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Chapter 22

FIBROUS MATERIALS - AS THE TECHNOLOGICAL ADDITIVE IN MANUFACTURE OF BUTADIEN-STYRENE RUBBERS AND ELASTOPLASTICS

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Preservation of an environment is one of the major problems of mankind. It is connected to increase of extraction and processing of natural resources. Growth of industrial potential is accompanied by education and accumulation of a significant amount of waste products. For manufacture of a target industrial output it is spent about 1/3 consumed source of raw materials, 2/3 make waste products and by-products. Amplification technological influences on a nature has caused a line of problems of ecological character.

Last years the heightened interest to fibrous a fillers which raw sources are huge is shown. Waste products of fibrous materials in plenties are formed at textile factories and the enterprises of a clothing industry: tangled fibrous, the ends of a yarn and a string, a rag, failures, combings and pile from a hairstyle of artificial fur etc. [1, 2]. Therefore an actual technical task is search of the most perspective directions in application of waste products of fibrous materials [1].

In various industries some part of formed textile waste products is used: strongly littered cotton fibrous waste products staunch oil wells at drilling. Rags and scraps can be used in manufacture of roofing felt and roofing material. Difficultly utilized lining materials are exposed of turning into fibrous and are used as cotton wool as fillers in manufacture of building materials, in quality is warm and soundproofing basis under linoleum [3].

In the published works [4, 5] fibrous fillers entered on rollers during preparation of rubber mixes. Thus rubber mixes got necessary rigidity, and durability their parameters vulcanizates в were improved. However such technology introduction fibrous filler did not allow to achieve uniform distribution filler in volume of a rubber mix that was reflected in physicomechanical parameters vulcanizates. Besides introduction fibrous filler on rollers demanded additional expenses of energy.

Therefore more interesting the following way of reception of the rubbers filled with fibres is represented:

1. preliminary introduction of a fibre in latex of rubber;
2. the subsequent coagulation of the latex filled with a fibre with reception of the rubber filled with a fibre;
3. preparation from rubber of a rubber mix and her vulcanization.

The purpose of the given work - studying of influence of the cotton, viscose and kapron fibres entered into latex butadiene-styrene of rubber of mark SKS-30 АRК, on process of coagulation, and also on properties of rubber, rubber mixes and them vulcanizates.

EXPERIMENTAL PART

Process of allocation of rubber of latex studied on coagulator, representing the capacity supplied with mixing device. Into him loaded 20 ml of latex SKS-30 АRК (the dry rest ~ 18 %). Coagulator thermostated 15-20 minutes at temperature 60^0C. After that entered 24 % a water solution coagulant - chloride of sodium. Finished process of coagulation by addition of 1-2 % of a water solution of a sulfuric acid up to size pH≈2.0-2.5. The dropped out deposit (coagulum) separated from a water phase filtering, washed out water, dried in a drying case at temperature 80-85^0C and weighed. Calculation of weight formed coagulum carried spent, proceeding from the dry rest of initial latex. After upholding a filtrate (or as it name in the industry of synthetic rubber, - "serum") in him visually defined possible presence small dispersion crumbs coagulum.

Fibrous filler (the cotton, viscose, kapron) entered into latex at different stages of process of coagulation:

- in a dry kind before addition coagulant in latex;
- moistened with water before addition coagulant in latex;
- in a solution tall soaps;
- simultaneously with coagulant as water-salt dispersion;
- simultaneously with a solution of a sulfuric acid as water-acid dispersion.

Length of a fibre (2; 5 and 10 mm) and (from 0.1 up to 1.0 % on weight of rubber) changed his contents during experiment.

Kinetic swelling vulcanizates filled with various fibres, studied in solvents of various polarity by the following technique. Cut out samples vulcanizates as squares in the size 1x1 sm which then weighed. Quantity of samples for each series of measurements - 5. Samples placed in solvents on eight. In each hour of them took out, made gauging their geometrical sizes and weighed. Last point of definition of the size and weights of a sample - in 24 hours. Then carried spent processing the received data:

- for a finding of a degree of swelling a (% of weights.) from weight swell a sample subtracted weight of an initial sample; the received weight of solvent divided into weight of an initial sample and multiplied on 100 %; from five received results for each sample chose the greatest (equilibrium) size α_{max};

- a constant of speed of swelling found under the formula

$k = (1/\tau) \cdot (\ln [\alpha_{max} /(\alpha_{max} - \alpha_{\tau})])$, where
τ – time, (h); α_{τ} - size of the current degree of swelling in time τ.

