Development of the calculation method of polymer compound mass to be applied onto the textile garment pieces

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Abstract. The article is dedicated to the development of calculation method of a base line mass of a polymer compound to be applied onto the textiles with an added performance of friability relative to each other. The method of strengthening of the yarnded joints of products from the range of fabrics of sparse structures is being considered. The obtained results of the research made possible to reveal the negative influence of such indicators as the friability and moving ability of the yarns on the quality of yarn crossections (move ability and friability of yarns in the fabric, it’s tensile strength, stiffness, etc.) and the product as a whole, which make possible to use progressive processing methods during the selection of garment production technology. To ensure the required quality and reliability of yarnded joints of garments made of highly expandable fabrics, the studies have been carried out. At the same time, as a control, a fabric was chosen without applying a polymer and another alternative variant was chosen as well, using the liquid-phase polymer compositions along the seams. The control and alternative variants of the samples were subject to comparative assessment according to the criteria of tensile strength, resistance to friability, flexural rigidity, air permeability and resistance to washing. As a result of the studies, the rational parameters of the technological conditions of applying the liquid-phase polymer composition onto the jointing stiches of the garment components were established to improve the performance properties.

1. Introduction.
It is known by history that within the territory of Uzbekistan, the amazingly beautiful, high-quality cotton, semi-silk, silk and other fabrics have been produced [1]. The traditions developed over several centuries had their rising ups and downs, but they never died. The manufacturing features have been passed from father to son, from teacher to student, and have been survived up to day. Nowadays, the traditional art weaving takes one of the leading places in the modern national art. National fabrics have not only historical and daily importance, but also great artistic value [2].
Despite all the positive aspects (appearance, air permeability, hygroscopicity, capillarity, hygiene, etc.), the classic national fabrics retain one negative feature - the yarns in the fabrics are prone to a high degree of moving and friability.

Resistance to friability and moving depends on the structure (interlacing) of the fabric formation, its fibrous composition, the structure of the yarn, the ratio of the linear densities of the warp and weft yarns, the structure phase of fabrics, finishes, etc., in short, on those factors that determine the strength of friction and mutual adhesion between warp yarns and weft in the process of manufacturing and finishing of fabrics [3]. For example, plain weave fabrics have less moving ability (compared to twill or satin weave fabrics) due to shorter and more frequent overlap between the warp and weft yarns. The stronger curvature of the warp yarns, compared with the wefts, leads to the fact that in the yarns the expansion occurs mainly by displacing the warp yarns against to the weft yarns. The value contributions to movement index of warp and weft and their total moving ability in cross-sections at all structure phases of fabric are summarized [13]. Therefore, the resistance to moving and friability can serve as an indirect indicator of the rationality of the structure of the produced fabric.

The works [4, 5, 6] have been devoted to solve the problems above, where the authors propose to decrease the moving and friability of yarns to increase the outsizes, to use additional operations on laying along the contour of sewing parts of adhesive glued materials, applying adhesive substances along the edges of the cut to prevent the friability of yarns.

However, the proposed methods for reducing the friability and moving of yarns in the fabric lead to the need to increase the outsizes for seams, as well as the application of additional technological operations of wet and heat treatment of parts in the sewing industry, which leads to an increase in the rate of yarns consumption due to additional parameters for seams and labor output ration of the technological process of manufacturing of sewing apparels.

The conducted studies [7], showed that the most common defects of sewing apparels made from textile fabrics are the friability and of the fabric yarns along the middle seam of the back, the relief seams of the back and the front, the seams of the hose connection with the armhole, the side and middle seams of the skirt. This circumstance makes necessary to conclude that there is a need for a deeper investigation of the friability of yarns in fabrics along the lines and development of more progressive ways to improve the stability of fabric structure and its strength properties.

The improvement of the strength indexes of yarnded joints in fabrics of sparse structures due to the reduction of the friability and moving of yarns will improve the quality and extend the life of products made of these fabrics. Consequently, the problem of objective and qualitative assessment of the wear resistance of yarnded joints in the fabrics of sparse structures, aimed at improving the quality of products and prolongation of life of products among them, is a very urgent task and is of practical and theoretical interest.

