1.16 ADHESIVE PROPERTIES OF SIZE COMPOSITIONS FOR COTTON WARPS

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Introduction

The purpose of sizing is to increase the breaking characteristics of the warps and to increase making fabrics endurance to friction and multicyclic loading on the loom. These factors are necessary for productive and cost effective weaving process.

When sizing warps have be evenly glued along the entire length and width of the charging warps. A protective film of a size should have approximately the same elongation rates as the warp threads. It should also provide yarns high equity, durability and endurance for multiple loads. A film of a size should not crumble. A filament impregnated with it should not be brittle. A size must have a high affinity to the fiber material, not to spoil the yarn and weaving equipment, easily desizing and be relatively cheap [1].

Despite variety of existing sizing products and sizing methods, also sizing compositions satisfying specific conditions of the certain enterprise, development of new energy and resource saving technologies is urgent.

Now in Ukraine textile enterprises not least takes manufacture of fabrics based on cotton. As the main component of sizing compositions used polysaccharides – the starch – which is relatively cheap, have a reliable source of raw materials and is fully biodegradable with no damage to the environment. However, films formed by a starch have an unsatisfactory set of physical and mechanical properties. It is known that the cost of a size, depending on the type of adhesive material can range from 23 % to 78 % of the cost of the process of sizing [2]. The cost of energy accounts for between 9 % and 24 % of the cost of the sizing [3]. Therefore, the creation of new sizing compositions makes it possible to improve the economic performance of weaving. We introduce developed sizing compositions for cotton warps using as adhesive the starch with hygroscopic additives of kaolin and potash alum, which have improved

adhesion to cotton weaving warps, but do not prevent the further process of fabrics finishing.

Surface tension of sizing compositions

The determination of the surface tension force was performed by the separation of the ring [4–6]. The measurement of the surface tension was carried out in five iterations to ensure the accuracy and the reproducibility.

To reduce the surface tension and to increase wetting ability of a size surfactants is added to composition. We have chosen non-ionic agent Synthanol ДС-10 which is a mixture of polyethylene alcohol and synthetic fatty alcohols ethers of the general formula $C_nH_{2n+1}O(C_2H_4O)_mH$.

To investigate the colloid-chemical properties of sizing compositions we carried out a study of the force of the surface tension of starch gels with different concentrations of the starch in the size [7]. The object of the research is:

1) the traditional starch size: 60 g of the starch has be poured at 25 °C water, mix thoroughly for 5–10 minutes, poured 0.35 g previously dissolved in a little water at 40 °C chloramine. All the mix, add water to 1 liter and boil for 30 minutes prior to the termination reaction to chloramine [8, P. 130]. If you change the content of the starch proportional change the content of chloramine;

2) the proposed composition: the starch, kaolin in a content 0.5 % of the weight of the starch, soft paraffins – 0.8 % of the weight of the starch;

3) the proposed composition: starch, alum in a content 0.5 % of the weight of the starch, soft paraffins – 0.8 % of the weight of the starch [9];

4) in the (1) was added Synthanol in a content 0.25 $g \cdot L^{-1}$.

The table 1 shows that the surface tension of all samples increases with increasing the adhesive component – the starch – concentration. The adding Synthanol to the solution of the size significantly reduces its surface tension. Sizes with the addition of kaolin and alum have a greater surface tension than the size with the Synthanol but significantly less than the traditional starch size. This can be explained by an adsorption finely dispersed particles of kaolin in the volume and the surface of the starch macromolecules and a decrease of the structurization. With this the excess stresses associated with a surface tension are removed.

Table 1 - The dependence of the sizing compositions surface tension force from the starch content

Composition	The surface tension σ, $mN \cdot m^{-1}$ at different concentrations of the starch, $g \cdot L^{-1}$				
	20	30	40	50	60
Traditional	80.34	85.65	88.91	92.13	95.36
Kaolin	66.21	68.87	70.02	73.41	75.52
Alum	65.00	67.51	68.98	72.20	74.66
Surfactant	52.14	58.24	60.51	65.87	67.45

The study of the surface tension and other colloid-chemical properties of starch-based sizes were carried out at 20 ºC. But it is known that higher temperatures significantly increase the thermal Brownian motion of the system, reduce the structurization of the system and thereby reduce the surface tension [10]. In production environment a sizing of cotton warps carries out at temperatures of 70–95 °C usually. Therefore, the technological process of warps sizing can be performed without the addition of surfactants: the presence of kaolin or alum in the starch gel is positive not only to reduce the surface tension, but also to reduce a foaming, which leads to an insufficient gluing of warps [11].