RESULTS AND THEIR DISCUSSION

Influence of a Way of Introduction, Quantity and the Size Filler on Process of Coagulation of Latex

At the first stage of experiment some kinds of processing fibrous filler before its mixture with latex butadiene-styrene rubber SKS-30 ARK were investigated. The size of fibres and their dosage maintained constants, accordingly: 2 mm and 0.5 % of weights of rubber. Fibrous filler entered to rubber five various ways:

1. Dry without preliminary processing. Filler entered directly into latex, mixed within 15-20 minutes. Then coagulated latex on above given technique.
2. Moistened with water. Filler immersed in a small amount of water for 5 minutes at temperature 20^0C so that it only was moistened. Damp filler entered into latex, mixed within 15-20 minutes. Then latex coagulated.
3. Moistened with a solution tall soaps. In a small amount of 5 % of a water solution tall soaps for 5 minutes at temperature 20^0C placed fibrous filler so that it was moistened. Moistened in a solution tall soaps filler entered into latex, mixed within 15-20 minutes. Then latex coagulated.
4. With a solution coagulant. For preparation such coagulation mixes fibrous filler entered into a solution coagulant (24% chloride of sodium) which is taken in the volume necessary for coagulation. Mixed within 15-20 minutes. Coagulation of latex carried spent with use as this coagulation mixes: a fibre + a solution of chloride of sodium.
5. With a solution of acidifying agent (2 % a sulfuric acid). Preliminary fibrous filler entered into a solution of a sulfuric acid which is taken in the quantity necessary for coagulation of latex. Mixed within 15-20 minutes. Then the received mix (a fibre + a sulfuric acid) used as acidifying agent, and coagulation carried spent by the standard technique.

Uniformity of distribution of fibres in polymer investigated by the following technique. A sample of latex with fibrous filler placed on glass and dried up in a drying case before formation latex a film having inclusions of a fibre. The samples received thus considered in an optical microscope. Morphology fixed with the help of the camera. Besides an estimation of distribution of a fibre in a matrix carried spent on cuts coagulum, latex formed after coagulation.

In samples in which the fibre entered without any preliminary processing (dry) or only moistened water contained, did not observe a positive effect consisting in uniform distribution of a fibre in a matrix of latex. Dry fibres in latex were confused and formed agglomerates which further at hashing stuck to a mixer. Fibres moistened with water, also were not in regular intervals distributed in a matrix, forming lumps.

Introduction of a dispersion of a fibre with a solution tall soaps rendered more favorable influence on uniformity of distribution of a fibre in volume of latex. Fibres settled down separately from each other in a sample, not forming congestions.

Introduction fibrous filler with coagulation resulted almost in uniform distribution filler though in a sample there were congestions of fibres.

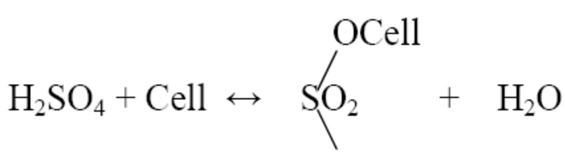
At research of a sample into which entered fibres simultaneously with a sulfuric acid, uniform distribution of fibres in volume is revealed. Fibres settled down separately from each other, and congestions fibrous filler in a matrix did not observe.

Proceeding from above stated, it is possible to draw a conclusion, that introduction of a fibre dry or moistened with water not expediently. Therefore in the further researches these kinds of preparation of composite materials did not use. Thus, for the further experiment the following most rational kinds of processing fibrous filler were chosen: the moistened 5 % a solution tall the soaps entered with coagulant (24 % a solution of chloride of sodium) and entered about 2 % a sulfuric acid. It is necessary to emphasize, that preliminary processing of a fibre by a solution tall soaps is accompanied by additional expenses.

