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S. A. Gordeyko, PhD student (BSTU);
N. V. Chernaya, D.Sc., professor, head of department (BSTU);
N. V. Zholnerovich, PhD (Engineering), assistant professor (BSTU);
V. L. Fleisher, PhD (Engineering), assistant professor(BSTU);
A. A. Drapeza, junior researcher (BSTU);
M. V. Andryuhova, PhD student (BSTU); **D. S. Makarova**, student (BSTU)

STRENGTH ENHANCEMENT OF PACKAGING PAPER USING NITROGEN COMPOUNDS

Nitrogen-containing compounds were synthesized for the first time in the department of chemical processing of wood. These polymers, which contain amino and amidogroups, different water solubility, regularity and linearity. The essence of obtaining nitrogen compounds studied based on the chemical interaction with rosin diethylenetriamine and adipic (fumaric) acid. Amino and amidogroups participate in the formation of additional strengthening ties. The tests of samples of paper containing his compositions containing compounds, have shown that the new synthesized polymers exhibit strengthening effect similar to the effect of import connections Maresin and Melapret.

Introduction. High-level requirements are applied to the strength of packaging paper used for food packaging and industrial products. A special role is played by reinforcing additives. Their presence ensures to achieve high values of such indicators as breaking force in the dry state, breaking length, stiffness at break, energy absorption at break.

In addition the modern development of paper and paperboard production is characterized by the need to substitute scarce and expensive primary fibrous material (cellulose) for affordable and cheaper secondary raw materials (waste paper). Cellulosic feedstock is characterized by homogeneous fractional composition and stable papermaking properties while junk feedstock has inhomogeneous fractional composition and hence unstable papermaking properties [1].

Therefore the use of waste paper in packaging paper technology dictates the need for high-performance reinforcement additives. At top paper and paperboard companies of the Republic of Belarus, the CIS and abroad reinforcing additives which include Maresin and Melapret are widely used. However their high cost hinders the use of these compounds in packaging paper composition because of the increasing of the cost of the finished product.

A method based on the use of their compositions containing compounds is applied a sone of the promising methods for hardening junk types of packaging paper. Their strengthening effect can be manifested in the formation of additional bonds between the nitrogen-containing groups and the hydroxyl groups of cellulose fibers [2]. Thes trength enhancement of the paper is the consequence of this process.

The work objective is to develop the new technological regime of using the new synthesized nitrogen-containing compounds to improve packaging paper strength.

Main part. Packaging paper samples weighing 80 g/m^2 were produced on a sheet-making apparatus «Rapid-Ketten» (company «Ernst–Haage», Germany) from paper pulp. Paper pulp is a dispersed system where dispersed phase is represented by fiber and dispersion medium by water.

Physical and mechanical testing of paper samples was performed on «Lorentzen & Wettre» (Sweden) set of instruments. The breaking length (R, m),breaking resistance (S, kN/m), tension and elongation(L,% of the original length), the absorbed energy (W, J/m^2), Young's modulus (Z, GPa), the rigidity of the paper samples (E, kN/m) were measured on the horizontal Tensile Tester machine according to ISO 1924/24, SCAN P67, TAPPI T494.

The following parameters were used to assess the paper samples strength at brake [3]:

– resistance at break

$$S = \frac{F}{b}, \tag{1}$$

where F – is a maximum tension effort, N; b – is an original sample width, mm;

– tension

$$R = \frac{100 \cdot S}{l}, \tag{2}$$

where S – is elongation at break, mm; l – is an original test sample length, mm;

– energy consumption

$$W = \frac{1000 \cdot U}{l \cdot b}, \tag{3}$$

where U – is an area under curve “force – elongation”, mJ; b – is an original test sample width, mm;

– hardness

$$E = \frac{C \cdot l}{b}, \tag{4}$$

where C – is a max curve slope on a graphin coordinates “force – elongation”(N/mm);

− young's modulus

$$Z = \frac{E}{t}, \qquad (5)$$

where E – is hardness at brake, kN/m; t – test sample thickness, mm;

− breaking length

$$R = 10^{-3} \cdot \frac{F \cdot L}{m \cdot 9{,}81}, \qquad (6)$$

where F – is breaking strength, N; L – test sample length, mm; m – test sample weight between clamps, g.

Standard hardwood sulphate pulp fibers (GOST 28172-89) were used for modeling unstable junk fibers in dispersed system.

These fibers have the homogeneous size distribution with 0.8-1.2 mm average length.

