**Theoretical Study of Designing Mixed-Composition Fabrics Based on Filling of Fibrous Material**

Matluba Doniyorovaa), Shamsiya Shumkarovab), Mohira Yoʻldashevac), Uralbek Jabborovd)

*Jizzakh Polytechnic Institute, Jizzakh, 130100, Uzbekistan*

*a)Corresponding author:* [*matlubadoniyorova1980@gmail.com*](mailto:matlubadoniyorova1980@gmail.com)

*b)*[*shoxbozshunkarov1971@gmail.com*](mailto:shoxbozshunkarov1971@gmail.com)

*c)*[*mohira-1989@bk.ru*](mailto:mohira-1989@bk.ru)

*d)uralbekjabborov8@gmail.com*

**Abstract.** Mixed-composition fabrics occupy a special place among textile products manufactured in our country, which have a high export index. Scientific research was conducted on the production of fabrics of mixed composition, the study of their physical and mechanical properties and the assessment of quality indicators. Yarns made of natural fibers provide hygienic properties of the fabric, and yarns made of synthetic fibers improve its performance properties. Theoretical studies were conducted on the design of raincoat fabrics of mixed composition using the unique features of two-layer complex weaves, with different colors and properties on the front and back sides, and the composition of the warp and weft yarns for the samples was selected. When designing blended fabrics, cotton yarns with a linear density of 29.4 tex were used on the warp, and cotton yarns (29.4x2 tex) and acrylic fiber yarns (40 tex) were used in the weft yarns in a ratio of 1:1. The densities of the warp and weft yarns of the proposed mixed-composition raincoat fabric were theoretically investigated based on other existing raincoat fabric parameters, without changing the linear densities of the warp and weft yarns of the proposed mixed-composition fabric. The possibility of manufacturing prototypes taking into account the total percentage of filling of various fabrics developed on the basis of existing raincoat fabrics was substantiated.

**Keywords.** Mixed composition, fabric, complex fabrics, weave, upper layer, lower layer, layer filling parameters, cotton yarn, acrylic fiber yarn, fabric density, fibrous materials, filling percentage.

**INTRODUCTION**

Our government is implementing effective reforms aimed at the future development of New Uzbekistan, the free and prosperous life of our compatriots, the realization of their desires and will, and the creation of all opportunities for each citizen to develop their talents and potential. Also, great attention is paid to their health and education in raising a spiritually mature generation. The main goal was to form a strong economy in our country, including the rule of law, ensuring security and stability, and in this regard, the Decree of the President of the Republic of Uzbekistan No. PF-158 on the Strategy “Uzbekistan - 2030” was approved on September 11, 2023. In this regard, in order to develop the "driver" sectors of the industry and fully utilize the industrial potential of the regions, a separate task was set to achieve 100% yarn recycling in the textile industry by 2030 and to establish the production of 400,000 tons of chemical fibers to meet the demand for high-quality, competitive textile fabrics.

In order to fulfill the above tasks, the literature on the production of mixed-composition fabrics was analyzed, and on this basis, research was conducted on the design of mixed-composition fabrics based on local natural fiber cotton yarns and chemical fiber acrylic yarns.

The first raincoats worn in rainy weather appeared in China several centuries ago and were made from bamboo fiber. In Europe, in the first half of the 19th century, Scottish chemist Charles Mackintosh created a new fabric that was waterproof, but difficult and uncomfortable to wear, by pouring tar (liquid rubber) between two layers of fabric. Later, T. Burberry invented gabardine, a breathable but waterproof and extremely durable fabric in the rain, and these fabrics were used as raincoat fabrics. Croatian researchers have investigated whether the Burberry raincoat fabric, which is used in various weather conditions, is made of linen or wool [1].