Introduction of a fibre simultaneously with coagulation or with acidifying agent is the most technological and perspective. Thus experiments with addition of a sulfuric acid showed on the one hand increase of an output(exit) коагулюма, and on the other hand uniform distribution of a fibre in volume of a formed crumb, in comparison with experiment with introduction of a fibre simultaneously with coagulant.

In table 1 dependences of completeness of coagulation of latex SKS-30 ARK on a way of input of various fibres are submitted at various charges of chloride of sodium.

The positive effect at introduction of a cotton fibre simultaneously with a sulfuric acid, can be connected by that the basic component of the given fibre / cellulose (Cell) is capable to form sour ethers of the following structure with a sulfuric acid:



The given reaction is convertible, as ethers of sulfuric acid and cellulose easily are exposed to hydrolysis. Thus, in a water solution between a sulfuric acid and the cotton fibre containing up to 98 % of cellulose, there will be a balance. This phenomenon, most likely, also promotes more uniform distribution given fibrous filler in volume of acidifying agent. On the basis of it it is possible to assume, that process of coagulation at additional introduction in acidifying the agent of a cotton fibre proceeds on more complex mechanism demanding realization additional more of in-depth studies.

The similar explanation of the reason of occurrence of a positive effect is quite applicable also in case of introduction in latex of a fibre of viscose with a sulfuric acid. Really, at reception of a fibre of viscose from xanthate cellulose there is a decomposition xanthate to clearing groups – OH and restoration of significant number of cyclic parts of cellulose up to glucopyranose, characteristic as well for fibres of a cotton.

In view of the received results dependence of process of coagulation on quantity of the cotton, viscose or kapron fibre processed by a sulfuric acid and entered into latex at a finishing stage of coagulation further was investigated. The contents of a fibre in rubber maintained in quantity 0.1; 0.3; 0.5; 0.7; 1.0 % on weight of rubber. The received data are submitted in tables 2-4.

The analysis of experimental data has shown, that application fibrous filler during allocation of rubber from latex results in small increase of an output coagulum. Apparently, it is connected to two reasons:

- reduction of losses коагулюма, connected to ablation of a fine crumb of rubber together with serum;
- entry fibrous filler in coagulum.

Researches serum a method of a filtration have shown absence fibrous filler in him**,** that testifies to full capture of a fibre by a formed crumb of rubber.

The best results were received at a dosage of a fibre in limits from 0.3 up to 0.7 % on weight of rubber.

By results of researches the optimum length of a cotton, viscose and kapron fibre makes 2-5 mm. Change of length of a fibre in this interval renders insignificant influence on change of weight selected coagulum.

It is visually marked, that in separated from serum the contents of a fine crumb of rubber is less than rubber, than in control experiences without application fibrous fillers. It allows:

- to reduce losses of rubber with throw sewage and by that to increase productivity of technological process;
- to reduce an ecological load by clearing constructions.

However the final conclusion about size of losses of a fine crumb can be made after introduction of this technology commercially as in laboratory conditions exact reproduction of existing industrial technological process is not obviously possible.

Table 1. Influence of a way of input of various fibres (2 mm) on completeness of coagulation (% of weights) latex SKS-30 ARК at various charges of chloride of sodium

The charge of chloride of sodium, kg/t of rubber	The contents formed coagulum at various ways of input of a fibre, % of weights.									
	Without a fibre (control)	Preliminary processed by a solution tall soaps			With coagulant			With acidifying agent		
		cotton	viscose	kapron	cotton	viscose	kapron	cotton	viscose	kapron
25	8.93	13.58	11.77	9.22	8.73	9.97	9.01	11.51	10.63	10.89
50	21.37	19.64	19.58	22.13	15.53	22.87	18.94	19.72	21.77	22.63
75	32.78	28.86	34.02	31.25	25.87	22.97	24.47	29.37	31.47	32.65
100	62.71	40.29	47.67	41.11	40.33	43.20	38.11	45.90	46.62	46.81
125	80.63	79.61	77.83	78.75	68.85	82.84	75.45	79.82	79.61	84.91
150	93.41	94.05	94.62	90.52	92.53	90.21	88.21	97.54	95.76	99.60

The note: a dosage of fibres of 0.5 % of weights on rubber; a solution tall soaps (5 %); coagulant - a solution of chloride of sodium (24 %); acidifying agent - a sulfuric acid (2 %).