The essence of pulp slurry preparation was that the dissolution was conducted in the fibrous raw material disintegrator BM-3. Splayed 4 % fiber mass was ground in a NDM-3 mill of LCR-1 set. Freeness of the pulp slurry was 40 °ShR [3].

Paper samples were different in the structure content of nitrogen compound. They were firstly synthesized at the department of chemical processing of wood with using of fumaric acid, adipic acid, diethylenetriamine (DETA) and rosin.

Their characteristics are given in Table1. Nitrogen-containing compound were introduced into the fiber suspension. Their mass flow was increased from 0.5 to 2.0 % from a.d.s. (R,%).

New synthetic nitrogen compounds (numbers 1-7) were different from traditionally used Maresin and Melapret ones in pH of the 2% working solution and the macromolecules charge. It was found that 2% aqueous solutions of newly synthesized compounds have a 9.25-11.20 pH and it is 3.42-3.75 for Maresin and Melapret. The table1 shows that the charge of synthesized compounds macromolecules differs significantly from the Maresin and Melapret charge. The acid number of new synthesized compounds containing nitrogen is substantially identical. It is within the range of 12.0-12.6 mg KOH/g for a compound with FA and 15.0 mg KOH/g for the compound with AA.

Test results of paper samples produced with the newly synthesized nitrogen-containing compounds and conventionally used compounds are in the table 2.

Table 2 shows that paper samples made of new synthesized nitrogen compounds number 5 (AA + DETA), number 6 (AA + DETA + rosin (5%)), number 7 (AA + DETA + rosin (10%)), number 8 (AA + DETA + rosin (20%)) have the same strength that as that of paper samples containing the conventionally used nitrogen-containing Maresin and Melapret compounds. It is evident from an increase of the breaking force of the dry sample from 26.3 to 56.7 N (is 2.2 times more), of the breaking length from 1.82 to 2.99 km (is 1.6 times more), of the energy absorption from 14.27 to 42.38 J/m^2 (is 2.9 times more), of the stiffness from 267.1 to 599.6 kN/m (is 2.2 times more), of young's modulus from 1.090 to 7.496 GPa (id 6.9 times more).

Table 1

Characteristics of nitrogen-based compounds

Nitrogen-based compound number	Constitution of compound	Nitrogen-based compound properties		
		pH	Acid number, mg KOH/g	Charge, mV
New synthesized				
Number 1	FK + DETA + rosin (5%)	9.25	12.6	−18
Number 2	FK + DETA + rosin(10%)	9.55	12.8	−20
Number 3	FK + DETA + rosin(15%)	9.45	12.8	−19
Number 4	AK + DETA (1: 1.2)	11.00	15.0	+22
Number 5	AK + DETA + rosin(5%)	10.8	15.0	−22
Number 6	AK + DETA + rosin(10%)	11.00	15.0	−97
Number 7	AK + DETA + rosin(20%)	11.20	15.0	+236
Traditionally used				
Number 8	Maresin	3.75	–	+758
Number 9	Melapret	3.42	–	+675

