Original Article

ACRYLIC EMULSION - COTTON CELLULOSE AND SYNTHETIC FIBRE COMPOSITE PAPER ADHESIVE

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Abstract

To give the paper the necessary mechanical strength, an acrylic emulsion is used as a polymer spacer. Its use leads to increased mechanical strength, which indicates the formation of new hydrogen inter-molecular bonds. In order to clarify the mechanism of interaction of synthetic polymers with fibrous components of paper and to determine the structure of the resulting composition, infrared spectroscopic and X-ray crystallography studies were conducted.

Key words: cotton cellulose, synthetic polymers, canifol, acrylic emulsion, adsorbing agent.

Introduction

To ensure strong adhesion of various fibers, moisture-proof paper, and strength in both humidified and dry states, a adhesive agent is introduced into the paper mass [1]. Today, many applications are being found for paper gaskets based on cans and synthetic gaskets. In order to give the necessary mechanical strength to paper based on cotton cellulose and synthetic fibers, we have used acrylic emulsion instead of canifolic adhesive as a spacer.

Experimental Part

Acrylic (polymethylate) emulsion (TU Uz. 61-14-94. of production «Navoiyazot» OJSC.) is obtained by emulsion polymerization of methylakilate and is a milky white liquid, mixed with water in any ratio. It does not disintegrate for a long time, has a relative viscosity of at least 1.75 (ratio of the emulsion expiry time to the water expiration time through the viscometer), the mass fraction of the residual monomer is not more than 0.35%. The main fibre raw material for paper is cotton cellulose from lint. To save expensive cotton cellulose, a portion of it is replaced by the waste of polyacrylonitrile (PAN)-fiber (nitron). Infrared spectra of experimental paper samples are taken from Parken Elmer's System 2000 FT-IR spectrometer in a wavelength range of 400-4000 cm^{-1}. In order to determine the structure of the paper composition X-ray-phase analysis of experimental types of papers was carried out. To determine the degree of crystallization of the obtained paper samples, X-rays were taken at the DRON-20 installation with Cu-anticathode [2-4]. The degree of crystallity is defined as the

ratio of the total dispersion of crystallites to the general dispersion from the amorphous and crystalline regions [5].

Production of prototype paper samples and evaluation of their quality was carried out at the test center for paper, cardboard and products from them by the joint-stock company «Angren Pack» according to the approved technological regulations. To characterize the strength of the paper, a number of indicators have been defined: breaking length, breaking force, and melt resistance. Breaking force (H) and breaking length (meter) - as the calculated length of a strip of paper, which, being suspended, at one end, will break under the action of its own weight, determined by GOST 13525.1-79. The resistance to bend under multiple bends in the transverse direction (number of double bends) is determined by GOST 13525.2-80. The ash content of the paper (%) is determined according to GOST 7629-93.

Results and discussions

In the production of various types of paper, resin-resistant dyspersia [1] is widely used as a sealing material. Canister - a solid resin, which is prepared from pine resin (live bait), is not soluble in water, so the gasket uses various types of glue, which is obtained by its interaction with alkalis. The canister gasket increases the hydrophobicity of the paper, while the physical-mechanical performance decreases. It has been found that the introduction of canifolic glue in a quantity up to 1.5% of the fiber mass has little effect on the strength of the paper, but with more glue strength and white decrease by 2-15% [1]. Synthetic fibers inserted into the paper mass, inserting between the macromolecules of cellulose, reduce the number of intermolecular hydrogen bonds, which leads to reduced mechanical strength of the paper sheet [1]. One way of solving this problem is to use a polymer adsorbent that binds macromolecules of cellulose between itself and synthetic fibers. Solutions and emulsions of synthetic polymers, containing functionally active groups, can be a worthy substitute for canifolic glue. The physical and mechanical properties of composite paper with the use of canifolic glue and acrylic emulsion as a gasket agent were investigated (Table. 1).

According to the results of research of physical-mechanical properties of paper, there is an advantage of the polymer spacer over the cans glue. In cases where acrylic emulsion is used, the breaking length of the paper is 15%, the breaking force is 30%, the resistance at the fracture is 16 times increased compared to paper adhesive with canifolic glue. The performance of the breaking length and breaking force depends on the strength of the adhesion of the fibers of the paper, the resistance on the die - and also on the flexibility of the fibers and the adhesive agent. It is known that macromolecules of polymers have high flexibility as opposed to molecules of low molecules [6, 7], Therefore, when applying acrylic emulsion, the ability of the paper to withstand double bends will increase significantly.