Chemical research has been conducted by Chinese researchers to improve the waterproof properties of fleece fabrics [2,3]. The fabric is treated with light pressure, the surface is coated with glue based on polyurethane and various other additives, the fabric is covered with a thin macromolecular hydrophilic polymer PU film, and cleaned with high-quality water, resulting in a high-strength, water- and vapor-proof fleece fabric that meets high technological requirements and is put on sale as a finished product. The research also studied the quality indicators, in particular, smoothness, strength, water permeability of the fabric surface, moisture penetration, and color fastness, based on the fleece fabric standard, and found that it meets the requirements of the standard.

Among the textile products produced in Uzbekistan, mixed fabrics occupy a special place among the products with high export indicators. A number of scientific research works are being carried out on the production of mixed fabrics, the study of their physical and mechanical properties, and the assessment of quality indicators. In particular, leading scientists such as E.Sh. Alimboev, O.A. Akhunboboev, B.Kh. Baymuratov, P.S. Siddikov, D.G. Aliyeva, S.A. Khamrayeva, D.N. Kadirova and researchers under their leadership have studied scientifically effective ways of producing mixed fabrics based on yarns spun from natural fibers such as cotton, silk, wool and their mixtures with chemical fibers [4].

In the research work of N.B. Yusupova on the design of suit fabrics with the required properties based on cotton and polyester fibers according to specified parameters [5], samples of suit fabrics of various compositions were obtained under production conditions and a comprehensive assessment of their quality indicators was carried out. A program of the methodology for designing suit fabrics according to specified parameters was also developed.

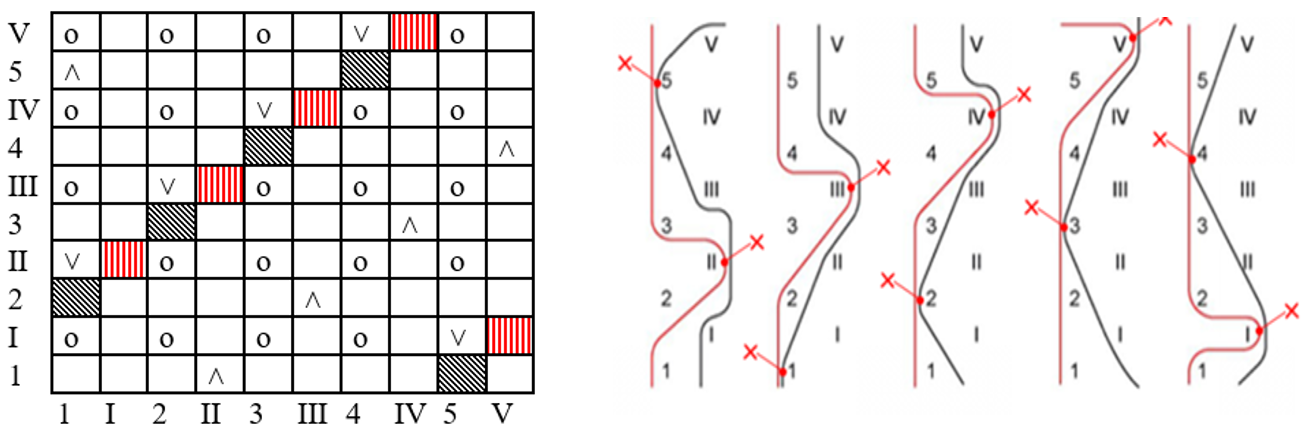
In the research work on the study and optimization of yarn tension in the production of shirt fabrics on shuttleless looms [6], in addition to cotton fibers, chemical yarns were used as warp yarns for shirt fabrics: lavsan, nitron, nylon, polypropylene. The properties of the prototypes, such as wear resistance, air permeability, tensile strength and relative elongation at break, were studied, and a conclusion was made about their compliance with the standard indicators of shirt fabrics. Also, in the research work on the creation, design and study of factors affecting the structure of new types of samples of the assortment of national fabrics with different fibers [7], a new two-layer fabric "Adras" was created, consisting of a layer of cotton warp and weft yarns in the upper layer and a layer of cotton warp and weft yarns in the lower layer, and a new composition of the "Adras" fabric from modified acrylic fiber yarn was developed, which has low wrinkling and elasticity close to silk yarn. A patent for an industrial design was received for the new "Adras" fabric from the Intellectual Property Agency of the Republic of Uzbekistan.