Contact angle of textile materials

The contact angle of sizing compositions was determined using the method of Rehbinder or projections of the drop on the screen [4–6]. The measurement of the surface tension was carried out in five iterations to ensure the accuracy and the reproducibility. The work of the adhesion of polymer films was determined according to the contact angle Θ.

The less structure formation in systems, the better the drop spreads on the surface of the textile material and wets it. A low surface tension and a high wetting ability must be inherent sizing preparations to ensure a sufficiently high technological performance of the weaving.

We were prepared to study four samples of the starch size, as described in the paragraph 1. In the study of the contact angle of cotton fibers has been found that the wetting of the size is best when the concentration of the adhesive substance decreases. But at low concentrations of the starch the size penetrates

the yarn between fibers and does not form a solid outer film and poorly washes with the desizing (Table 2).

Table 2 - The dependence of the contact angle from the content of the starch

Composition	The contact angle Θ, gr, at different concentrations of the starch, $g \cdot L^{-1}$				
	20	30	40	50	60
Traditional	67	74	79	84	85
Alum	48	49	50	54	56
Kaolin	47	50	51	54	56
Surfactant	39	40	41	44	47

The size with the addition of Synthanol wets the fibers surface of the best. In the presence of kaolin or alum in sizing gels in spite of the strengthening of the structure there is a better wetting effect than the traditional starch size. This is due to an adsorption of finely dispersed particles both polymer macromolecules of the starch surface and polymer macromolecules of the cellulose surface of the textile material. This significantly increases the adhesion of the size to fibers. Since the introduction of textile-processing chemicals of kaolin and alum promotes a certain reduction of the surface tension even without the presence of surfactants. Thus, surface capillary forces dominate over the strength of the structure at certain concentrations.

As mentioned in the paragraph 1, a warps sizing process carries out at high temperatures, which leads to a decrease in the contact angle, so that this fact is favorable for the successful use of developed sizing compositions.

Determination of the adhesion of polymer films to fiber

The value of the adhesion of the liquid to the solid calculated from the equation of Dupré as the sum of the surface tension of a solid, a solution and an interface. The work of the adhesion calculated from the equation of Dupré–Young [4–6, 12].

Values that we have received from the research should be considered as approximate, because we did not investigate individual substances but compositions. This is because the larger intermolecular interaction within the

same phase, the smaller the intermolecular interaction at the interface [12].

The Table 3 shows the dependence of the adhesion of the starch films fiber from the starch content in compositions of sizes (see paragraphs 1, 2). As can be seen, the magnitude of the adhesion of all sizing films increases with the increasing concentration of an adhesive – the starch. In the size with the surfactant the magnitude of the adhesion increase rapidly, but in the traditional starched size the dependence is more complicated. Obviously this is due to an increase of the contact angle. Films containing additives of kaolin and alum have the adhesion value by 10–15 % higher than sizes as without the addition of a surfactant and with the addition.

Table 3 -The dependence of the film sizes adhesion from the content of the starch

Composition	The work of the adhesion W_a, mJ·m^{-2}, at different concentrations of the starch, g·L^{-1}				
	20	30	40	50	60
Traditional	111.73	109.26	105.87	109.91	103.67
Alum	108.49	111.80	112.39	114.64	116.41
Kaolin	111.37	113.14	113.12	116.54	117.75
Surfactant	92.66	102.85	106.18	113.26	113.45

To determine the optimal content of films adhesives-fixers (kaolin or alum) we have investigated the dependence of the work of the adhesion from the content of kaolin in the starch size (Table 4, Figure 1). The most stable growth of the work of the adhesion is observed when the content of kaolin is 0.50–0.75 % by the weight of the starch. Such a stable effect is not observed at 0.25 % kaolin. Obviously this content is insufficient to stabilize the starch gel.

Introducing to the size 1.00–1.25 % kaolin especially at high concentrations of the starch observed a decrease of the adhesion, which is probably also associated with a decrease in the wetting ability of gels at high concentrations of the starch. So with a high content of additives of kaolin and alum even in the presence of a sufficient magnitude of yarn glued size films will be fragile.