Table 1

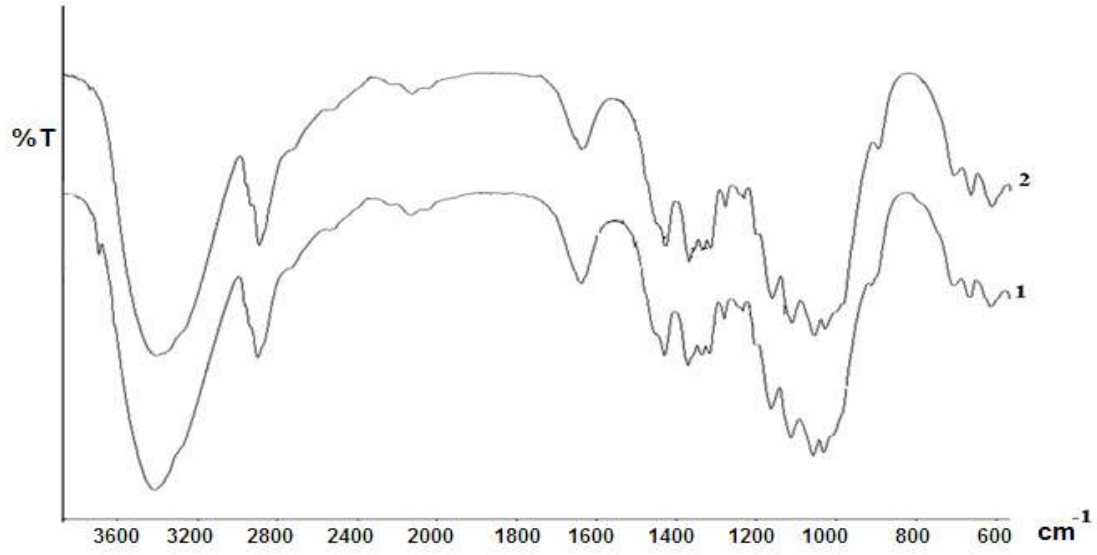
Dependence of physical-mechanical properties of experimental paper on the nature and quantity of the spacer

indicators / options	Sizing agent							
	Resin glue				Acrylic Emulsion			
	1	2	3	4	5	6	7	8
Amount of adsorbent in paper pulp, %	0,5	1,0	1,5	2,0	0,5	1,0	1,5	2,0
Cotton cellulose, %	100	95	90	85	100	95	90	85
Waste PAN fiber, %	-	5	10	15	-	5	10	15
Breaking length, m	3000	3030	2890	2530	3194	3364	3369	3461

Bursting force, N	31,0	32,0	26,0	15,0	34,6	32,8	33,4	40
Resistance to bending, etc.	44	54	64	66	66	182	221	259
Ash content, %	4,0	4,6	4,6	4,9	4,7	4,6	4,7	4,9

In order to find out the mechanism of interaction of polymethyl acrylate of acrylic emulsion with fibrous components of paper and to determine the structure of the resulting composition, IR-spectroscopic and X-ray crystallization studies were carried out. Figure 1 shows the IR spectra of samples of cotton cellulose-based paper containing canifolic (Rosin) glue (1) and acrylic emulsion (2). Characteristic cellulose absorption bands have been found in IR spectra. The absorption bands at 3342-3418 cm^{-1} refer to the valence oscillation of OH-bonds, and at 2990 cm^{-1} to the valence oscillations of CH groups. The absorption band at 1431-1434 cm-1 refers to the strain oscillations of the CH_2- and CH-groups, and at 1317-1372 cm^{-1} and 1163 cm^{-1} refers to the strain oscillations of the OH- and CH -groups. The absorption band at 1113 cm-1 refers to the asymmetric valence oscillations of the pyranic ring. The bridge's valence oscillations have an absorption band of 1059 cm-1 (asymmetric) and 900 cm-1 (symmetric). The absorption bands in the 560-708 cm-1 region relate to the deformation oscillations of the OH-groups and skeletal oscillations of the C-C-bonds or to the absorption of the piron ring. The absorption band at ~1640 cm^{-1} has been attributed to fluctuations in adsorbed water molecules. All spectra contain a large number of bands due to the presence of large areas of high molecular ordering [8].