Table 2. Influence of size of the contents (% of weights) and lengths (mm) of the cotton fibre entered with acidifying agent, on completeness of coagulation (% of weights) rubber SKS-30 ARK from latex at various charges of chloride of sodium

The charge of chloride of sodium, kg/t of rubber	The contents of a fibre, % of weights on rubber															
	0 %	0.1 %			0.3 %			0.5 %			0.7 %			1.0 %		
		2 mm	5 mm	10 mm	2 mm	5 mm	10 mm	2 mm	5 mm	10 mm	2 mm	5 mm	10 mm	2 mm	5 mm	10 mm
25	8.93	11.14	12.65	12.14	12.15	12.56	12.29	11.51	13.39	11.89	13.20	12.78	13.08	13.26	12.64	11.75
50	21.37	20.36	21.02	19.73	20.5	20.78	19.91	19.72	21.40	20.99	20.85	23.68	21.87	20.31	23.11	21.02
75	32.78	31.37	30.21	29.44	29.3	31.49	28.74	29.37	31.56	28.78	29.66	32.05	29.65	29.17	31.93	30.14
100	62.71	42.49	40.97	40.80	45.7	43.45	40.16	45.90	41.69	42.26	45.48	41.67	45.12	43.34	41.26	39.53
125	80.63	88.12	80.16	75.12	87.5	76.51	75.50	79.82	73.85	76.12	88.13	75.92	78.11	80.32	78.44	76.48
150	93.41	96.00	95.24	93.85	95.6	97.78	94.30	97.54	97.13	95.92	95.12	97.93	95.94	95.09	95.43	93.20

Table 3. Influence of size of the contents (% of weights) and lengths (mm) of the viscose fibre entered with acidifying agent, on completeness of coagulation (% of weights) rubber SKS-30 ARK from latex at various charges of chloride of sodium

The charge of chloride of sodium, kg/t of rubber	The contents of a fibre, % of weights on rubber															
	0 %	0.1 %			0.3 %			0.5 %			0.7 %			1.0 %		
		2 mm	5 mm	10 mm	2 mm	5 mm	10 mm	2 mm	5 mm	10 mm	2 mm	5 mm	10 mm	2 mm	5 mm	10 mm
25	8.93	12.60	11.02	9.26	12.60	9.94	7.68	10.63	10.01	8.08	9.44	10.34	9.76	11.70	11.58	10.69
50	21.37	23.08	22.79	20.38	29.50	20.93	20.65	21.77	20.97	19.87	21.52	23.33	20.89	20.34	22.33	17.77
75	32.78	31.57	28.29	32.14	29.76	30..96	28.7	31.47	31.61	30.42	33.71	30.22	34.16	29.07	28.82	26.91
100	62.71	44.31	43.65	42.40	46.67	46.13	39.5	46.62	39.67	37.89	45.29	46.89	42.28	44.38	41.30	37.68
125	80.63	83.55	84.93	89.18	92..59	92.67	81.63	79.61	84.82	83.94	86.34	85.67	82.99	70.11	75.39	88.59
150	93.41	97.66	98.70	96.46	95.41	99.03	96.11	95.76	97.67	95.09	94.38	96.93	94.83	93.28	93.51	94.08

Table 4. Influence of size of the contents (% of weights) and lengths (mm) of the kapron fibre entered with acidifying agent, on completeness of coagulation (% of weights) rubber SKS-30 ARК from latex at various charges of chloride of sodium