Table 4 - The dependence of the film sizes adhesion from the content of the kaolin

Content of starch, $g \cdot L^{-1}$	The work of adhesion W_a, $mJ \cdot m^{-2}$, at different concentrations of kaolin, $g \cdot L^{-}$, % of the weight of the starch				
	0.25	0.50	0.75	1.00	1.25
20	106.85	111.37	112.46	109.43	105.39
30	110.90	113.14	113.78	110.54	106.45
40	110.95	113.12	114.67	110.98	107.61
50	111.50	116.54	116.67	111.87	107.21
60	108.43	117.75	117.99	109.,89	104.91

Thus, from series of experiments it was found the optimal content of the adhesive – 0.50–0.75 % by the weight of the starch. Finely dispersed particles of kaolin are probably play filling of polymer compositions which affect positively both adhesive and cohesive properties of size films.

According to another theory of an adhesion (electric) there is the orientation of neutral molecules containing polar groups; that is an electric double layer on the border of the adhesive – substrate is formed, which is a result from the interaction of these molecules (a formation of hydrogen bonds by the donor-acceptor mechanism and by Coulomb forces) [12].

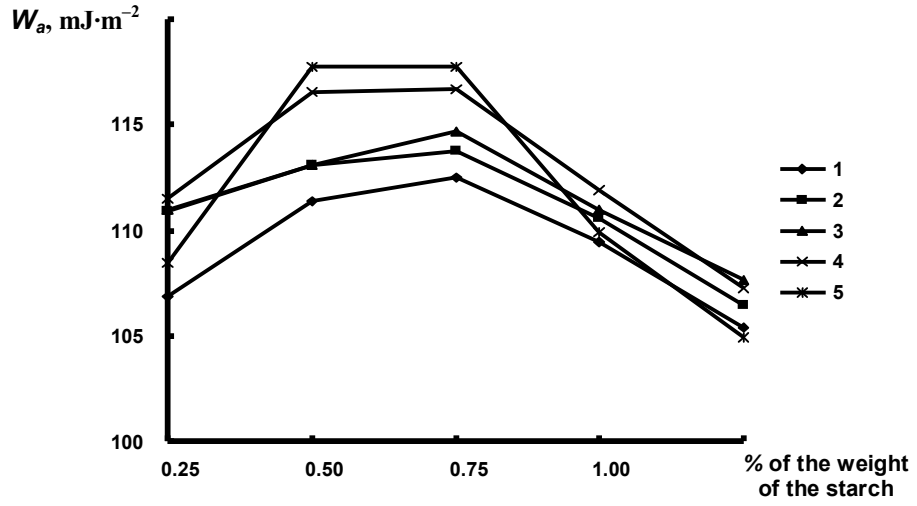

Fig. 1. The dependence of the film sizes adhesion from the content of kaolin in the gel at concentrations of the starch ($g \cdot L^{-1}$): 1 – 20, 2 – 30, 3 – 40, 4 – 50, 5 – 60.

Finely dispersed amphoteric aluminum compounds as well interact with molecules of the starch and the cellulose due to its potential-forming layer of ions.

It can be assumed that the presence of amphoteric aluminum compounds affects the formation of the fine structure of the polymer during drying with the arrangement between elements of its supramolecular structure, the formation of solid films and the change in their anti-friction properties.

It is likely that the proposed composition (with a larger value of the adhesion to the fiber) will promote the formation the higher value of yarn glued on the filament with a certain content of the adhesive. This is a prerequisite for adhesives (the starch) saving.

Thus, we investigated the dependence of the yarn glued from the adhesive concentration in the traditional starch size, the starch size with kaolin and the starch size with alum (Table 5). From this table it is clear that the value of yarn glued sizing compositions with hygroscopic additives at the same concentration of the starch is approximately 15–20 % more than in sizes without additives. This fact is well supported as a molecular and an electrical theory of the adhesion. The required value of the yarn glued on the film is formed at lower concentrations of the starch.

Table 5 - The dependence of the yarn glued from the content of the starch in the size

Size	The value of the yarn glued, % at different concentrations of the starch, $g \cdot L^{-1}$								
	20	25	30	35	40	45	50	55	60
Traditional	2.4	2.7	3.1	3.3	3.9	4.3	4.8	5.3	5.9
Alum	2.4	2.7	3.4	4.0	4.8	5.5	5.9	6.7	7.2
Kaolin	2.5	2.9	3.3	4.1	4.7	5.5	6.0	6.6	7.3

Analyzing experimental data that were presented in paragraphs 1–3 we can conclude that best indicators of the force of surface tension, the contact angle, the adhesion work and the value of yarn glued have proposed sizing compositions at the concentration of the starch about 45 g·L–1 with the addition of kaolin or alum in the content of about 0.5 %, soft paraffins – at 0.8 % by the weight of the adhesive.