**MATERIALS AND METHODS**

In the modern textile industry, mixed fabrics made from natural and synthetic fiber yarns are widely used [8]. Natural fiber yarns serve to ensure the hygienic properties of the fabric, while synthetic fiber yarns serve to increase its operational properties [9]. The produced fabric is resistant to mechanical stress and is durable, as well as convenient to use [10].

There are various methods for producing mixed fabrics. In the first method, mixed fabrics are produced by using yarns made by mixing fibers of similar nature in different proportions (for example, 67%:33%, 50%:50%). In the second method, two or more yarns with different fiber compositions are twisted together to form a mixed-composition yarn, which makes it possible to obtain a mixed-composition woven fabric. In the third method, the fiber composition of the yarns used for the warp and weft of the fabric is different from each other, and the properties and appearance of the fabric produced by this method are fundamentally different from those produced by the above two methods.

The research work examined the issue of designing mixed-composition fabrics in the third method. Fabrics are divided into two groups: the first group is simple (single-layer) fabrics formed by basic and small patterned weaves using one system of warp yarns and one system of weft yarns. The second group is complex fabrics formed by at least two systems of warp yarns and one system of weft yarns, or one system of warp yarns and two systems of weft yarns, or two or more systems of both warp and weft yarns. Unlike simple fabrics, in complex fabrics it is possible to increase the surface density and thickness of the fabric without increasing the linear density of the yarns. It is important that the linear density of the yarns of the second system is higher or lower than the linear density of the main yarns. Secondly, it is possible to obtain a fabric with a sheen along the warp on the front side of the fabric and a sheen along the weft on the back side. In addition, using yarn with different fiber compositions, it is possible to obtain the front and back sides of the fabric with different properties and colors [11-14].



**FIGURE 1.** Two-layer fabric with layers connected in a “mixed” way based   
on the main weaves twill 1/4 and twill 4/1

**a) Two-layer fabric**

**b) Cross-section of the fabric along the warp**

In order to obtain mixed-composition checkered fabrics with different colors and properties of the front and back sides, using the features of a two-layer complex weave (Figure 1), theoretical studies were conducted on their design and the composition of the warp and weft yarns for the samples was selected (Table 1). In the production of mixed-composition fabrics, a two-layer complex weave was used (Uzbekistan patent No. SAP 2662, 2024).

As the object of the study for all the studied samples, it was planned to use cotton single yarn with a linear density of 29.4 tex as warp yarns. To obtain raincoat fabrics of mixed composition, cotton yarn with a linear density of 29.4x2 tex and acrylic yarn with a linear density of 40 tex (yarn ratio 1:1), presented in Table 1, were chosen as warp yarns.

**TABLE 1.** Composition of warp and main yarns for the developed fabrics of mixed composition

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Linear density of yarns in a fabric, tex | | | | Ratio of warp yarns of the upper and lower layers |
| for the upper layer | | for the lower layer | |
| warp yarn -  cotton based | weft yarn -  cotton based | warp yarn -  cotton based | weft yarn -  acrylic fiber |  |
| 29.4 | 29.4x2 | 29.4 | 40 | 1:1 |

**RESULTS AND DISCUSSION**

Theoretical studies were conducted on the design of mixed fabrics taking into account the percentage of filler. In this case, the following design study was conducted, assuming that the surface density of the designed mixed fabrics is the same. The calculation was made based on the parameters of the actual fabric. The density of the designed raincoat fabric in the direction of the warp was determined as follows:

 (1)

where:  and - linear density of warp yarns in the actual and designed fabrics;  and - warp density of the actual and designed fabrics.

The density of the weft of the design raincoat fabric was determined as follows:

 (2)

where:  and - linear density of weft yarns in the actual and designed fabrics;  - weft density of the actual fabric.

Considering that the designed fabric uses two systems of warp yarns with different fiber content and linear density, their average linear density was calculated. It was taken into account that the warp yarns have two different linear densities.