Fig. 1. Infrared spectra of cotton cellulose paper specimens with PAN waste fibres containing resin-based glue (1) and acrylic emulsion (2)



The most characteristic bond for cellulose molecules is the hydrogen bond, with an energy of about 25-35 kJ/mole. Although the hydrogen bond is weaker than the covalent bond, the total energy of these bonds in high molecular compounds, where the size of molecules and the number of atoms is very large, is much greater than the valence forces [1, 6]. All other things being equal, the greatest probability of formation of hydrogen intermolecular bonds arises between the most polarized atoms, i.e. between the strongest donors and proton acceptors. The absorption band at 1640 cm^{-1} in the infrared spectra of the samples may relate to valence oscillations of the carbonyl polymethyl ate group forming a hydrogen bond with cellulose. Toughening of cellulose structure, the emergence of new hydrogen bonds leads to improvement of paper mechanical properties. The degree of crystallization of cellulose can be judged by the ratio of absorption bands at 1372 cm^{-1} and 2900 cm-1. The absorption band at 1372 cm^{-1} is responsible for the crystal region, and at 2900 cm^{-1} for the amorphous

region [9]. For experimental papers produced with the use of canifolic glue and acrylic emulsion, the degree of crystallization increases, respectively, from 59 to 63%. These results are confirmed by X-ray crystallography analysis.

The structure of cotton cellulose paper when using binders for bonding fibers depends on their microstructure and application. Organic polymer based binders contribute to the formation of fibrillary structure of cellulosic fibres, improve adhesion. The structure of compositions made with various binders - canifolic adhesive and acrylic emulsion - investigated by x-rays [10-14].

That analysis shows that none of the detected adsorbents are crystalline. The acrylic emulsion has a crystallization degree of about 15-20%.

Comparison of the X-rays of the adhesive agent - canifolic glue and paper with the addition of canifolic glue shows that a small crystalline area appears in the paper mass (fig. 2).

Figure 2. X-ray patterns of rosin glue (a) and papers based on cotton cellulose with the introduction of waste PAN fiber containing rosin glue (a')

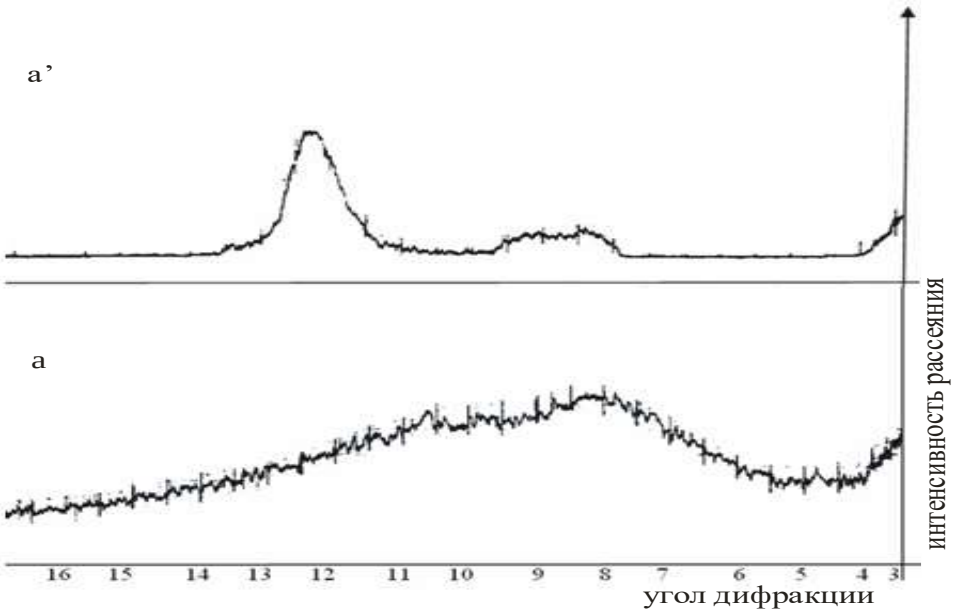
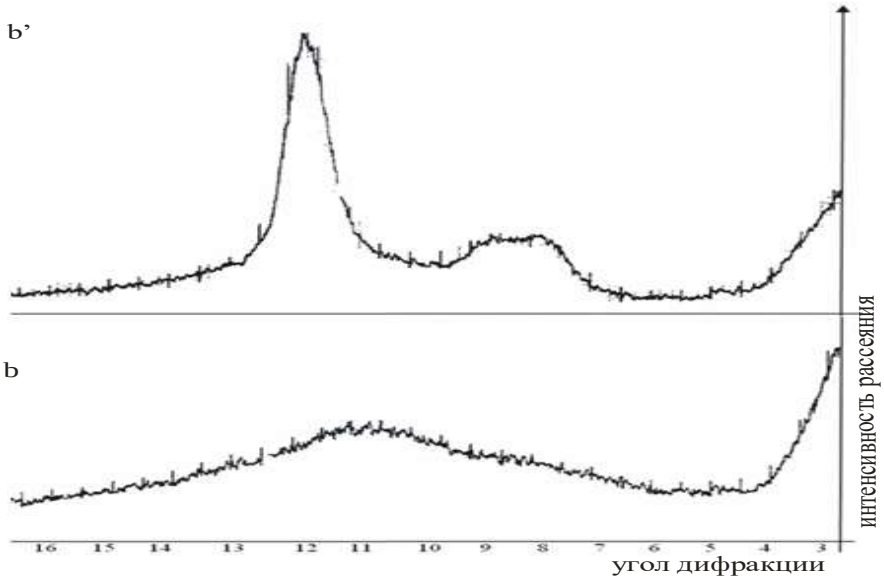


