**Theory of Evaluation and Prediction of Terry Towel Strength**

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**Abstract**. In this article, a series of experiments was carried out to determine and evaluate the distribution of external tensile force along the ground warp yarn of terry towel in different ways. The proposed solution and algorithm can be used for ongoing assessment and preliminary prediction of the properties of manufactured and designed terry fabrics. The conclusions of the quantitative experiments performed do not change in terms of quality - taking into account that in the improved fabric, the ground warp yarns alternately pass one, then two and three weft yarns, as the amount of external force applied to the sample moves away from the applied cross-section, the level of tension increases.

**Keywords**: Terry towel, strength, warp and weft yarns, tension, fabric

**INTRODUCTION**

There are different methods and technology of weaving of terry fabrics, they are distinguished by their uniqueness and complexity. The stress states of such fabric samples under the influence of external forces are complex and anisotropic in nature.

The indicators that determine the strength coefficient of the yarn interact with the flexibility angle, the strength coefficient of the warp and the weft yarn is different in different phase structures. It is known that as a result of the mutual pressure between the yarns in both systems, a fabric of variable density is formed in the direction of the weft and the warp. The yarn of one system is interconnected to the second system, as a result, depending on the friction force, the angle of flexibility of the yarn of one system to the yarn of the second system is formed [1].

# LITERATURE SURVEY

The strength coefficient, friction properties, and various characteristics of ground warp and weft yarns in toweling fabrics are discussed below.

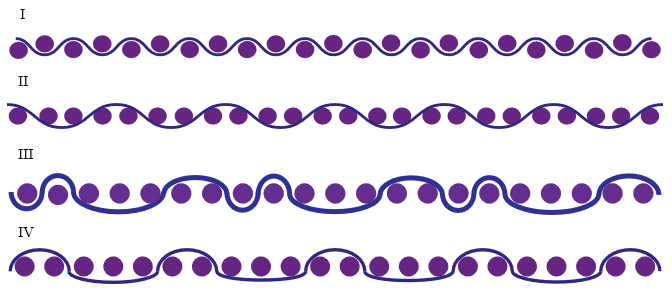
1. When determining the coefficient of strength, it was seen that the ground warp and weft yarns are absolutely flexible, have a strict cylindrical shape at all distances, and are not subjected to crushing and stretching deformations. The connection between the yarns of both systems in the fabric is based on frictional forces that resist the relative displacement of the yarns and help to create a surface similar to the real situation. It is proposed to simplify by taking one forming element of the fabric in the direction of the weft yarn to study the strength of the yarns in the determination of the fabric strength coefficient. When studying the texture of towels, it is appropriate to study the characteristics of not only fluffy but also waffle towels. Towel properties after rubbing on waffle towels obtained by new interlacings were analyzed [2].
2. 18 different samples were taken and analyzed in work 2 to study and predict the water absorption properties of terry fabrics. A mathematical model was created using the full-factor experimental method, and the titer of yarn, the total number of piles in 1 , pile height, surface density, time and level of moisture absorption were cross-analyzed. A mathematical model of water absorption was developed, and the properties of terry textile products and their results of practical experiments were interconnected. According to the experiments, a mathematical model of the theoretical and experimental values ​​of fabrics was developed and compared [3].
3. The algorithm for evaluating the dependence of yarn flexibility deformations on the main parameters of the fabric and the results of the conducted numerical experiments are presented in [4].
4. Theoretical and experimental methods of researching the flexible strength of yarns in fabric are proposed. It is recommended to use the theoretical and experimental methods of determining the developed inner strength, flexible deformations and the coefficient of flexible of the fabric in designing the properties of new yarns and evaluation of existing ones.

The law of distribution of external tensile force applied along the warp and weft yarns through the fabric is fundamentally different from the distribution of such forces along a simple yarn. This work is devoted to justifying the specific properties of each fabric and its strong influence on fabric strength.

In particular, the state of strength of the tensile force placed ground warp yarns in toweling fabric and the theoretical formulation of its assessment, analytically solutions, the algorithm for conducting numerical experiments, and the results of the performed numerical experiments and their analysis are presented. Numerous experiments were conducted to determine and evaluate the legitimacy of the distribution of external tensile force along the surface ground warp yarns of toweling fabric in different ways. A number of experiments have been conducted to determine and evaluate the distribution of external tensile force ground warp yarns of toweling fabric in different ways.

