Giving hydrophobicity and study of properties of cotton fabric

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Abstract. An effect of a hydrophobic composition based on polymers on the hydrophobicity and performance properties of cotton fabrics of various surface structures has been studied. The processing of the fabric was carried out by a plus method. The persistence of the achieved hydrophobic effect was evaluated by the emergence of the first drops of water through the tissue and the wetting angle. High hydrophobicity values were observed in samples treated with an aqueous emulsion of fluorine-containing dispersions. The stability of the water-repellent property is achieved by heat treatment of padded samples at a temperature of 150^{0}C for 2 minutes. The colorimetric method has studied changes in the color characteristics of cotton fabric after hydrophobic finishing.

1 Introduction

Water-repellent properties are important for textile fabrics for various reasons: from fabrics used to manufacture tents, umbrellas, raincoats, and special-purpose clothing, to fabrics used in sewing clothes for operating room doctors. Hydrophobicity is a physical and chemical property of a surface when a liquid wetting it has a wetting angle $\theta > 90°$ (θ is the contact angle of the liquid with the plane of the solid). When the threads are coated with a hydrophobic film, the liquid does not pass through the material but either drains freely or separates into small drops that remain on the surface and do not wet it. Subsequently, upon processing, a modified material remains air- and vapor-permeable while maintaining the main hygienic properties [1].

Increasing requirements for the quality and competitiveness of textile materials necessitates the creation of new highly effective chemicals that provide the raw materials for the textile industry with a set of positive properties. Hydrophobization is one of the important, widely used methods for the special finishing of textile materials. The most effective and accessible for this kind of finishing are organosilicon compounds of the siloxane type [2].

Substances that impart hydrophobicity to textile materials consist of non-polar molecules, significantly reducing fabric wettability. At the same time, the material, after processing, must retain positive qualities - appearance, texture, physical and mechanical strength, air conductivity, and other sanitary and hygienic properties. Some substances lend a material moderate hydrophobicity, reducing water absorption for a while. Other

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substances render material with absolute water-repellent properties, in which a complete spreading of a drop of water occurs. Such materials are called "superhydrophobic". Hydrophobic treatment of a textile material with an acrylic emulsion and a solution of an amide of a higher carboxylic acid reduces the absorption of moisture several times, and a material with moderate hydrophobicity is formed. During the hydrophobic treatment of cotton knitted fabric with an emulsion of poly perfluoro acrylate and oligomeric diisocyanate, a superhydrophobic textile material is formed, which is recommended to be used for the waterproofing cover of cotton riots [3]. Grafting with polycaprolactam [4] and polyurethane [5] imparts hydrophobic properties to cellulose. Fluorine-containing agents with excellent hydrophobic and oleophobic properties are good finishing agents used for treating textiles, leather, paper, and other surfaces [6].

Several scientists have proposed a copolymer emulsion of fluoroacetate to impart hydrophobicity to textile materials [7]. This emulsion is prepared by miniemulsion polymerization in the presence of stearyltrimethylammonium chloride (STAG) and 2,2'-azobis (2-amidinopropane) dihydrochloride as a water-soluble initiator. An aqueous solution based on organosilicon compounds was used to hydrophobized textiles while maintaining their operational and hygienic characteristics. The study of the effect of aqueous solutions based on silane (trademarks A-1100 and A-187) on the hydrophobic properties of textile materials found that this dressing is better suited for fabrics intended for sewing overalls [8]. The authors of [9] proposed a hydrophobic coating that is used on cellulose fiber and then mixed with untreated fiber to obtain a modified yarn with optimized water-repellent properties. The hydrophobic surface of hybrid fibers is designed to resemble synthetic fibers such as polyester or polyamide. In dynamic tests, 90% of the water was transferred from the hydrophobic cellulose fabric to the hydrophilic cellulose layer, and less than 10% of the added volume was retained in the capillaries of the hybrid material.

The authors of [10] created the scientific foundations for a new method of surface modification of fibers of fabrics and nonwoven materials to obtain textile materials with the properties of superhydrophobicity, oleophobicity, and dirt-repellency based on the use of organofluorine substances that form nanoscale layers from interpolymer complexes, in which the polymer plays the role of a fixing, anchor component. They found that due to the formation of a fragmented nano-roughened layer, a superhydrophobic textile material can be obtained. Wetting angle $\theta > 130^0$. The proposed method for modifying textile materials makes it possible to obtain an effect resistant to dry cleaning but not able to be preserved when washing in an alkaline environment.

With the help of special purpose-made finishing, textile materials are given new properties that they do not have [11]. Hydrophobic properties [12], oleophobicity, resistance to microorganisms, anti-combustion [13], and fire resistance properties can be attributed.

For the fabric to achieve this property, special preparations are applied to it [14], but this must be done so that the pores of the fabric are not blocked.