The charge of chloride of sodium, kg/t of rubber	The contents of a fibre, % of weights on rubber															
	0 %	0.1 %			0.3 %			0.5 %			0.7 %			1.0 %		
		2 mm	5 mm	10 mm	2 mm	5 mm	10 mm	2 mm	5 mm	10 mm	2 mm	5 mm	10 mm	2 mm	5 mm	10 mm
25	8.93	10.64	9.49	11.42	10.49	10.11	12.92	10.89	9.77	10.67	11.38	9.72	9.77	10.54	9.21	11.36
50	21.37	21.13	19.84	22.96	21.35	22.5	20.46	22.63	20.13	20.92	22.51	20.67	22.67	24.07	21.35	22.41
75	32.78	30.94	28.78	32.38	31.32	29.10	33.97	32.65	32.99	28.23	28.16	29.10	35.93	31.62	29.37	31.10
100	62.71	40.12	38.35	42.15	39.55	41.21	41.85	46.81	35.71	41.81	43.55	39.41	40.83	44.55	42.38	39.91
125	80.63	82.20	85.79	85.33	82.56	88.47	87.04	84.90	90.10	89.59	85.19	86.16	90.16	84.80	83.63	88.31
150	93.41	94.00	93.42	93.55	94.67	96.95	94.52	99.60	99.36	99.79	95.04	96.61	98.31	94.15	94.14	95.75

Influences of a Cotton, Viscose and Kapron Fibre on Properties of Rubber Mixes and Vulcanizates

In all experiments fibrous filler entered into latex simultaneously with acidifying agent at a finishing stage of process of coagulation. Research of properties of the allocated rubbers carried spent according to requirements of GOST 15627-79 on rubber SKS-30 ARK (tables 5-7). The received results compared to properties of standard samples - samples without fibres.

It agrees to the data given in table 5, introduction of a cotton fibre in polymer results in increase of disorder of a parameter of viscosity of rubber and a rubber mix, and also to growth of plasticity of a rubber mix.

Adsorption sewing (structure) rubber of agents (sulfur, accelerators, activators) on a surface of fibres results in reduction of a degree sewing vulcanizate. As a result of it there is a decrease of durability, a strain at 300 % lengthening and relative lengthening at break**.** At the contents of fibrous 0.7 % of weights increase the size of resistance of tear with 53 up to 56-61 kN/m and reduction of size of resistance to a repeated stretching is observed.

Growth of resistance to ageing (100^0C, 72 h) can be explained by end of process of vulcanization in result desorption to any part of sewing agents from a surface of fibres.

From the data given in table 6 it is visible, that presence of a viscose fibre results in insignificant decrease of viscosity as rubber with 55 up to 51 ÷ 53 units, and a rubber mix with 57 up to 55 ÷ 56 units. The minimal twisting moment with 4.8 (at a standard sample) up to 5.5 ÷ 6.5 H×m (table 8) is simultaneously increased. In a matrix of a rubber mix orientation of badly moistened fibres of viscose in a direction, perpendicular to a direction of the appendix of loading (calander effect) is not shown. It the increase rehabilitation samples with 1.4 up to 1 5÷1 8 mm speaks mainly at length of fibres of 5 mm and the contents of 0.7 % of weights. (table 6) and the reduction of creep of rubber mixes connected to it. Presence of additives of a fibre increases disorder of size of plasticity of a rubber mix within the limits of 0.31 ÷ 0.38 units (table 6).

For vulcanizates with a viscose fibre adsorption of a part of sewing agents on fibrous filler also takes place. Owing to pauperization of rubber by sulfur and accelerators the degree of lace vulcanizates decreases. In comparison with vulcanizates without fibrous filler it results to

- to increase of optimum time of vulcanization of composites with 27.5 (at a standard sample) up to 28 ÷ 30 minutes,
- to decrease of durability and a strain at 300 % lengthening,
- to increase relative lengthenings and residual deformation at break.

However the essential increase of sizes of resistance tear with 53 up to 71 ÷ 96 kN/m and resistance to a repeated stretching with 70 до72÷96 the thousand cycles (table 6), proportional to size of the contents and length of viscose fibres in composites is observed. It speaks display reinforcing effect of fibres, before revealed for vulcanizates, filled with fibres a stage mixing rubber [8].