**THE METHOD OF THEORETICAL ASSESSMENT OF THE GROUND WARP YARN STRENGTH OF THE TERRY FABRIC**

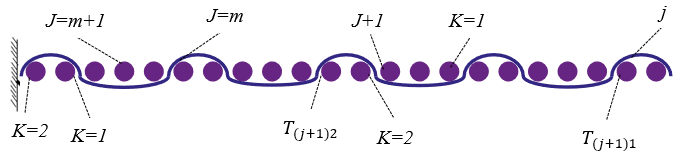
As it is known [4], the tensile strength of any sample is checked in its existing cross-section (for example, where the cross-sectional surface has a nominal value in tension). Here we look at sections where the ground warp yarns alternately pass two and three weft yarns in an improved terry fabric weave as a cross-section for strength testing.



**FIGURE 1.** Placing of ground warp yarns in fabric

Analyzes and experimental studies were carried out in cases III and IV of Figure 1 for ground warp and weft yarns. Here: I) - in the traditional fabric, the yarns of the ground warp alternated with all the yarns of the weft; II) - in traditional fabrics, ground warp yarns are two alternately weft yarns; III) – and IV) – in the improved fabric [1, 3] the ground warp yarns alternately pass two, three, and then two weft yarns in a semi-circle.

In the mechanics of solid bodies, it is based on the fact that the longitudinal layers of a central stretching elastic rod do not exert compressive force each other [4]. Based on this, we assume that when the sample under consideration is statically stretched along the yarns of the ground warp, these yarns do not exert a compressive force on each other. In addition, usually, 2-3 pile yarns pass between the ground warp yarns in the terry fabric (Fig. 1, view III) [1] and this situation serves to justify the above hypothesis. In order to create an algorithm for qualitative and quantitative assessment of the effect of improvement on stability in this way and to simplify the development of relevant conclusions, we will consider the calculation project expressed in form 2 case IV. In the algorithm here, the cases where the groun warp yarns in the improved fabric (Fig. 1) go twice around the weft yarns alternately (case IV in   
Fig. 2) a not taken into account.



**FIGURE 2.** Case IV. Algorithmic expression of yarn tension in the ground warp

We number the pieces of the two weft yarns of the ground warp yarn in the sample, which are half-circled from above, with odd numbers starting from 1 (Fig. 2), i.e., j=1, 3, 5..., m and We number the semicircular sections of the three weft yarns below with even numbers j=2,4, 6..., m+1, where m is an even number. Then the total number of weft yarns in the sample is Q:

will be equal to. Table 1 shows the results of testing the weft yarns according to the adopted algorithm.

Later on convenience in creating algorithms and electronic programs for further numerical experiments the parameters defining the state of tension of the right side of the pieces of the ground warp 2 or 3 half-circled weft yarns 1 and provide the same parameters on the left side with 2 additional indices. For example, we define the tension force of the right side of the piece of ground warp yarn wire in the form 1 by 1 and the left side by .

**TABLE 1.** The number of weft threads in the fabric

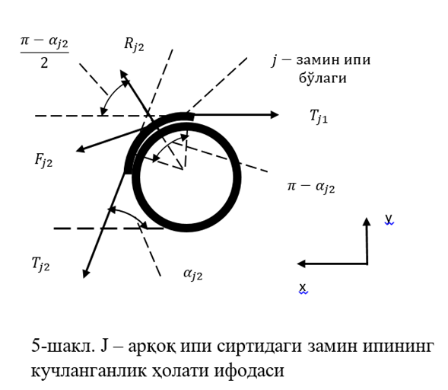
|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  | The total number of weft yarns is |
| 15 | 30 | 48 | 78 |
| 25 | 50 | 78 | 128 |
| 35 | 70 | 108 | 178 |
| 45 | 90 | 138 | 228 |
| 55 | 110 | 168 | 278 |

**RESULTS AND DISCUSSION**

Below we present the formulation and algorithm of the problem of estimating the external stretching force of arbitrary j, j+1 and j+2 groups of weft yarns in the fabric (here and after we consider j to be an odd number). We apply the cutting method of mechanics the ground warp yarn of the considered floor to the piece (Fig. 2) that covers the optional j - two weft yarns from the left side [5, 6, 7]. Since the ground warp yarn touches the weft yarns, these yarns are affected by the forces of tension T, pressure R and friction F distributed along the curve of the ground warp yarn in the area of interaction.