We have tried to improve the hydrophobic property of cotton fabric by using different compositions of finishes. The work aims to study and identify the water-repellent properties of various compositions based on the study of fabrics with hydrophobic properties acquired in the final finishing process.

The color quality of the samples was determined in the scientific laboratory of Kor-Uz Textile Technopark on the device X-Rite Ci7800 [15].

In the present scientific work, the possibility of using coupling agents based on Tubiguard SCS-F and chlorosulfonated polyethylene in the process of imparting water-repellent properties to cotton fabrics has been studied. The object of the study is a cotton fabric consisting of 100% cotton fiber. As water repellents, auxiliary substances were studied to impart water and oil-repellent properties: -Tubiguard SCS-F - Bezema CHT (Switzerland), which is a fluorine-containing dispersion of a nonionic nature [16], as well as chlorosulfonated polyethylene. Chlorosulfonated polyethylene is a rubbery product obtained by reacting polyethylene with chlorine and sulfur dioxide. This product is characterized by high weather and chemical resistance. Acetic acid, aromatic and chlorinated hydrocarbons have a destructive effect on it. Chlorosulfonated polyethylene is well combined with other rubbers while improving their properties.

The cotton fabric samples were processed with a solution of hydrophobic dressings according to the Bezema method according to the manufacturer's recommendations. Finishing was carried out by the padding method at the bath modulus M=1.7:1 continuously in a laboratory padding machine at room temperature. Then the samples were pressed to a weight gain of 80-90%. After that, the samples were dried in a mini-dryer at a temperature not exceeding 100^0C; then heat treatment was carried out in Chamber manuals - HB-105SG drying cabinet (Made in Korea) at a temperature of 150-170^0C [18] for 5-10 minutes to fix the water repellent.

The water resistance of the samples was determined on the device - WR-1600E. The color characteristics of cotton fabric samples after hydrophobic finishing were carried out on an X-RiteCi7800 laboratory spectrophotometer (also from a Korean manufacturer) [17].

The effectiveness of the studied water repellents was evaluated by the water resistance and color characteristics of cotton fabric after the final finishing. The influence of the concentration of finishes on the water-repellent properties of cotton fabric is listed in table 1.

Table 1. Dependence of water resistance of cotton fabric samples on type of sizing

Supplement concentration, % (wt.)	Supplement based on		
	Tubiguard SCS-F	Ecoperl Active	Chlorosulfonated Polyethylene
	Water resistance, mm water column		
1	-	-	-
2	80	-	-
3	120	80	70
4	220	130	100
5	220	150	120

As it follows from the above data, the effectiveness of the fluorine-containing coupling agent is higher compared to Ecoperl Active and chlorosulfonated polyethylene one.

The sizing compositions used, interacting with the hydroxyl groups of the cellulose macromolecule, and also due to the blocking of these functional groups due to the formation of a hydrophobic coating of hydrocarbon chains in the fiber, contribute to the acquisition of the hydrophobicity of cotton fabric, which is illustrated in Fig. 1-4.