Table 2

Strength values of the paper samples at break

R, % from a.d.s.	Breaking stress of dry sample, N	Tensile strength, kN/m	Breaking length, km	Elonga-tion, mm	Exten-sion, %	Energy absorption, J/m^2	Young's modulus, GPa	Stiffness at break, kN/m
Fibrous Slurry								
0	43.5	2.90	2.22	1.70	1.70	34.92	5.175	414.0
Fibrous Slurry + nitrogen-based compounds number 1								
0.5	21.1	1.41	1.79	1.29	1.29	12.40	0.975	233.9
1.0	23.4	1.46	1.99	1.18	1.18	13.60	1.284	283.8
1.5	22.8	1.52	1.94	1.03	1.03	10.09	1.080	262.5
2.0	24.6	1.64	2.09	1.24	1.24	13.96	1.211	284.5
Fibrous Slurry + nitrogen-based compounds number 2								
0.5	23.2	1.54	1.97	1.00	1.00	11.59	1.285	320.0
1.0	28.5	1.90	2.42	1.36	1.36	18.02	1.244	325.8
1.5	25.2	1.68	2.14	1.09	1.09	12.16	1.187	295.5
2.0	23.9	1.60	2.03	1.30	1.30	14.21	0.995	249.7
Fibrous Slurry + nitrogen-based compounds number 3								
0.5	27.1	1.81	2.30	1.48	1.48	19.11	1.172	303.6
1.0	22.4	1.49	1.90	1.39	1.39	14.44	0.944	242.6
1.5	29.9	2.00	2.54	1.17	1.17	15.90	1.436	360.5
2.0	24.4	1.63	2.07	1.00	1.00	11.13	1.178	312.1
Fibrous Slurry + nitrogen-based compounds number 4								
0.5	26.3	1.75	2.24	1.18	1.18	14.27	1.283	315.7
1.0	30.0	2.00	2.55	1.60	1.60	22.60	1.211	300.3
1.5	26.7	1.78	2.27	1.68	1.68	21.30	1.090	267.1
2.0	27.1	1.81	2.31	1.17	1.17	14.42	1.223	315.6
Fibrous Slurry + nitrogen-based compounds number 5								
0.5	41.3	2.75	1.98	1.48	1.48	27.77	5.055	404.4
1.0	39.9	2.66	2.15	1.42	1.42	25.58	4.769	381.5
1.5	**52.2**	**3.48**	**2.91**	**1.34**	**1.34**	**31.16**	**6.561**	**524.9**
2.0	**56.2**	**3.75**	**2.99**	**1.62**	**1.62**	**42.38**	**6.803**	**544.3**
Fibrous Slurry + nitrogen-based compounds number 6								
0.5	47.3	3.15	2.42	1.34	1.34	28.41	6.031	482.5
1.0	42.5	2.83	2.33	1.51	1.51	29.28	4.998	399.9
1.5	44.6	2.98	2.57	1.50	1.50	30.61	5.391	431.3
2.0	43.3	2.89	1.95	1.77	1.77	35.81	5.055	404.4
Fibrous Slurry + nitrogen-based compounds number 7								
0.5	**51.3**	**3.42**	**2.46**	**1.47**	**1.47**	**34.46**	**6.355**	**508.4**
1.0	50.2	3.35	2.28	1.06	1.06	22.99	6.907	552.5
1.5	53.2	3.55	2.41	1.52	1.52	36.85	6.601	528.1
2.0	**55.6**	**3.71**	**2.47**	**1.53**	**1.53**	**39.53**	**6.997**	**559.8**
Fibrous Slurry + nitrogen-based compounds number 8								
0.5	46.5	3.10	2.33	1.19	1.19	24.61	6.327	506.1
1.0	**56.7**	**3.78**	**2.73**	**1.37**	**1.37**	**35.59**	**7.496**	**599.6**
1.5	46.7	3.12	1.97	1.10	1.10	22.65	6.342	507.4
2.0	40.6	2.71	1.82	1.20	1.20	22.53	5.476	438.0
Fibrous slurry+ Maresin								
0.5	52.1	4.14	2.72	1.78	1.78	51.34	7.191	575.3
1.0	47.5	3.16	2.04	1.10	1.10	22.57	6.215	497.2
1.5	50.6	3.37	2.82	1.76	1.76	41.63	5.701	456.1
2.0	49.8	3.32	2.75	1.69	1.69	38.80	5.684	454.7
Fibrous slurry + Melapret								
0.5	59.1	3.94	2.89	1.30	1.30	34.21	7.710	616.8
1.0	51.6	3.44	2.78	1.21	1.21	27.87	6.803	544.3
1.5	56.7	3.78	2.66	1.69	1.69	44.63	6.517	521.3
2.0	51.4	3.43	2.27	1.42	1.42	33.14	6.461	516.9

Designated value of the quality indicators of nitrogen compounds number 5 (flow 1.5 and 2.0%), number 7 (flow 0.5 and 2.0%), number 8 (1.0% rate from a.d.s.) demons trates a high efficiency of synthesized compounds in the process of paper samples hardening.

Conclusion. Nitrogen-containing compounds first obtained at the department of chemical processing of wood by chemical interaction of adipic (fumaric) acid with diethylenetriamine and rosin have 9.25-11.20 pH, their acid value is 12.6-15.0 mg KOH/g and a charge is from−97 to +236 mV. It was found that compounds which include adipic acid with diethylenetriamine and rosin have high reinforcing properties. The required strength of the paper is provided with the flow rate of 1.5 and 2.0% (number 5), 0.5 and 2.0% (number 7) 1.0% from a.d.s. (number 8). New synthesized polymers exhibit a strengthening effect similar to the effect of imported Maresin and Melapret compounds.

When the flow rate of 1.5 and 2.0% (No. 5), 0.5 and 2.0% (No. 7) 1.0% of a. s. in. (No. 8) provided the required strength of the paper, as new synthesized polymers exhibit a strengthening effect similar to the effect of import and compounds Maresin Melapret.

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