_3	*Encoded value*
$X_{io} + \Delta X_i$	20.96	0.0058	0.85	+1
X_{io}	18.63	0.0041	0.70	0
$X_{io} - \Delta X_i$	16.30	0.0023	0.55	-1

TABLE 2 EXPERIMENT MATRIX

№	x_1	x_2	x_3	Y
1	-1	-1	-1	2
2	+1	-1	-1	2
3	-1	+1	-1	1
4	+1	+1	-1	0
5	-1	-1	+1	1
6	+1	-1	+1	1
7	-1	+1	+1	0
8	+1	+1	+1	1
9	+1	0	0	2
10	-1	0	0	3
11	0	+1	0	3
12	0	-1	0	2
13	0	0	+1	1
14	0	0	-1	2

Regression coefficients are calculated, the significance level is chosen, the mathematical notation of the adjusted model is represented by Eq.1:

$$\hat{Y} = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + \cdots$$

$$\ldots + b_{12}x_1x_2 + b_{23}x_2x_3 + b_{13}x_1x_3 + \cdots \quad (1)$$

$$\ldots + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2$$

The mathematical model for the solved problem is obtained after substituting the numerical values of the regression coefficients (table 3) in Eq.1, and is presented in Eq.2. The significance of the coefficients was determined at the p=0.05 level.

TABLE 3 REGRESSION COEFFICIENTS

b_0	b_1	b_2	b_3	b_{12}
2,75	-0,1	-0,3	-0,3	0
b_{23}	b_{13}	b_{11}	b_{22}	b_{33}
0,25	0,25	-0,25	-0,25	-1,25

$$\hat{Y} = 2{,}75 - 0{,}1x_1 - 0{,}3x_2 - 0{,}3x_3 + \cdots$$

$$\ldots + 0{,}25x_2x_3 + 0{,}25x_1x_3 - \cdots \quad (2)$$

$$\ldots - 0{,}25x_1^2 - 0{,}25x_2^2 - 1{,}25x_3^2$$

After that, the adequacy of the mathematical model was checked according to Fisher's criterion. Said model is adequate if the condition is met:

$$F_R = \frac{S^2_{ад}}{S^2_b} \le F_{tb}(\alpha, \upsilon_1, \upsilon_2) \qquad (3)$$

III. RESULTS

Graphical diagrams of the combined influence of the input factors on the objective functions are constructed.

From the calculations and analysis of graphs, it can be concluded that the speed of the sled and the force of the pulling mechanism are the main factors affecting the disentanglement. The size of the loop has negligible effect on the presence of defects. It is pre-extended by means of stress reduction.

At the maximum length of the loop and the maximum force of the pulling mechanism, a minimum number of defects are observed (Fig. 1) - the size of the loop and the tension force help to form new loops and to pass them under the knitting line.

Thus, the pulling force is distributed over a larger amount of thread and the tension in it is reduced. While reducing both the size of the loop the force of the pulling mechanism, an increase in unravelling is observed. Then, in the loops when crossing over, tension arises from the small thread in them and from insufficient pulling when forming new loops.

For the combination of factors, weaving the tread and machine speed, the diagram is similar (Fig.2).

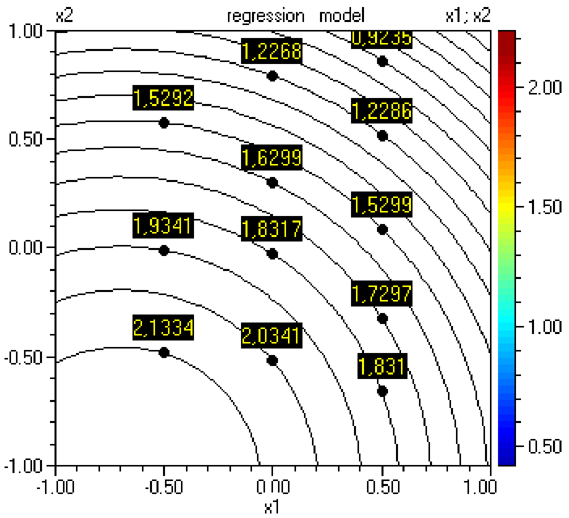

Fig. 1. Influence of X_1 - weaving the thread and X_2 – fabric tension, on Y – unravelling of the product

The weaving of the thread is of primary importance for the appearance of defects. At intermediate speed, they are highest in number. With a decrease in speed, the defects decrease - the needle has enough time to pull out a thread, form loops after crossing the preceding loops. This process is eased in trials with longer loop lengths. As the speed increases, unraveling also decreases - the time of crossing the loops is reduced, and hence the time of the tension in the thread.

Combination of factors such as knitting speed and force of the pulling mechanism creates conditions for reducing unraveling (Fig.3).

As the values of both indicators increase, a decrease in the number of defects is observed. This is due to shorter time for the loops to cross each other and cause friction between the threads.