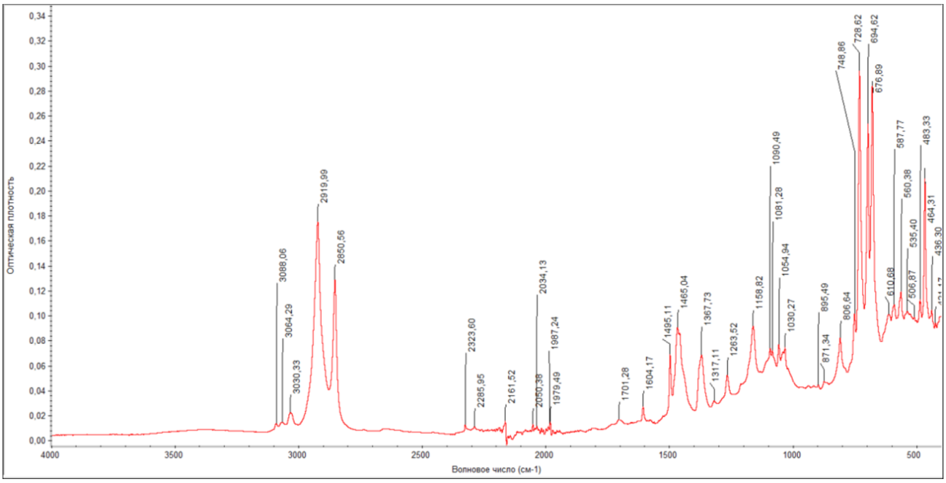

Fig. 1. IR spectrum of chlorosulfonated polyethylene

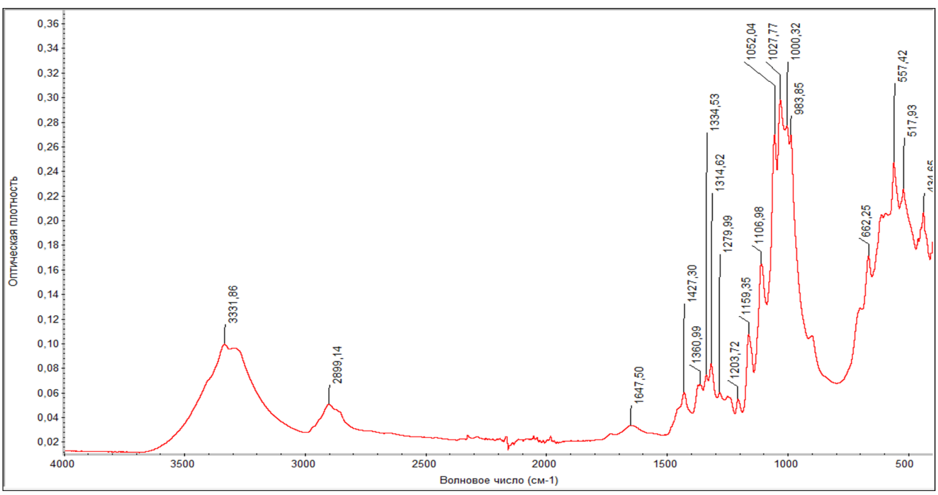

Fig. 2. IR spectrum of cotton fabric coated with chlorosulfonated polyethylene

Of those data presented in Figure1 and 2, IR spectra shows that the absorption bands of chlorosulfonated polyethylene based on high-pressure polyethylene correspond to vibrations of 2850-2919 cm^{-1}, related to asymmetric $-CH_3$ groups, and stretching vibrations of –OH groups belong to the region of 3030 cm^{-1}. Peaks in the region of 2850 cm^{-1} correspond to the symmetry of $–CH_2–$ groups. Weak peaks related to $–CH_2–$ groups correspond to vibrations in the region of 1465-728 cm^{-1}. Also, vibrations 1701 cm^{-1} related to –CO, 1158-1263 cm^{-1}– and S=O bonds 806-610 cm^{-1}–to C-S were determined. The characteristic absorption bands in chlorosulfonated polyethylene are the peaks related to 1367cm^{-1} and 806-610cm^{-1} R-SO_2-CI and C-CI bonds, respectively.