The vectors of tension and friction forces are directed along the tangent applied to each point of the impact area [6, 7]. We define the tension forces at the boundary points of the impact area appropriately by and , respectively (Fig. 2). The tension force in the figure is directed along the horizontal -axis, and the tension force forms an angle awith this axis.

The vector of the pressure force R lies in the plane where the vectors of the tension forces and are located and is upright directed to the forces applied to each point of the impact area. We consider the equal effector of this force to be directed along the bisector of the central angle formed by the radii of the weft yarn passing through the boundary points of the impact area [4, 5]. Herein the line of action of the pressure force makes an angle of with the horizontal -axis.



**FIGURE 3.** J is the expression of tension of the ground warp on the surface of the weft

The vector of the frictional force is placed at the point where the vector of the pressure force is placed at each point, and this force vector is upright directed. We consider that pressure and frictional forces are reasonably related by Coulomb's law

here in: - is the coefficient of friction.

The conditions for the balance of the considered ground warp yarn on the surface of the weft yarns are expressed as follows:

=0 (1)

=0 (2)

These equilibrium equations are Coulomb's law:

(3)

together with form a closed system where the unknowns and are determined.

We reduce these equations to the following form:

=0

=0

In here:

From the last equations, we find the following solution:

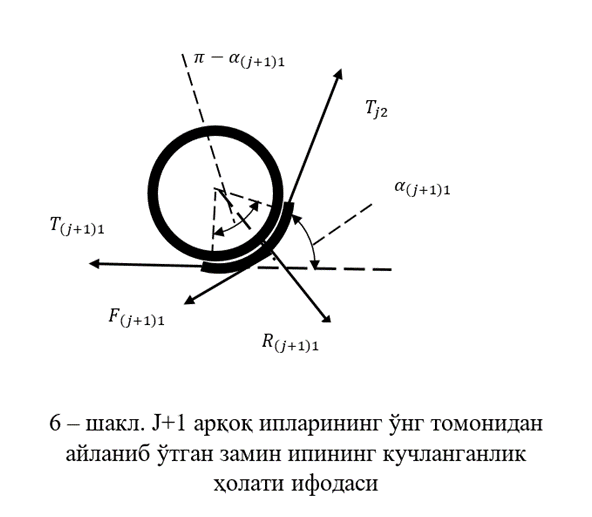
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Now we will see the piece of ground warp yarn is half circled under the second piece of yarn - three weft yarn of yarn. Algorithm divides this situation into two - first we consider the conditions of equilibrium of the piece of ground warp yarn on the right side of the weft yarns, and then on the left side separately. The right part of the ground warp yarn of the three weft yarns is represented in figure 3.

In this case, and on the right and left sides of the ground warp yarn affected by tensile forces. Here, the tension force 1 is directed along the horizontal -axis, and the tension force is equal in magnitude to the according to Newton's third law previous one and opposite in direction. That is why the value of the angle will be equal to the value of the angle .

We take the line of influence of the resistance force to be located on the bisector of the central angle formed by the radii passing through the boundary points of the area affected by the piece of string on the ground warp yarn (Fig. 3). The line of action of the frictional force is upright directed to the line of action of the resistance force and intersects with it on the surface of the ground warp yarn.