Table 5. Properties of rubbers, rubber mixes and rubbers on basis SKS-30 ARK, filled with a cotton fibre of various length (mm) and with the various contents (% of weights)

The name of a parameter	Without a fibre	2 mm		5 mm		10 mm	
		0.3%	0.7%	0.3%	0.7%	0.3%	0.7%
Muni's viscosity MV 1+4 (100^0C):							
- rubber	55	57	56	52	56	52	55
- a rubber mix	57	58	57	56	57	55	58
Karrer's plasticity , r/m, conditional units	0.34	0.34	0.36	0.36	0.35	0.39	0.37
Capacity for restoration, mm	1.4	1.4	1.4	1.4	1.4	1.2	1.2
Conditional strain at 300 % lengthening, MPa	9.4	9.0	8.6	8.6	8.1	8.3	7.8
Conditional durability at a stretching, MPa	26.3	25.3	24.1	23.4	21.6	25.5	20.7
Relative lengthening at break, %	618	605	615	570	486	616	582
Relative residual deformation, %	12	14	12	10	10	14	12
Elasticity on recoil, %:							
- 20^0C	40	39	39	39	34	34	34
- 100^0C	53	52	55	54	57	52	60
Shore's hardness, conditional units	57	56	57	56	61	58	57
Resistance tear, kN/m	53	52	61	56	59	52	55
Resistance to a repeated stretching, thousand cycles	70	69	77	57	62	49	53
Factor of ageing (100^0C, 72 h):							
- on durability	0.44	0.51	0.48	0.53	0.51	0.46	0.60
- on relative lengthening	0.33	0.37	0.33	0.39	0.41	0.33	0.41

The note: temperature of vulcanization 143^0C; duration of 60 minutes.

Table 6. Properties of rubbers, rubber mixes and vulcanizates on basis SKS-30 ARК, filled with a viscose fibre of various length (mm) and with the various contents (% of weights)

The name of a parameter	Without a fibre	2 mm		5 mm		10 mm
		0.3%	0.7%	0.3%	0.7%	0.3%
Muni's viscosity MV 1+4 (100^0C):						
- rubber	55	53	53	53	52	51
- a rubber mix	57	55	56	55	56	55
Karrer's plasticity , r/m, conditional units	0.34	0.38	0.31	0.32	0.35	0.36
Capacity for restoration, mm	1.4	1.4	1.7	1.8	1.5	1.4
Conditional strain at 300 % lengthening, MPa	9.4	3.9	4.9	6.3	5.8	6.0
Conditional durability at a stretching, MPa	26.3	24.3	20.0	23.0	22.0	23.0
Relative lengthening at break, %	618	698	690	680	675	688
Relative residual deformation, %	12	18	18	16	14	14
Elasticity on recoil, %:						
- 20^0C	40	43	43	46	44	44
- 100^0C	53	49	50	53	50	51
Shore's hardness, conditional units	57	55	56	55	59	57
Resistance tear, kN/m	53	71	75	81	96	95
Resistance to a repeated stretching, thousand cycles	70	70	72	76	96	85
Factor of ageing (100^0C, 72 h):						
- on durability	0.44	0.63	0.77	0.53	0.56	0.60
- on relative lengthening	0.33	0.45	0.43	0.33	0.33	0.41

The note: temperature of vulcanization 143^0C; duration of 60 minutes.

Table 7. Properties of rubbers, rubber mixes and rubbers on basis SKS-30 ARK, filled with a kapron fibre of various length (mm) and with the various contents (% of weights)

The name of a parameter	Without a fibre	2 mm		5 mm		10 mm	
		0.3%	0.7%	0.3%	0.7%	0.3%	0.7%
Muni's viscosity MV 1+4 (100^0C): - rubber - a rubber mix	 55 57	 57 59	 56 58	 55 59	 57 58	 57 58	 58 60
Karrer's plasticity , r/m, conditional units Capacity for restoration, mm	0.34 1.4	0.33 1.3	0.34 1.2	0.33 1.4	0.36 1.2	0.34 1.3	0.34 1.3
Conditional strain at 300 % lengthening, MPa	9.4	5.6	7.1	6.1	6.6	5.9	6.0
Conditional durability at a stretching, MPa	26.3	29.0	23.0	23.1	23.0	23.0	20.5
Relative lengthening at break, %	618	680	610	670	640	670	650
Relative residual deformation, %	12	16	14	14	14	14	14
Elasticity on recoil, %: - 20^0C - 100^0C	 40 53	 38 50	 42 52	 40 52	 42 50	 40 50	 43 50
Shore's hardness, conditional units	57	57	57	54	55	56	57
Resistance tear, kN/m	53	89	90	81	85	66	73
Resistance to a repeated stretching, thousand cycles	70	78	82	93	73	76	78
Factor of ageing (100^0C, 72 h): - on durability - on relative lengthening	 0.44 0.33	 0.65 0.46	 0.67 0.40	 0.72 0.40	 0.69 0.41	 0.80 0.45	 0.96 0.54

The note: temperature of vulcanization 143^0C; duration of 60 minutes.