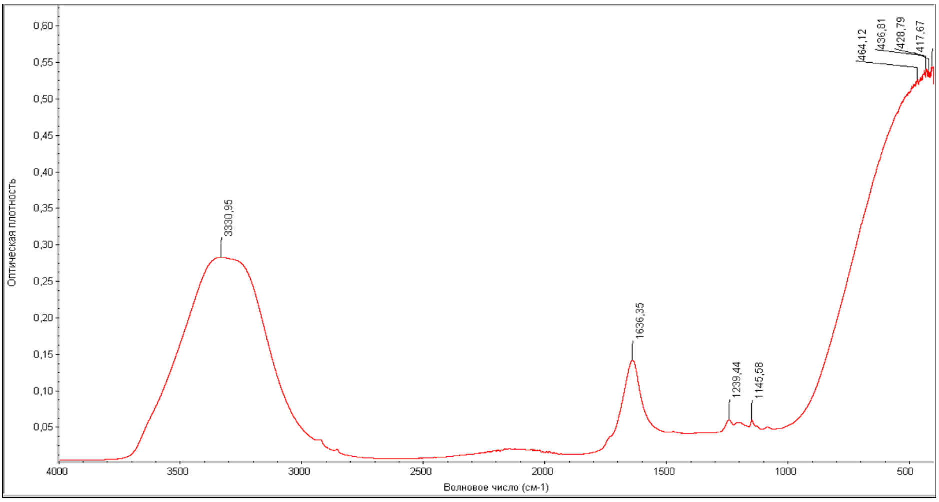

Fig. 3. IR spectrumTubiguard SCS-F

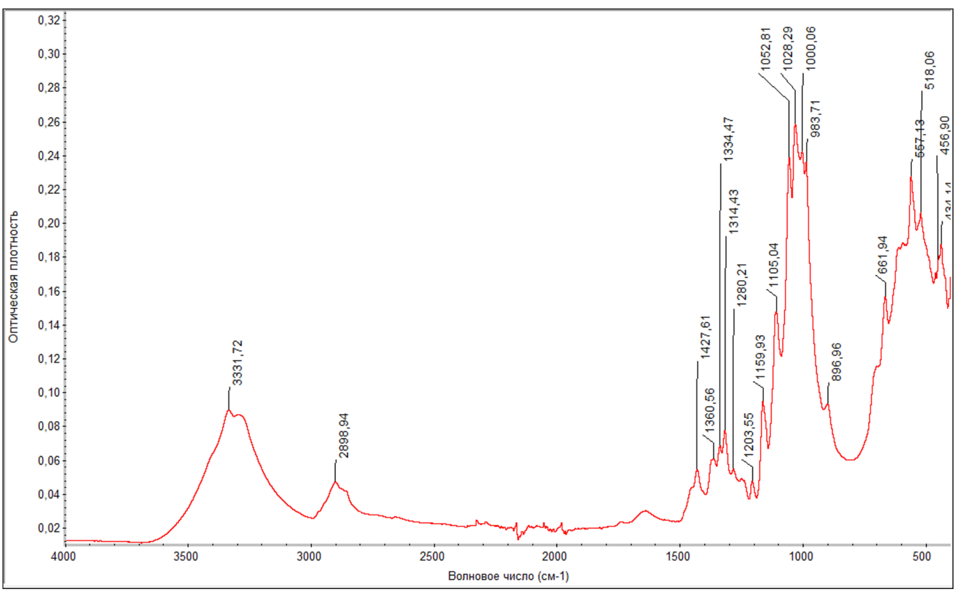

Fig. 4. IR spectrum of cotton fabric finished with TubiguardSCS-F.

In samples treated with a sizing based on Tubiguard SCS-F, the band disappears in the region 1634.44 cm^{-1} – 1631.56 cm^{-1}, the intensity of the absorption band 1334.47 and 1314.43 cm^{-1} increases, a new band appears 1734.26 cm^{-1}. The same trend persists even after 5 washes. That confirms the bonds' strength between the cellulose macromolecule and Tubiguard SCS-F.

Experimental results on the study of the influence of variable factors of the sizing process on the degree of whiteness and color indicators of the samples are listed in Table 2 and illustrated in Fig. 5.

Table 2. Effect of hydrophobic finish on color values of samples (Tubiguard SCS-F)

Samples	Color indicators of samples			Coloring resistance to, points	
	intensity, K/S	brightness, L^*	Color tone, h^*	A soap	A friction
Original	14	57	68	5/5/5	5/5
Finished	12	55	69	5/5/5	5/5

When applied to the fabric, the used dressings form transparent, highly elastic films on its surface, which have a high adhesive ability concerning cellulose. Therefore the intensity, brightness, and color tone of the dyed cotton samples of the soil tissues do not change.

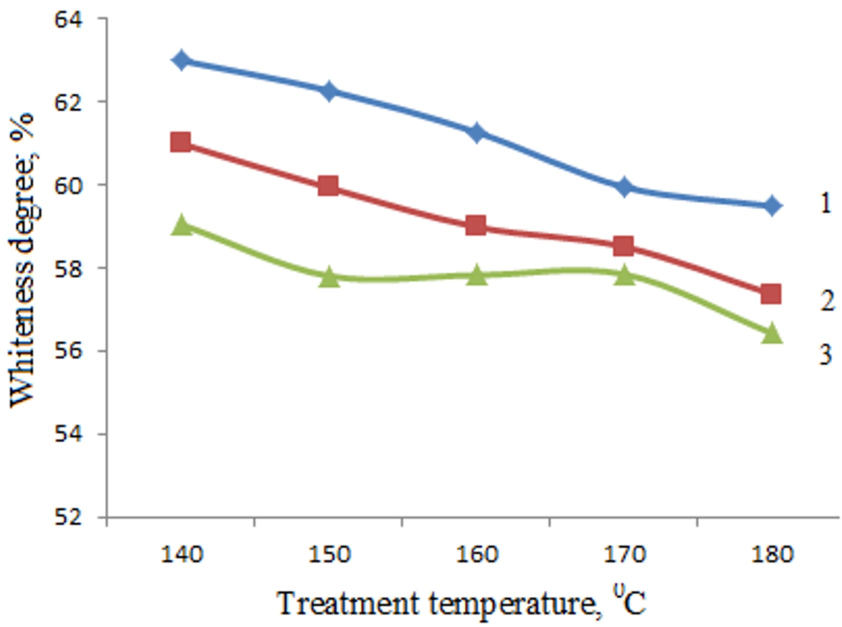

Fig. 5. Dependence of degree of whiteness on temperature of heat treatment of process of hydrophobic finishing of cotton fabric samples (Tubiguard SCS-F).

However, dressing the bleached fabric shows a slight decrease in the degree of whiteness. Based on the data obtained, carrying out the heat treatment process at a temperature of 1500C for 2 minutes is recommended.

2 Conclusions

The study's results contribute to the expansion of a range of fabrics with a hydrophobic property for household and technical purposes by regulating the composition of the hydrophobic composition and the processing mode.

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