The application of a polymer composition onto the surface of textile fabrics will significantly improve the physical and mechanical properties of fabrics. In this case, it is especially important to increase the form stability of a garment. An important initial parameter when applying a polymer coating is the structure of the fabric, its surface density. The density of a fabric forms a certain thickness of the fabric.

The thickness of a fabric is an indicator that has a valuable influence on its purpose and processing in the garment manufacturing. The thickness of the fabric depends on the thickness of the yarn and its twist, the interlacing of yarns, the density, and the method of forming the fabric itself and the nature of the finish.
As thicker the yarn, the thicker is fabric, when all other parameters being equal. With the increase of the number of twist of the yarn, its diameter decreases, but to a certain limit, after, the yarn is shortened and, consequently, increase in its cross section. Depending on the type of weave of the single layered fabric has been manufactured, its thickness may be different. The smallest thickness is a character of plain weave fabrics, and higher is for twill, satin and finely combined weave fabrics, the largest one for fabrics of complex weaves.

Fabric thickness depends on the degree of bending of the warp and weft yarns. If the warp and the weft are uniformly bending one another, floating in a space length of one diameter, the thickness of the fabric will correspond to the diameter of one weft and one warp yarn (Figure 1. a). There are fabrics in which the weft yarn is not bent at all, but the main yarn goes around it completely. In this case, the thickness of the fabric will correspond to one diameter of the weft yarn and two diameters of the warp yarn (Figure 1. b).

If the weft is curved less, displacing in a surface by half a diameter, and the warp is larger, floating by one and a half diameter, then the thickness of the fabric will correspond to one diameter of weft and one and a half diameter of the warp yarn (Figure 1. c).

Thus, the thickness of single-layer fabrics can be in the range of two to three diameters of yarns from which fabric is produced.

To determine the mass of the polymer coating that has absorbed into the surface of the fabric, it is necessary to calculate the consumption and mass of the weft yarn and warp yarn for a single fabric structure. For a single layered fabric’s structure, the total volume is determined from saw

\[ V = t_1 \cdot t_2 \cdot h, \]

where, \( t_1 \) – distance between the warp yarns or the width of a single fabric structure;
\( t_2 \)– distance between weft yarns or the width of the single-structure fabric in the transverse direction;
\( h \) – fabric thickness.
The Figure 2 shows the scheme of the single structure of the fabric according to the variant, Figure 1, a. From the calculation scheme, it is possible to determine the consumable length of the weft yarn for a single structure of fabric:

\[ l_y = l_{KB} + l_{BC} + l_{CD} + l_{DM} + l_{ME} + l_{ET} \]  \hspace{1cm} (1)

At that, the length of separate areas of a weft yarn will be as follows:

\[ l_{KB} = \frac{l_{AB}}{2} = (r_1 + r_2) \tan \frac{\alpha}{2}; \]

\[ l_{KB} = l_{CD} = l_{DM} = l_{ET} \]
The length of the weft yarn \( l_{BC} \) is defined in the following manner. Based on the Figure 2, it is seen that \( l_{BC} \) constitutes with a horizontal line the ground \( \alpha/2 \), thus, its sides are mutually perpendicular, accordingly, with \( l_{OBD} \) and \( l_{OBC} \). So, taking into account \( l_{BC}=l_{DM} \), we have:

\[
t_1 = 2l_{BC} \cdot \cos \frac{\alpha}{2} + 4(r_1 + r_2) \sin \frac{\alpha}{2}
\]  

(2)

From received (2) we will define \( l_{BC} \):

\[
l_{BC} = \frac{t_1}{2 \cos \frac{\alpha}{2}} - 4(r_1 + r_2) \cdot \tan \frac{\alpha}{2}
\]  

(3)

where, \( r_1 \), \( r_2 \) – there after the radii of cross sections of the weft and warp yarns.

