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Study on pigment dyeing opportunities of polyester and cotton-mix fiber

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Abstract. The process of coloring the dyeing pigments in polyether and cotton fibers for different fabrics, which are inclined to dye, have been studied in this article. Based on the experiences on pigments dyeing, it was suggested to study the materials with the dyeing pigment substances with the purpose of improving the technology of color forming.

1. Introduction

Products made of mixed fiber have a number of privileges: the increase of mechanic strength, the increase of abrasion and bending stability, elasticity, stability against the effects of chemical reagents (acid, alkali), stability increase in wet and dry condition forms, reduced contaminants. At the same time, hydrophobic properties of the product (i.e. added fiber) or its crudeness cause a series of shortcomings: its hydrophobic properties decrease, sanitary and hygienic properties and dyeing of garments and sheets deterioration, fibers on fabric surface are covered in the manner that it affects to quality. Production of yarn from natural and synthetic fiber mixes yarn, knitted fabrics, and further production of fabric, knitted fabrics and finished products is an important way to expand the range of products. To solve the above-stated problem, the development of effective technologies of dyeing the mix-fiber textile fabrics, the study and research of preserving fabrics consumer properties at dyeing is one of the most significant issues. Through the positive solution of this issue, we can fulfill the following tasks (1) expansion of the range of products and advanced processing of raw materials.

2. Theoretical part

Cotton and polyester mix-fiber fabrics with a ratio of 75/25, 57/43, 44/56 are considered as the object of the scientific research. The cotton-polyester mix-fiber fabrics were dyed using the pigment dyeing technology. The physical-mechanical features of dyed samples were analyzed by their color characteristics (3,4).

3. Experimental part

Dyeing of textile fabrics containing the waterleaf and hydrophobe fibers, selection of dyeing color class or their mixtures, textile axiliary within paint solution and dyeing technology substances is of special importance. Usually, disperse dyeing substances are selected for polyester fibers, and active, cube and direct classes of dyeing substances are selected for cotton fiber, and based on them the dyeing technological procedure is carried out on single and dual phase methods. Single phase method is focused on the aggressiveness of dyeing substances and mutual temperature trend (5). However, the application of pigment dyeing is considered ecologically effective for fiber textile materials. It can be used for dyeing mix-fiber textile materials of various nature. There can appear no sorbtion and
diffusion procedures in this type of dyeing technology. Therefore, the mutual compatibility of components within dyeing solution is out of proper focus, and this in its turn provides an opportunity of even quality dyeing (6,7). Until the recent years, two types of polymer preparations (forming stains and seaming) have been used in pigment dyeing process (8). The main shortcoming of these compositions is not meeting the requirements of environmental safety, because their use causes the allergic and toxic air emissions - formaldehyde pollute cloth, working area and air. Nowadays, the invention of stain producing new thermoreactive copolymers, together with the above mentioned polymers capable to complete both tasks, requires development of dyeing technologies which do not produce poisonous substances while using pigment dyeing. At this stage of the research studies experiments on creation of pigment dyeing solution composition and their comparison by received colors were carried out based on the number of new copolymers. The following pigment dyeing composition (9) for cellulose fabrics (in %) have been used as a basis for preparation of dyeing composition samples with cotton and polyester mix-fiber fabrics: pigment – 0,1-0,3; stain creating – 2,0-5,0; antimigrant – 0,050-0,075; wetting – 0,06-0,08; water – up to 100.

As stain creating materials acrylic and urethane-based preparations, emulsion thickeners, prevocel WOF 100 as a wetter, manutex RS as antimigrant were used. The efficiency of mixtures used in experiments is shown in diagram 1.

![Diagram showing the effect of the mixture type to color intensity in pigment dyeing.](image)

**Figure 1.** The effect of the mixture type to color intensity in pigment dyeing. 1-Laurusu-33; 2-Emulsion thickener; 3-Karbamol SEM; 4-Repellan KFS; 5-Rusinu-14-i; 6-Akvapola-10; 7-Akvapola-21.

The obtained results show that in dyeing composition urethane (Akvapola-10, Akvapola-21) and acrylic (Laurusu-33, Rusinu-14-i) polymers' samples color intensities are not lower than the results of the samples of previously used polymers. It is well known, that the problem of fabrics solidification after pigment dyeing led to less widely usage of this dyeing substance for textile materials. The solidification indicators of the sample materials dyed by the new mixture preparations were investigated, the obtained results are shown in 2-diagram.
The effect of the mixture type to the fabrics solidification level in pigment dyeing. 1-Laurusu-33; 2-Emulsion thickener; 3-Karbamol SEM; 4-Repellan KFS; 5-Rusinu-14-i; 6-Akvapola-10; 7-Akvapola-21.

