INFLUENCE OF VARIOUS TEXTILE AUXILIARY SUBSTANCES ON WRINKLE OF CELLULOSE-CONTAINING FABRIC

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Abstract

In recent years, the issue of replacing formaldehyde-containing preparations used in the final finishing of cotton fabrics with compounds without formaldehyde or with a low content of it has become particularly relevant. The paper is devoted to the study of the possibility of using various textile auxiliaries for low-crease finishing of cotton fabric. The possibility of using acetone-formaldehyde resin as a low-formaldehyde binder instead of traditionally used preparations has been shown. The fabric finished according to the recommended technology with the use of ACF-resin, in comparison with the traditional one, has a lower weight gain and wash ability of the dressing, a higher crease resistance and tensile strength. The effectiveness of the use of phosphorus-containing alkaline earth metals as catalysts for the cross-linking of cellulose macromolecules in the compositions of the sizing agent, both with polycarboxylic acids and with a low formaldehyde-containing ACF-resin preparation, has been established. An increase of total wrinkle recovery angle (WRA) of cotton fabric has been achieved more than 200 degrees at a concentration of crosslinking catalysts equal to 4%. The use of polycarboxylic acids, in particular 1,2,3,4-butanetetracarboxylic and maleic acids, together with phosphorus-containing alkaline earth metal catalysts, leads to the formation of additional strong covalent bonds between cellulose fiber macromolecules, which further contributes to the stabilization of the system by increasing the proportion of elastic elastic deformation.

Keywords**:** cotton fabric, crease-resistant finish, catalyst, cross-linking, total wrinkle recovery angle, breaking load.

Introduction

Chemical finishing contributes to the improvement of product quality, giving the fabrics not only a good appearance, fullness, softness but also imparts new qualities to them, such as low wrinkling, low shrinkage, etc. Low-crease and low-shrink finishing of textile materials is one of the main processes for the final finishing of cotton fabrics. A huge number of hydroxyl groups in the cellulose macromolecule leads to the formation of a dense network of intermolecular hydrogen bonds, which tends to hold any shape of the product. However, due to the instability of hydrogen bonds, a commensurate change in shape is possible. In this regard, cellulose fibers, both natural and regenerated, have low elastic properties, and products made from them are easily crushed. To increase the proportion of elastoelastic deformation, it is necessary to introduce additional strong covalent bonds-crosslinks between fiber macromolecules, which contributes to the stabilization of the system.

Products made of low-wrinkle fabrics have a beautiful and solid appearance in wear, require minimal maintenance during operation [1]. The crease resistance of a fibrous material is understood as its ability to quickly restore its original shape, its appearance, straightens wrinkles, creases formed under the action of a crushing load. The effect of wrinkle resistance with low wrinkle finishing of cotton fabrics should be at least 200 degrees, dry before washing and not less than 185 degrees after washing, while the strength of the finished fabrics should be at least 180 N [2].

Until recently, formaldehyde-containing preparations were used as the main binders for these purposes, which, by releasing free formaldehyde during drying, heat treatment, during storage and operation of finished fabrics, created unfavorable working conditions. Formaldehyde addition products, known as agents of N-methylol or N-methylolamide, while being effective and inexpensive, at the same time have a number of serious drawbacks associated, firstly, with the release of carcinogenic formaldehyde during finishing and storage [3]. The next disadvantage of N-methylol agents is their combined use with Lewis acids, catalysts for rapid crosslinking of cellulose macromolecules at high temperature. The formation of cross-links between cellulose macromolecules is accompanied by the breaking of many hydrogen bonds, which is clearly reflected in the decrease in mechanical strength. Another disadvantage of certain nitrogen-containing coatings is their ability to retain chlorine during bleaching, which leads to discoloration of the color and loss of strength of the fabric during subsequent ironing.

Since the late 80s, intensive research has been carried out on the possibility of using polycarboxylic acids as formaldehyde-free drugs: 1,2,3,4-butanetetracarboxylic (BTCA), 1,2,3-propanetricarboxylic, 1,2,3,4-cyclopentanetetracarboxylic acid, BTCA with various additives. On the basis of a comparative study of various catalysts in the low-crease finishing of BTCA cotton fabrics, the authors [4,5]found that the best performance was obtained using the $NaH_2PO_2 \cdot H_2O$ catalyst.

The paper shows the results of sorption and mechanical properties of flax fibers treated with citric and 1,2,3,4-butanetetracarboxylic acids. Pretreatment of the fiber in a sodium hydroxide solution in an ultrasonic field contributes to an increase in the internal dimensions of the fiber and thus allows achieving intermolecular “crosslinking” of cellulose with a smaller decrease in mechanical strength. Mercerized cotton is more effectively cross-linked with 1,2,3,4-butanetetracarboxylic acid [6].