We determine the percentage of filling of the designed fabric with fibrous materials.

The percentage of filling of the fabric with fibrous materials depending on the weave is determined as follows:

 (3)

The warp yarn diameter was determined as follows:

 (4)

where: - diameter of warp yarn; -warp fill factor, depending on the fiber composition of the yarn, for cotton yarn C=1.23÷1.26.

The percentage of fabric filling with fibrous materials by the warp is determined as follows:

 (5)

where: - diameter of weft yarn;

The weft yarn diameter was determined as follows:

 (6)

The percentage of filling of the fabric with fibrous materials is determined as follows:

 (7)

where: - Filling the designed fabric with fibrous materials on the warp; - Filling the designed fabric with fibrous materials on the weft.

Without changing the linear densities of the warp and weft yarns of the designed mixed raincoat fabric, the densities of the designed raincoat fabric by warp and weft were calculated based on other current parameters of the raincoat fabric and are presented in Table 2.

According to it, in the first version of the current raincoat fabric, the linear density of the warp yarns is 29.4x2 tex, and 50 tex, the density of the fabric by warp 180 yarns/10 cm, the density by weft 230 yarns/10 cm, in this case, when calculating the densities by warp and weft of the designed mixed checkered fabric by warp, the density by warp 256 yarns/10 cm, the density in the weft 236 yarns/10 cm.

**TA 2.** Results of calculating the density of the designed raincoat fabric of mixed composition

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| № | Fabric samples | Linear density of yarns in a fabric, tex | | Fabric density,  yarns/10cm | | |
| Warp yarn | Weft yarn | In the warp yarn | In the weft yarn |
| 1. | actual | 29.4x2 | 50 | 180 | 230 |
| designed | 29.4 | 30x2 (40) | **256** | **236** |
| 2. | actual | 15.4x2 | 50 | 200 | 210 |
| designed | 29.4 | 30x2 (40) | **204** | **214** |
| 3. | actual | 29.4x2 | 29 | 200 | 190 |
| designed | 29.4 | 30x2 (40) | **314** | **148** |

Calculation of the warp and weft densities of the designed raincoat fabric of mixed composition based on the warp of linear density 29.4 tex and weft threads of two different linear densities 30x2 tex and 40 tex allowed theoretical calculation of the percentage of filling of fabrics. This is also a necessary indicator when calculating the coefficient of connexity when choosing the type of weaving machine for this designed raincoat fabric.