When solidification indicators of cotton and polyester mix-fiber fabrics after pigment dyeing were determined, we found out that the samples dyed using mixtures based on thermosetting acrylic and urethane copolymers have smooth surface characteristic shown in the above diagram. The reason for that is that copolymers are small particles, and their water emulsions deeply penetrate into fiber’s structure and here after drying and fixation procedure the stain creation procedure comes to an end. The content of butyl acrylate monomery and acryl acid esters in polymers leads to choosing smooth and elastic textile materials (10).

The next research stage tested the abrasion tolerance and color smoothness of the obtained color from mix-fiber fabrics (Table 1).

Table 1. The effect of seaming preparations types to abrasion tolerance and color smoothness.

| Seaming preparation types | Color abrasion strength, points | Color smoothness, % |
|--------------------------|--------------------------------|---------------------|
|                          | Cotton and polyester mix-fiber fabrics, |          |
|                          | 75/25 | 57/43 | 44/56 | 75/25 | 57/43 | 44/56 |
| Laurusu-33               | 4/4   | 4/4   | 4/4   | 1,2   | 1,2   | 1,2   |
| Emulsion thickener       | 3/3   | 4/3   | 4/3   | 1,4   | 1,1   | 1,5   |
| Karbamol SEM             | 3/4   | 4/3   | 4/4   | 1,4   | 1,2   | 1,4   |
| Repellan KFS             | 4/4   | 3/4   | ¾     | 1,3   | 1,0   | 1,2   |
| Rusinu-14-i              | 4/4   | 4/3   | ¾     | 1,1   | 1,3   | 1,0   |
| Akvapola-10              | 3/3   | 4/4   | 3/3   | 1,1   | 1,2   | 1,2   |
| Akvapola-21              | 4/3   | 4/4   | 4/3   | 1,2   | 1,1   | 1,1   |

The results indicate, that even both when water dispersion of copolymers with small particles and previously applied mixtures were used, non-smooth colors appeared and their abrasion tolerance was not strong enough. The reason for that is, that dimensions of used dispersions are smaller than dimensions of pigment particles, and they penetrate inside the fiber in advance and fill in fiber hollows. The main part of pigment large particles remains on surface and they are smoothly spread on fiber and fiber hollows.

The process of dyeing textile materials is not final, and in order to have final ready fabric it is decorated finally after it is dyed and printed. During final decoration process in addition to acquiring
new characteristics, the fabrics also receive the functionality as per new requirement level. But, during final decoration process, because of creation of stain on fabrics surface after using specific preparations, the color intensity of fabrics decreases and even sometimes its tones can change. Allowing for these factors, the level of change of effected color quality of the fabric surface after the final pigment dyeing using preparations have been studied. According to the above indicated order and content on the surface of dyed fabrics’ samples, based on final decoration technology polymer layer was created. The samples of cotton and polyester mix-fiber fabrics with various fiber ratio were soaked in pigment dyeing substance solution, and after drying and thermosetting process it was thermo treated by polymer solution of seaming preparations. Then, the samples were pressed off, dried and again thermos treated. The effect of stain creating substance type on color intensity of dyed fabric is shown in Table 2.

Table 2. The effect of the type of stain creating substance on color intensity of dyed fabrics.

| Seaming preparations types | Color intensity, % Cotton and polyester mix-fiber fabrics, % |
|----------------------------|----------------------------------------------------------|
|                            | 75/25 | 57/43 | 44/56 |
| Laurusu-33                 | 18    | 35    | 36    |
| Emulsion thickener         | 13    | 25    | 26    |
| Karbamol SEM               | 8     | 23    | 18    |
| Repellan KFS               | 15    | 27    | 27    |
| Rusinu-14-i                | 16    | 32    | 33    |
| Akvapola-10                | 12    | 33    | 20    |
| Akvapola-21                | 13    | 21    | 28    |

After dyed fabrics surface is treated by stain creating polymer, we can see that the color intensity of the sample with more cotton fiber (75/25) content is lower by value than the color intensity of surface untreated samples. Because the structure of cotton fiber is porous, it deeply penetrates into polymer fiber, as a result the fiber’s surface will not be covered by monolith stain, therefore their color intensiveness has less values. The same situation occurs when all types of seaming substances are used. The color intensiveness of the samples of cotton and polyester fibers with their ratio close to each other, we can see that when the stain appears on fabrics surface the intensiveness increases. The analysis of color intensiveness and smoothness of samples of the surface modified fabrics are given in Table 3.