As a result of studies conducted with 1,2,4-butanetricarboxylic and 1,2,3-propanetricarboxylic acids, the authors of the work showed the formation of five-membered anhydrides. The introduction of catalysts and an increase in the temperature of heat treatment is achieved by accelerating the rate of esterification of the hydroxyl groups of cellulose and increasing the crease resistance of the fabric. It was found that 1,2,3-propanetricarboxylic acid is the most effective [7].

In [8], a regularity was revealed for the introduction of bifunctional complexones with 2-4 carboxyl groups into the cellulose structure, leading to modification of the fiber, which acquires improved physical and mechanical characteristics: resistance to creasing without loss of mechanical strength.

The effectiveness of sodium hypophosphite with respect to maleic acid, which is an unsaturated dibasic acid, has been shown in studies by Clark M. Welch Bethlehem C. Andrews [9]. Two molecules of maleic acid are attached to one molecule of a phosphorus-containing catalyst to form a tetra carboxylic acid. Since in most cases crosslinking catalysts are acidic salts, their greater effect in accelerating the desired crosslinking of cellulose in tissue points to new mechanisms of catalysis that do not work with a simple neutralization of the carboxyl groups of a polycarboxylic acid with a strong base acting as a buffering agent. It has been experimentally found that the catalyst is effective at concentrations as low as 0,3% by weight in the treatment bath, but finish longevity is maximized at higher concentrations. The concentration range is 0,3-11%. For a carboxyl group to be reactive, it must be capable of forming a cyclic 5- or 6-membered anhydride ring with the adjacent carboxyl group in the polycarboxylic acid molecule.

Computational methods

As an object of research, two assortments of cotton fabric art. Coarse calico with a density of 142 g/m^2 (wrinkle recovery angle of the fabric 88 degrees, breaking load on the warp 401,8 N, on the weft 416,5 N) and art. Coarse calico with a density of 228,2 g/m ^{2} (wrinkle recovery angle of the fabric 121,1 degrees, breaking load on the warp 1005,4 N, on the weft 408,5 N).

All chemicals were used as purchased, without any further purification or treatment. The process of imparting a low-crease finish consists of impregnating a fabric sample in the composition of the sizing (pH=9-10), followed by wringing, drying at 100-110°C, heat treatment at 140°C for 2 minutes.

Wrinkle Resistance Comparison by AATCC Test Method #66-1984.Fabricbreakingload tests were carried out on a dynamometerAG-1 (Japan).

Results and discussion

The department of Chemical Technology has developed a technology for low-crease finishing of cotton fabrics based on acetone-formaldehyde (ACF) resin. In this work, a composition based on ACF-resin was recommended to reduce fabric wrinkling. Acetone-formaldehyde resin (ACF-resin, crosslinking agent), polyvinyl alcohol (PVA, filler), sodium acetate (catalyst) and caustic soda (pH regulator) were introduced into the composition of the coupling agent [10]. The most acceptable concentration of the cross-linking agent was chosen as 80 g/l, at which the total wrinkle recovery angle (WRA) of the fabric reaches up to 138 degrees, when for the untreated fabric this figure is 88 degrees. Of no small importance is the presence of polyvinyl alcohol in the composition of the coupling agent, which, having a sufficient amount of hydroxyl groups, can enter into an esterification reaction with the ACF-resin under heat treatment conditions or, forming a WRA face film, create difficulties in the crosslinking reaction between the fiber cellulose and the crosslinking agent. The variation in the concentration of the film-forming component was kept in the range of 5-20 g/l. The optimal concentration of sodium acetate was chosen as 5 g/l, at which the WRA of the cotton fabric is 138 degree. A comparison was made of the quality indicators of cotton fabric finished with compositions based on experimentally developed and traditional ones using metazine (Table 1).

Table 1

Comparative table of quality indicators of cotton fabrics

Composition	Fabric weight gain, %	Durable press ratings, %	Wrinkle recovery angle, degree		Breaking load, N	
			before washing	after washing	warp	weft
based on metazine	10	8,6	128	126	333,2	274,4
based on ACF- resin	7,3	4,4	138	136	382,2	406,7
untreated fabric	-		88	-	401,8	416,5

As can be seen from Table 1, the fabric finished according to the recommended technology using ACF-resin, as compared to the traditional one, has a lower weight gain and durable press ratings, a higher WRA value, and also tensile strength.

The influence of various textile auxiliaries on the crease resistance of cotton fabric has been studied. The following chemical substances were chosen as the objects of research: epichlorohydrin, acrylamide, glycerin, polyethylene glycol, glucose, tartaric, citric and maleic acids, as well as various catalysts, such as sodium dihydrophosphite, potassium hydrogen phosphate. The above chemicals in the amount of 25 g/l were introduced into the coupling agent containing ACF-resin - 80 g/l, PVA - 10 g/l, CH_3COONa -5 g/l. Studies have shown that epichlorohydrin, acrylamide, glycerin, polyethylene glycol, glucose do not contribute to an increase in tissue WRA values, apparently, when they are present together with ACF-resin in one dressing, they react with it at a higher rate than with cotton cellulose and thereby remove from reaction sphere ACF-resin, which further contribute to a sharp decrease in fabricWRA values. The results of studying the effect of glycerol concentration on fabric wrinkling showed that it has an extreme character and, even at a concentration of 25 g/l, does not contribute to an increase in low fabric turnover. The results obtained are shown in Table2.