Table 8. Dependence vulcanizations of rubber mixes on the basis of rubber SKS-30 ARК filled with a viscose and kapron fibre

Parameter	Standard sample (without additives)	The size (mm) and quantity (% of weights on rubber) fibres										
		Viscose fibre					Kapron fibre					
		2 mm		5 mm		10 mm	2 mm		5 mm		10 mm	
		0.3 %	0.7 %	0.3 %	0.7 %	0.3 %	0.3 %	0.7 %	0.3 %	0.7 %	0.3 %	0.7 %
The minimal twisting moment, N × m	4.8	6.3	6.0	5.5	5,5	6.5	8.5	7.5	7.0	7.5	7.5	7.0
The maximal twisting moment, N × m	36.5	30	32	34	33	36	31	34	32	34	32	32
Time of the beginning of vulcanization, minutes.	3.5	5	4	4	5	4	5	5	4	5	4	5
Optimum time of vulcanization, minutes	27.5	30	29	28	29	29	21	20	21	19	15	21

Growth of resistance to ageing (100^0C, 72 h) can be explained with end of process of vulcanization as a result of gradual desorption to any part of sewing agents (sulfur, accelerators, activators) from a surface of these fibres.

Anisotropy elastic - durability properties vulcanizates with fibres results in growth of disorder of hardness, and also to reduction of elasticity on recoil at 100^0C with 53 (a sample of comparison) up to 49÷51 % for viscose and up to 50÷52 % for kapron (tables 6, 7).

From table 7 it is visible, that presence of a kapron fibre at quantity from 0.3 up to 0.7 % of weights. And length 2÷10 mm results in insignificant increase of Muny viscosity: - rubber with 55 up to 56 ÷ 58 units; and a rubber mix with 57 up to 58 ÷ 60 units**.** At introduction of a kapron fibre in comparison with a viscose fibre there is a significant growth of the minimal twisting moment with 4.8 (at a standard sample) up to 7.0 ÷ 8.5 (kapron) against 5.5-6.5 N·m (viscose) (table 8). It indirectly specifies the big compatibility of a matrix butadiene-styrene rubber with a surface of the kapron entered into rubber with acidifying agent at a finishing stage of process of coagulation in comparison with viscose.

Orientation in a matrix butadiene-styrene rubber (SKS-30 ARK) more compatible fibres of kapron in a direction, perpendicular to a direction of the appendix of loading (calander effect), speaks decrease rehabilitation a rubber mix with 1.4 (without a fibre) up to 1.2 ÷ 1.3 mm (with a fibre) (table 7). Presence of additives of a kapron fibre limits disorder of size of plasticity of a rubber mix within the limits of 0.33 ÷ 0.36 units.

Adsorption on a surface of a kapron fibre of a part of sewing agents, results in reduction of a degree сшивки vulcanizates, to reduction of durability and a pressure(voltage) at 300 % lengthening in comparison with vulcanizates without a fibre, to growth of relative residual deformation and lengthening at break. It is marked decrease(reductions) of optimum time of vulcanization with 27.5 (at a standard sample) up to 15 ÷ 21 mines because of presence fibrous filler the basic character (polymer with amide groups) with properties of the accelerator of vulcanization (table 8 [10]).

The essential increase (table 7) of resistance tear with 53 up to 66 ÷ 90 kN/m and resistance to a repeated stretching with 70 up to 73-93 thousand cycles speaks display reinforcing effect of kapron fibres long 5-10 mm, before revealed for vulcanizates, filled with fibres a stage mixing rubber [9].

Growth of resistance to ageing (100^0C, 72 h) speaks end of process of vulcanization in result desorption parts of sewing agents from a surface of fibres.