Table 3. The effect of seamed preparation types to color abrasion strength and color smoothness of modified surface.

| Seaming preparations types | Color abrasion strength, points | Color smoothness, % |
|----------------------------|--------------------------------|---------------------|
|                            | Cotton and polyester mix-fiber fabrics, % |                      |
|                            | 75/25 | 57/43 | 44/56 | 75/25 | 57/43 | 44/56 |
| Laurusu-33                 | 4/4   | 4/4,5 | 4/4   | 1,0   | 1,0   | 0,9  |
| Emulsion thickener         | 4/4,5 | 4,5/4 | 4/4,5 | 1,1   | 0,8   | 1,1  |
| Karbamol SEM               | 4,5/4 | 4/4   | 4/4,5 | 1,1   | 1,0   | 1,0  |
| Repellan KFS               | 4/5   | 5/4   | 4,5/4 | 1,0   | 0,9   | 0,8  |
| Rusinu-14-i                | 4/4   | 4/4,5 | 4/4,5 | 0,9   | 1,0   | 0,8  |
| Akvapola-10                | 5/4   | 4/4   | 5/4   | 0,9   | 0,9   | 0,9  |
| Akvapola-21                | 5/4   | 5/4   | 5/4   | 1,0   | 0,8   | 0,7  |

Even when all polymer types were used, we could see that color abrasion tolerance increased, and the reason for that is fiber internal dimensions are bigger than fiber porosity dimensions, and because
of this, pigments are stuck in the fiber surface and remain under the second layer of stain created on the fabrics surface during its modification process. Thus, the fabrics surface soaked in the dyeing solution with pigment and seaming substance, dried, undergone thermal treatment and the surface treated with polymer water dispersion and keep it under thermal treatment during 3-4 minutes at 130-140°C degrees, having high color intensity, abrasion tolerance and receiving smooth colors are proposed. When the fabrics surface in advance dyed with pigment substance is treated by Laurusu-33 and Rusinu-14-i preparations which have high value of color intensity, as well as by Akvapola-10 and Akvapola-21 preparations which have abrasion tolerance and smooth colors, due to reception of high quality colors, in the next studies these preparations will be used.

In the next studies the fabrics surface was dyed using doctor roll method together with pigment and stain creating thermo reactive mixture of acrylic and urethane copolymer. In the first of previous methods the fabric was soaked into pigment solution, in the second method the soaked dyed fabrics surface was modified by polymers, in the third method the fabric surface was dyed directly by pigment finish. After the fabrics surface is dyed it gets dried and then it undergoes thermal treatment procedure during 4 minutes at 130-140°C degrees. The color intensity of the samples with dyed pigment surface is shown below. The sharp increase in color intensity is related to creation of the whole stain on fabrics’ surface. The monolithic closure of the fabrics surface structure negatively effects its air permeability.

Table 4. Color intensity of surface dyed fabrics using various polymer preparations

| Seaming preparations types | Color intensity, % | Cotton and polyester mix-fiber fabrics, % |
|----------------------------|-------------------|------------------------------------------|
|                            |                   | 75/25                                   | 57/43 | 44/56 |
| Laurusu-33                 | 28                | 54                                       | 63    |
| Rusinu-14-i                | 25                | 50                                       | 61    |
| Akvapola-10                | 23                | 58                                       | 39    |
| Akvapola-21                | 27                | 46                                       | 51    |

But, having an opportunity of jointly carrying out dyeing and final decoration processes, it positively effects fabrics’ abrasion tolerance. The indicators of air permeability and abrasion tolerance of fabrics’ samples using various pigment dyeing are shown in the following diagrams.

By assortment usage area the pigment dyeing method can be selected. The fabrics containing 75/25 ratio cotton and polyester fibers are designed for summer-spring clothes, and they can be dyed using the first method - impregnation-drying-thermo fixation. Light and average intensity color appear after this process. When sewing everyday clothes from fabrics containing 57 and 43% polyester fiber, it is recommended to use the second method, i.e. dyeing with advanced impregnation method, then modify fabrics surface with polymer solution and apply the proposed high intensity and strength coloring technology.
Figure 3. Air permeability of fabrics samples dyed with pigment using various methods. 1-dyeing in pigment and polymer solution; 2- dyeing in pigment and polymer solution and surface modification; 3-dyeing fabrics surface with thickened pigment and polymer solutions.

Figure 4. Abrasion tolerance of fabrics samples dyed with pigment using various methods. 1-dyeing in pigment and polymer solution; 2- dyeing in pigment and polymer solution and surface modification; 3-dyeing fabrics surface with thickened pigment and polymer solutions.

4. Results
The use of the third method – doctor roll technology for dyeing fabrics surface is recommended for production of work clothes and products for technical use out of cotton/polyester (44/56) fiber ratio.

5. Discussion
Production of yarn from natural and synthetic fiber mixes yarn, knitted fabrics, and further production of fabric, knitted fabrics and finished products are important way to expand the range of products. In solving the above indicated problem, development of effective technologies for dyeing mix-fiber textile fabrics, study and research of preserving fabrics’ consumer properties at dyeing is one of the most significant issues. Based on the experiences on dyeing of pigment forming the studying materials with the dye pigment substance were suggested in order to improve the color forming of technology.
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