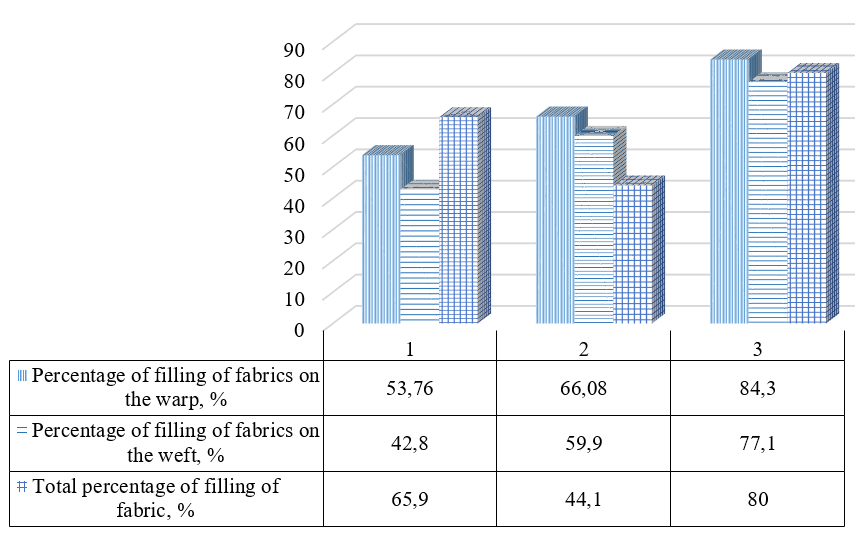
**ANALYSIS OF RESEARCH RESULTS**

In the second variant of the raincoat fabric used (Table 2), the linear density of the warp threads is  tex and tex, the fabric density by warp is  yarns/10 cm, the density by weft is  yarns/10 cm, in this case, when calculating the densities by warp and weft of the designed checkered fabric of mixed composition, the density by warp is  yarns/10 cm, the density by weft is  yarns/10 cm. Also, in the 3rd variant of the current checkered fabric, the linear density of the warp threads is tex, and tex, the fabric density by warp is  yarns/10 cm, the density by weft is  yarns/10 cm. In this case, when calculating the densities by warp and weft of the designed checkered fabric of mixed composition, the density by warp is  yarns/10 cm, the density by weft is  yarns/10 cm. To calculate the filling factor of the designed fabric based on pile fabric of mixed composition with fibrous materials, calculations were performed on the basis of the calculated densities of the warp and weft threads of the designed fabric (formulas 3-5) without changing the linear density of the warp and weft threads for three fabric options and are presented in Table 3.

**TABLE 3.** Results of theoretical calculation of the filling percentage of the designed fabrics

|  |  |  |  |
| --- | --- | --- | --- |
| № | Percentage of filling of fabrics on the warp, % | Percentage of filling of fabrics on the weft, % | Total percentage of filling of fabric, % |
| 1. | 53.76 | 66.08 | 84.3 |
| 2. | 42.8 | 59.9 | 77.1 |
| 3. | 65.9 | 44.1 | 80 |

The table above shows the percentage of filling of the developed fabrics by warp and weft, as well as the total fiber material. For analysis, the data are presented as a histogram in Figure 2.



**FIGURE 2.** Histogram of the results of theoretical calculations of the percentage of filling of the designed fabrics

In this case, since the linear density of the warp and weft threads remained unchanged in all variants, only the effect of the fabric density by warp and weft on the percentage of filling of the fabrics was analyzed. That is, in the sample of the 1st variant, with the density by warp  yarns/10 cm and the density by weft  yarns/10 cm, the percentage of filling of the fabric by warp was  %, the percentage of filling by weft was %, and the percentage of total filling was relatively the highest - %. In the sample of the 2nd variant, with a warp density of  yarns/10 cm and a weft density of  yarns/10 cm, the fabric fill ability by warp was %, by weft – %, and the total fill ability was %. At the same time, the total fill ability of the fabric in the 2nd variant was 9.1% lower due to the higher warp density of the sample of the 1st variant.

**CONCLUSIONS**

Scientific research was conducted on the production of fabrics of mixed composition, the study of their physical and mechanical properties and the assessment of quality indicators. Yarns made of natural fibers provide hygienic properties of the fabric, and yarns made of synthetic fibers improve its performance properties. Theoretical studies were conducted on the design of raincoat fabrics of mixed composition using the unique features of two-layer complex weaves, with different colors and properties on the front and back sides, and the composition of the warp and weft yarns for the samples was selected. When designing blended fabrics, cotton yarns with a linear density of 29.4 tex were used on the warp, and cotton yarns (29.4x2 tex) and acrylic fiber yarns (40 tex) were used in the weft yarns in a ratio of 1:1. The densities of the warp and weft yarns of the proposed mixed-composition raincoat fabric were theoretically investigated based on other existing raincoat fabric parameters, without changing the linear densities of the warp and weft yarns of the proposed mixed-composition fabric. The possibility of manufacturing prototypes taking into account the total percentage of filling of various fabrics developed on the basis of existing raincoat fabrics was substantiated. As a result of theoretical studies, it can be concluded that in the samples developed on the basis of the filling indices of real raincoat fabrics, in option 1 with a warp density of pp/10 cm and a weft density of pp/10 cm, the overall percentage of fabric filling is relatively high %, and these filling indices are advisable to use in the manufacture of pilot samples. The high filling coefficient of the developed fabric allows to reduce its hygroscopicity.

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