At that, the length of the weft yarn in the single structure of fabric will be as follows:

\[
l_y = 4(r_1 + r_2) \cdot \tan \frac{\alpha}{2} + \frac{t_1}{\cos \frac{\alpha}{2}} - 4(r_1 + r_2) \cdot \tan \frac{\alpha}{2}
\]  

(4)

According to the Figure 2 b, in the same way we may calculate the length of the warp yarn of a single layered fabric:

\[
l_o = 4(r_1 + r_2) \cdot \tan \frac{\beta}{2} + \frac{t_2}{\cos \frac{\beta}{2}} - 4(r_1 + r_2) \cdot \tan \frac{\beta}{2}
\]  

(5)

where, \( \alpha \) – wrap angle by weft yarn to the warp yarn;
\( \beta \) – wrap angle by warp yarn to the weft one;
\( t_1 \)–distance of a single cross section of fabric along the weft yarn length;
\( t_2 \)– distance of a single cross section of fabric along the warp yarn.

Total volume of a single cross section of fabric is defined from the expression according to the Figure 2.

\[
V_E = t_1 \cdot t_2 \cdot (h + \Delta h)
\]  

(6)

where, \( h \) - total thickness of warp and weft yarns;
\( \Delta h \)–warp and weft yarns shifting in a single structure of fabric section.
It is known that when a polymer coating is applied to the surface of a fabric, the polymeric material fills the free space between the warp and weft yarns. In addition, depending on the density of the fabric yarns, the polymeric matter also penetrates between the fibers of yarns. Part of the polymer composition can also be absorbed into the fibers of the fabric yarn. To determine the equal amount of polymer matter when applied onto a single section of fabric, we calculate the volume of the polymer matter:

\[ V_n = V_E - V_Y - V_O + \Delta V_n \]  

where, \( V_Y, V_O \) - are, accordingly, the volumes of weft and warp yarns of a single section of fabric;

\( V_n \) - is a volume of polymer matter soaked and penetrated into the structure of fiber. As per the data of experimental studies, it reaches up to \((0.08 \div 0.11) V_n\).

Taking into account of a cross section of yarns (6), will become as following:

\[
V_n = t_1 \cdot t_2 \left[ t_1 + r_2 \right] \left[ (r_1 + r_2) + 2 + \Delta h \right] - 2\pi (r_1 + r_2) \cdot \left( \alpha \cdot r_2^2 + \beta \cdot r_1^2 \right) - \frac{\pi \cdot r_2^2 \cdot t_1}{\cos \frac{\alpha}{2}} - \frac{\pi \cdot r_1^2 \cdot t_2}{\cos \frac{\beta}{2}} + 8\pi (r_1 + r_2) \cdot \left( r_2^2 \cos \frac{\alpha}{2} + r_1^2 \cos \frac{\beta}{2} \right) - \Delta V_n
\]

\[
V_n = t_1 \cdot t_2 \left[ (r_1 + r_2) + 2 + \Delta h \right] - 2\pi (r_1 + r_2) \cdot \left( \cos \alpha \cdot r_2^2 + \cos \beta \cdot r_1^2 \right) - \frac{\pi \cdot r_2^2 \cdot t_1}{\cos \frac{\alpha}{2}} - \frac{\pi \cdot r_1^2 \cdot t_2}{\cos \frac{\beta}{2}} + 8\pi (r_1 + r_2) \cdot \left( r_2^2 \cos \frac{\alpha}{2} + r_1^2 \cos \frac{\beta}{2} \right) - \Delta V_n
\]

Figure 3 provides the scheme of polymer composition application on to the surface of a single section of a fabric.
The relationship between the linear and bulk density of the weft and warp yarn, we can fix the following relationship:

\[ h_1 = \frac{a_1}{t_1} \]

**Figure 3.** Scheme of polymer composition application onto the surface of a fabric

**Figure 4.** Structural view pattern of a single layered fabric
\[ \rho_y = \frac{\rho_{yl}}{\pi \cdot r_2^2}; \rho_o = \frac{\rho_{ol}}{\pi \cdot r_1^2} \]  

(9)

where, \( \rho_o, \rho_o \) – bulk density of weft and warp yarns of fabric accordingly;

\( \rho_{yl}, \rho_{ol} \) – linear density of weft and warp yarns. At that, the mass of weft and warp yarns in the single layered structure of fabric is defined, based on the following formula:

\[ m_y = \rho_{yl} \cdot l_y; m_o = \rho_{ol} \cdot l_o \]  

(10)

Mass of a polymer composition to be applied on to the fabric is defined based on the following expression:

\[ m_n = V_n \cdot \rho_n \]  

(11)

where, \( \rho_n \) - specific density of polymer.