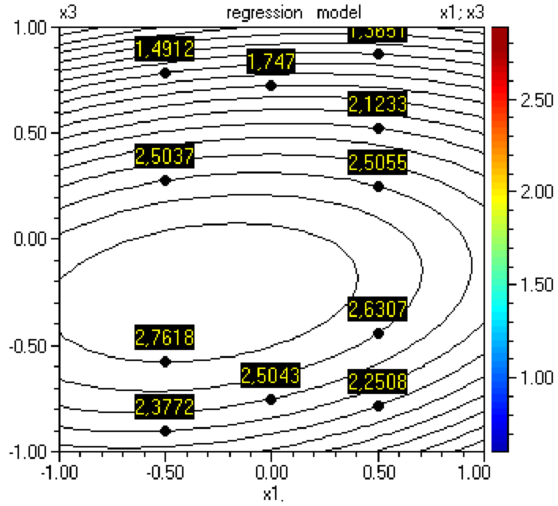

Fig. 2. Influence of X_1 - weaving the thread and X_3 – machine speed, on Y – unravelling of the product

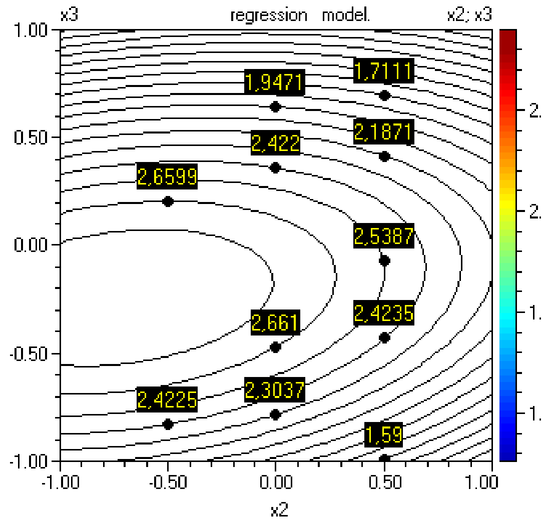

Fig. 3. Influence of X_2 - fabric tension and X_3 – machine speed, on Y – unravelling of the product

The pulling force helps to correctly stitch the subsequent stitch rows, and hence to reduce the tension in the knitted structure itself. These tests are valid for braids made from yarn with 50% cotton included. This composition of the textile thread, along with the structure and technological parameters, explains the stresses and reactions that arise in the knitting.

To prepare the program and the execution of a knitted article, several preliminary operations are necessary such as preparing and processing the textile thread, developing a program and subprogram with input parameters based on the analyses done, performing visual simulation and translating into machine language, loading and execution of the program by the machine.

For high-quality knitting process it is necessary, after analysis, to set in the program those technological parameters that ensure minimal unraveling of the knitting. On the basis of these results, the machine shrink ability along the loop post is also established for the combination of factors. Through these two indicators of the knitted product, interdependencies are established, as well as the quality indicators of the yarn. It was concluded that structures with entangles made of cotton yarn with a longer loop length have less unraveling.

IV. CONCLUSIONS

Until now, the knitting process has considered ways in which the crossing of groups of loops that make up the entangles is facilitated. This is done in the event that the material from which a given structure is fabricated does not allow it to be stretched beyond a certain limit. This mode of loop crossing does not require reversible transport of opposite loop fields, which serve as the background of the structures under consideration.

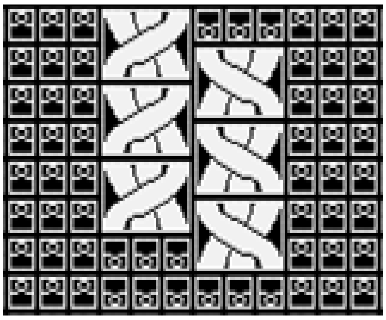

Fig. 4. Displacing the two adjacent entangles by one row

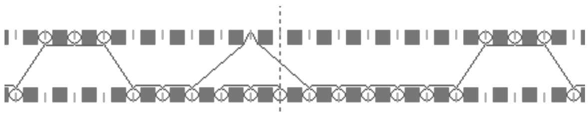

Fig. 5. Interlacing of additional yarn on the opposite bed and subsequent unloading

Such reversible transport of loops is necessary when the displacement of the entangles is large - 6 and more needle steps, and the yarn does not have great elasticity and strength. Otherwise - when shifting the needle beds by a maximum of 4 or - 4 needle pitches, the shift is carried out in several stages and the stitches are not subjected to much stretching.

When making double entangles, for better loop formation, it is necessary to move the two adjacent entangles by one row (Fig.4). As a result of this displacement, floats are formed in the middle of this tangle, which help the loops to cross. In the staggered knitting of these modules, the connecting pages pass from one needle bed to the other, thus giving more thread length to two adjacent loops. This length helps the crossing of the groups of loops to take place without the appearance of defects. A thread break can occur between a loop of the wrap background and a loop of the braid that is crossed with an offset. The unraveling in these cases may be due to a random factor or to improperly fitting knitting parameters.

In multi-stitch cross-stitch knits with more needle pitches, a background of purl stitches is required to be transported even in a knit made of elastic material. When this kind of braids with a left and right slope are combined next to each other - double braids, sometimes braiding of additional yarn on the opposite bed and subsequent unloading is used (Fig.5).

This is done in order to reduce the tension in the loops of the crossing groups. In this way, the sides of the loops subjected to maximum stretching are strengthened. Using different types of yarn means different ways of knitting and crossing loops, but obviously, the larger the loop, the easier it is to knit and transport loops.

V. ACKNOWLEDGMENTS

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