Desizing process

After the weaving process the size should be removed from the tissue so as not to create obstacles to its further finishing. In the case of desizing of starch films there are certain difficulties since the starch size is poorly soluble in water. It is necessary to soak the fabric for the swelling of the polymer film, to convert insoluble polymers into a water-soluble state by the depolymerization and to wash them [13].

The increased adhesion of sizing films to fiber as a positive effect gives an increasing the efficiency of the warps processing in the weaving. But the same effect can affect processes of a desizing, a bleaching and a coloring and negate the overall economic impact of the technological process of a final fabrics production.

For desizing fabrics treated with the proposed compositions a peroxide-alkaline desizing method was selected [14] for the following reasons. Compounds of aluminum due to their amphoteric are sensitive to changes in pH. In an alkaline environment acidic properties of aluminum compounds with the formation of a negative potential-forming layer of ions appear [15–17]. Thus, adding of alkali a cohesive strength of the film and an adhesive strength the fiber–the film is significantly reduces, and a desizing process takes place without complications.

Finely dispersed particles of amphoteric aluminum compounds have a well-developed surface. They are good adsorbents and adsorb on their surface soft paraffins contained in the size, and those wax-like substances that have been deleted in the process of the digestion.

To determine the ease of the fabrics desizing we have studied the process of the swelling of size films at 20 °C and 60 °C in water for 1.5 h with different concentrations of the starch. The content of kaolin (alum) is 0.5 % by the weight of the starch, the content of soft paraffins – 0.8 % by the weight of the starch. The degree of the swelling S (%) was determined as the ratio of the mass of dry and swollen films (Table 6).

Analyzing data in the Table 6 we conclude that the swelling of starch films is more intense at higher temperatures. The degree of the swelling of films clearly increases with the increasing concentration of the starch in the film. The

dependence of the degree of the swelling of all three films is the same. Thus, the addition of kaolin or alum to the starch size does not prevent its removal during desizing. The degree of removal of the starch is 85–90 %.

Table 6 – The degree of the swelling of size films at different temperatures and concentrations of the starch

Size	The degree of the swelling, *S*, % of size films at different concentrations of the starch ($g \cdot L^{-1}$), at 20 °C/60 °C				
	20	30	40	50	60
Traditional	116/198	154/241	245/330	301/374	369/435
Alum	108/180	161/250	248/319	276/360	358/446
Kaolin	110/185	142/235	243/311	291/370	375/456

An application of the size with the reduced starch content significantly improves wastewater. The presence of a certain content of the starch is not very harmful because starches are good adsorbents and are able to adsorb other substances that are biodegradable difficultly. Thus, new biodegradable substances form, and the hydrosphere self-cleaning process only accelerates.

In the application of developed sizing compositions for cotton warps dust emission decreases due to a formation of films with a high elasticity and hygroscopicity, which crumble less than films formed by traditional techniques [3].

Conclusions

1. Starches are the most widely used, environmentally and economically justified sizing agents. Adding in sizing compositions hygroscopic and modifying textile-processing chemicals need for flexible, robust and stable sizing films on the yarn.

2. Starch sizing compositions with the addition of 0.5 % kaolin or alum of the mass of the starch have: a) the force of the surface tension 20–30 % less in a comparison with traditional compositions; b) the value of the contact angle, which is much less and approaches to the values of the contact angle of sizing compositions with the addition surfactants which improve the penetration of starch gels into the yarn; c) the adhesion value is 15 % more than the traditional starch size, this leads to an increase in the value of the yarn glued by 20 %, which gives the possibility to save adhesives.

3. The optimal composition of size components was developed: a corn starch – 45 g · L^{-1}, hygroscopic additives – 0.5 % of the weight of the starch, a softener – 0.8 % of the weight of the starch. An adhesion of the size to cotton fibers is maximal at that ratio of sizing components.

4. The increase of the adhesion of the film does not prevent but facilitate an easy removal of the size and an efficient fabrics desizing due to the potential-forming ions layer of the amphoteric aluminum compounds. The removal of the starch size is 85–90 %.

5. Using proposed compositions for a cotton yarn is environmentally safe.

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