Fig. 3. X-ray diffraction patterns of acrylic emulsion (b) and papers based on cotton cellulose with the introduction of waste PAN fibers containing acrylic emulsion (b')



Comparison of the X-rays of the adsorbent - acrylic emulsion and the paper with it shows that the crystallization of the paper sample is increasing, as evidenced by increased dispersion intensity (Fig.3).

The dependence of scattering intensity on the carbon diffraction of the canifol glue is typical for amorphous substances, so the degree of crystallization is 0 (Table. 2). The maximum dispersion intensity of the amorphous state of the canifoli glue is observed at diffraction angle 8. In paper with canifolic glue, in acrylic emulsion and in paper with it, the maximum dispersion intensity of the crystalline regions is observed at diffraction angle 11-12. The calculated degree of crystallization was less than that obtained from IR spectroscopic studies (59 to 63%). But here too, the degree of crystallization of the paper using acrylic emulsion is greater than the paper with canfolic glue [15-20].

Table 2

Dissipation intensity and degree of crystallity of the spacer and paper

substance	Diffraction angle at maximum intensity	Degree of crystallinity, %	Substance	Coal diffraction at maximum intensity	Degree of crystallinity, %
Rosin	8	0	acrylic emulsion	11	15-20
Paper with the introduction of rosin glue	12	35-40	Paper with the introduction of acrylic emulsion	12	55-60

Acrylic emulsion is well wetted with water, easily mixed with the rest of the components, forming a uniform paper mass. The results of X-ray and X-ray crystalline studies of the papers are consistent with the data of microscopic and physical-mechanical studies (fig. 4).

Pis. 4. Microscopic images of the surface of cotton cellulose-based paper with the introduction of waste PAN fibre containing: a resin-based adhesive, b acrylic emulsion.

a b

1 cm=50 μm 1 cm=50 μm

It is shown that the addition of acrylic emulsion allowed obtaining on the paper a more homogeneous composition with an improved smoothness index. It has been established that the paper produced with the use of acrylic emulsion is characterized by an increased level of gloss.

Conclusion

Cotton pulp paper pulp using synthetic fiber waste and polymer adsorbents has a number of advantages. The use of affordable secondary raw materials, synthetic fiber waste, the simplicity of the composition and the flow of paper reduces the cost of production, reduces the environmental burden on the natural environment.

With the use of functionally active polymers as a sealing agent, the mechanical strength of the paper is increased by the formation of new hydrogen-based interconnections and by improving the paper structure. The addition of an acrylic emulsion made the paper more uniform and smoother. It has been established that the paper produced with the application of acrylic emulsion is characterized by an increased level of gloss.

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