As it is being viewed equations (1) - (3) will have the following form:



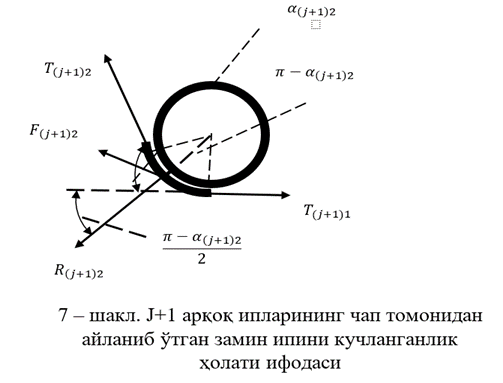
**FIGURE 4.** Expression of the tension state of the ground warp yarns that are passed from the right side of the J+1 weft yarns

We reduce the above equations to the following form:

in here:

The last equations have the following solution:

Now we see the case where the ground warp yarn is to the left of the three weft yarns. The designations adopted here are presented in Figure 4. The equilibrium equations and Coulomb's law in this case will be as follows:



**FIGURE 5.** Expression of the tension state of the ground warp yarn passed from the left side of the J+1 weft yarns

In this case, the problem has the following solution:

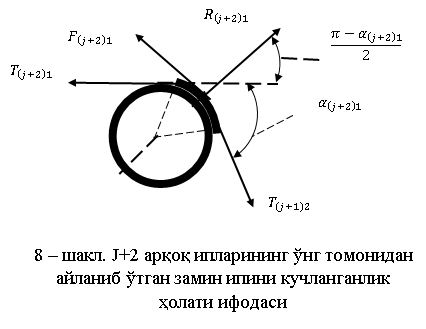
,

in here:

We see the case where the ground warp yarn is located on the right side of the three weft yarns on the ground under consideration (Fig. 6). In this case, the above equations will have the following form:

Taking into account Coulomb's law, we reduce the above equations to the following form:

in here:



**FIGURE 6.** Expression of the tension state of the ground warp yarn that is passed from the right side of the J+2 weft yarns

The issue at hand here would have the following solution:

Thus, the thread of the ground warp yarn in question is affected by the two yarns of the weft affected on the left side (Fig. 3), then, on the right, ground warp yarn - three weft yarns (Fig. 4) and In order to evaluate the strengths of the states affected by the left (Fig. 5) and the next - two weft yarns to the right (Fig. 6), a system of analytical solutions was obtained using the equilibrium conditions of statics and Coulomb's law. Using the obtained solutions, it is possible to create a system of analytical solutions to estimate the distribution of the external force along the arbitrary length of the warp on the ground, giving the corresponding values to

**CONCLUSION**

Here, a number of experiments were carried out for a fabric in which the ground warp yarns alternated four times two around the upper part of the weft yarns and four times around the lower half of the weft yarns. That is, in the numerous experiments carried out, on the ground warp yarns:

- four times, two weft threads half-circled the upper part;

- four times, three of the weft threads half-circled the lower part.

Thus, the total in the experimented sample piece:

2\*4 + 3\*4=20

weft yarns are located and the total number of semi-circulations is 8.

If, in the fabric, the ground warp yarns passed from the 20 weft yarns alternately two half turns, then the total number of turns will be 10. If ground warp yarn go around all the weft threads, the total number of such turns will be 20.

It was based on the fact that above that the degree of propagation of the external force along one ground warp yarn depends on the number of semi-circulations of the weft yarn;

- if the number of revolutions increases, the level of dispersion of the external force decreases. Based on this, the above mentioned three weaves:

- in the first one, the total number of semi-circulations is 8 - the least, and therefore the degree of dispersion of external force along the yarns of the ground warp is relatively high;

- in the second, the total number of semi-circulations is 10 - average, and therefore the level of dispersion of external force along the yarns of the ground warp is also average;

- in the third, the total number of semi-circulations is 20 - the most, and therefore the degree of dispersion of the external force along the yarns of the ground warp is relatively large.

The above numerical experiments were performed for case IV in Figure 3. That is, in the calculation experiments, it was considered that the ground warp yarns of the fabric alternately pass two and three weft yarns alternately. If, in this case, it is taken into account that the warp yarns of the ground-improved fabric alternately pass through two and three weft yarns, and after each three weft yarns, two more weft yarns a passed separately, the number of pieces of the weft yarns considered in table 1 increases. However, the conclusions of the quantitative experiments performed do not change in terms of quality - taking into account that in the improved fabric, the ground warp yarns alternately pass one, then two and three weft yarns, as the amount of external force applied to the sample moves away from the applied cross-section, the level of tension increases.

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