It is necessary to note that for the variant given in the Figure 1 \( b \), the mass of the weft and warp yarn is defined, based on the following expressions:

\[ m_{yl} = \rho_{yl} \left[ 4 \left( r_1^1 + r_2^2 \right) \frac{\alpha_1}{2} \cos \frac{\alpha_1}{2} - 8 \left( r_1^1 + r_2^2 \right) \cdot \tan \frac{\alpha_1}{2} \right] \]  

\[ m_{ol} = \rho_{ol} \cdot t_2^1 \]  

(12)

Volume of a polymer composition to be applied onto the fabric surface for the variant given in the Figure 1 \( b \), will have:

\[ V_{n1} = 2 t_1^1 \cdot t_2^2 \left( r_1^1 + 2 r_2^1 \right) - 2 \pi r_2^1 \cdot t_1^1 \cdot \frac{r_1^1}{\cos \frac{\alpha_1}{2}} \left( r_1^1 + r_2^1 \right) - 8 \pi (r_2^1)^2 \cdot \Delta V_{n1} \]  

(13)

where, \( r_1^1, r_2^1 \) - are radii of a weft and warp; \( t_1^1, t_2^1 \) – distance between weft and warp yarns; \( \alpha_1 \) - wrap angle by weft yarn the warp one.

At that, we may have the expression for calculation of the mass of polymer composition to be applied onto the surface of fabric for the variant given in the Figure 1, \( b \):

\[ m_{n1} = V_{n1} \cdot \rho_n \]  

(14)

**Conclusions.** The results of experimental studies are presented in Figures 5-8. As can be seen from the given graphs, the mass of the applied polymer composition on the surface of the textile in the
direction of the warp and weft yarns, as well as the width of the single parameters for the warp and weft yarns has the linear relationship.

Thus, the maximum mass (m) of the polymer composition at a maximum radius $r_1$ of warp yarns (Figure 5). With a minimum radius of warp yarns of textile, the mass of the polymer composition is 55.4% from maximum value. At that, the average value of mass of the polymer composition at the range being considered of the warp yarn radius is 77.7% of the maximum value.

![Figure 5](image5.png)

**Figure 5.** Diagram of relationship of a polymer composition with a radius of the warp yarn made of cotton

Maximum mass (m) of the polymer composition at a minimum radius $r_2$ of the weft yarns (Figure 6). At the maximum radius of the textile warp yarns, the weight of the polymer composition is 70.5% of the maximum value. At that, the average value of mass of the polymer composition at the range being considered of the radius of the weft yarns is 85.25% of the maximum value.

![Figure 6](image6.png)

**Figure 6.** Diagram of relationship of a polymer composition with a radius of the weft yarn made of cotton

From the given schemes (Figure 7 and 8), the mass of the applied polymer composition on the surface of the textile from the width of single indices along the warp and weft yarns has the linear relationship.

Thus, the maximum mass (m) of the polymer composition at a maximum value of a single structure $t_1$ for the warp yarns (Figure 7). At a minimum value of a single structure for the warp yarns, the mass of the polymer composition has 54.9% of the maximum value. At that, the average value of
the mass of the polymer composition at the range being considered of the warp yarn radius is 77.45% of the maximum value.

![Figure 7. Diagram of relationship of a polymer composition from the width of a single layered structure fabric of warp yarn](image)

The maximum mass \( m \) of the polymer composition at a maximum value of a single structure \( t_1 \) for the weft yarns (Figure 7). At a minimum value of a single structure for the weft yarns, the mass of the polymer composition has 51.85% of the maximum value. At that, the average value of the mass of the polymer composition at the range being considered of the warp yarn radius is 75.9% of the maximum value.

![Figure 8. Diagram of relationship of a polymer composition from the width of a single layered fabric of weft yarn](image)

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