Table 2

The influence of the type of TA on quality indicators on cotton fabric

The name of textile excipients	Fabric weight gain, %	Wrinkle recovery angle (WRA) of fabric, degree			Durable press ratings, %	Increase of WRA, degree
		warp	weft	WRA, degree		
Untreated fabric	-	46,0	42,0	88,0	-	-
Epichlorohydrin	4,5	60,4	58,0	118,0	5,1	30,0
Glycerol	6,0	69,8	68,9	139,0	7,5	51,0
Acrylamide	4,8	61,0	60,0	121,0	4,8	33,0
Glucose	6,8	60,0	54,4	114,0	4,5	26,0
Polyethylene glycol	5,9	66,0	64,0	130	4,5	42,4

Many polycarboxylic acids can form ether and ester bonds with the hydroxyl groups of cellulose, so the introduction of such acids as maleic, tartaric and citric acids into the sizing composition based on ACF-resin leads to an increase in tissue WRAup to 166, 154 and 145 degree compared to the untreated fabric, which has an WRA of 88 degree. The more intense effect of maleic acid compared to tartaric and citric acids is due to the presence of a double bond in its molecule, which activates carboxyl groups in the esterification reaction with cotton cellulose. The study of the influence of the concentration of sodium hypophosphite and potassium hydrophosphate catalysts showed that among the studied catalysts, potassium hydrogen phosphate at a concentration of 12,5 g/l provides low sizing rins ability and a high tissue WRA value (200±3 degrees), as well as a decrease in the amount of free formaldehyde by 5 once[11].

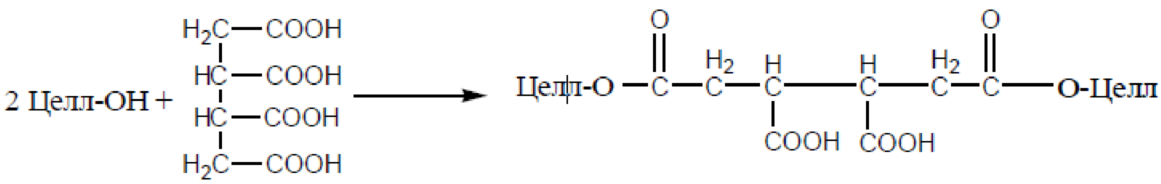
In present work, the studies were also carried out on the use of polycarboxylic acids, such as 1,2,3,4-butanetetracarboxylic (BTCA) and maleic (MA) together with phosphorus-containing catalysts to reduce the wrinkling of cellulose-containing fabric. The work was done in the Textile Department of the University of Ghent (Belgium). For this purpose, an aqueous treatment bath was prepared containing 0,5 or 5% by weight of a polycarboxylic acid at a certain concentration of catalyst as a crosslinking catalyst. The prepared sample of cotton fabric was moistened as part of the sizing for 0,5 minutes, passed between the squeezing rolls with a degree of extraction of 95±5%. Then dried at 85°C for 10 minutes and subjected to heat treatment at a temperature of 180^{0}C for 2 minutes. Then the fabric was treated in a 1 g/l sodium carbonate solution, washed at 50°C for 10 minutes, and dried in an oven at 85°C for 10 minutes. The wrinkle index of cotton fabric was determined depending on the concentration of the catalyst. The results obtained are presented in Table 3.

Table 3

Influence of the concentration of polycarboxylic acid and catalyst on wrinkle recovery angle of fabric

Concentration of acid, %		Concentration of catalyst, %		Wrinkle recovery angles (WRA), degree
BTCA	MA	$NaH_2PO_2 \cdot H_2O$	K_2HPO_4	
0,5		0,4		148,0
	0,5	0,4		135,2
0,5			0,4	141,6
	0,5		0,4	143,2
5		4		222,4
	5	4		152,4
5			4	211,6
	5		4	157,0
Untreatedfabric				121,4

The results in Table 3 show that potassium hydrogen phosphate is not inferior to sodium hypophosphite in terms of crease resistance in both 1,2,3,4-butanetetracarboxylic and maleic acids. Increasing the concentrations of the sizing components by a factor of 10 significantly increases the crease resistance value. The mechanism of the crosslinking reaction using the example of BTCA and cellulose is as follows:



Conclusions

Thus, the use of polycarboxylic acids, in particular BTCA and MA, together with phosphorus-containing alkaline earth metal catalysts leads to the formation of additional strong covalent ether bonds between cellulose fiber macromolecules, which contributes to the stabilization of the system by increasing the proportion of elastic deformation in it.

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