Studying Kinetics Swelling Vulcanizates, Filled with Fibres

The important parameter for an estimation of properties of received composites is presence or absence of interphase interaction of a matrix of rubber (vulcanizate) with a surface fibrous filler (viscose or kapron), allocation of rubber entered at a stage from latex.

With the purpose of an estimation of display of interphase interaction of additives of a fibre with a matrix of rubber investigated kinetic swelling filled vulcanizates on a basis butadiene-styrene rubber in solvents of various polarity. Interphase interactions estimated on size of an equilibrium degree of swelling (α_{max}) and a constant of speed of swelling (k, h^{-1}) of samples vulcanizates, containing viscose or kapron filler. Used solvents n-oktan, toluene,

Table 9. Influence solvents, sizes and quantity of addition viscose fibre and kapron fibre of an equilibrium degree of swelling (α_{max} , % of weights) of vulcanizates and a constant of speed of swelling (k, h^{-1}) of samples vulcanizates on basis SKS-30 ARK

Size / quantity fibres in rubber, mm / % of weights	Viscose fibre						Kapron fibre					
	n-octane		toluene		chloroform		n-octane		toluene		chloroform	
	α_{max}	k	α_{max}	k	α_{max}	k	α_{max}	k	α_{max}	k	α_{max}	k
2 / 0.3	168	-0.93	360	-1.43	675	-1.07	140	-1.38	272	-1.73	550	-1.38
5 / 0.3	162	-0.93	316	-1.43	600	-1.07	142	-0.97	276	-1.73	525	-1.38
10 / 0.3	145	-0.93	294	-1.43	582	-1.43	134	-1.19	252	-1.20	520	-1.66
2 / 0.7	150	-1.19	302	-1.33	590	-1.33	128	-1.73	270	-1.73	540	-2.14
5 / 0.7	154	-1.19	312	-1.33	614	-1.43	120	-1.43	243	-0.84	514	-2.25
10 / 0.7	-	-	-	-	-	-	122	-1.54	262	-0.93	524	-1.96

chloroform (table 9) have parameter of solubility (ρ) accordingly 15.4 ÷18.2 and 18.8 (mJ) 0.5 × ($m^{-1.5}$) [9].

Viscose Fibre

Irrespective of a nature of solvent of unequivocal dependence of influence of the sizes and size of the contents of a viscose fibre in an interval from 0.3 up to 0.7 % of weights. On size α_{max} for vulcanizates it is not revealed.

With increase of polarity of solvents in a number(line) oktan < toluene < chloroform irrespective of the contents of a viscose fibre is established growth of sizes (α_{max}) for these solvents accordingly in intervals 145 ÷ 168, 294 ÷ 360 and 582 ÷ 675 % of weights. The greatest sizes (α_{max}), received in chloroform for vulcanizate with viscose filler, specify increase of polarity vulcanizate, containing viscose, and also on approach (approximation) of size of its average parameter of solubility $\rho_{vulc/viscose}$ to parameter of solubility of chloroform ρ_{ch} = 18.8, in comparison with size $\rho_{кrubber}$ = 17.4 $(mJ)^{0.5} \cdot (m^{-1.5})$ for initial unfilled and nonvulcanized rubber SKS-30 ARK [10]. The reason of it is presence of more polar viscose fibre ($\rho_{viscose}$ = 31.9 $(mJ)^{0.5} \cdot (m^{-1.5})$ in a matrix vulcanizate and occurrences additional vulcanization grids [11].

Apparent driving force - size α_{max} did not render influence on speed of swelling filled vulcanizate.

Distinction in thermodynamic compatibility of various solvents and filled with a viscose fibre vulcanizate was defined with speed of swelling of the last. For system « vulcanizate - octan » with the greater size of a square of a difference of parameters of solubility $\beta = (\rho_{rubber} - \rho_{octan})^2$= 4 (mJ) · ($m^{-3}$) [9,10] smaller speed of swelling (k = 0.93 – 1.19 h^{-1}) is revealed. For system « vulcanizate - toluene » (or « vulcanizate - chloroform ») with smaller sizes β = 0.64 (или 1.96) (mJ) · (m^{-3}) speeds of swelling k were more: k = 1.33-1.43 (or 1.07 – 1.43 h^{-1}) accordingly.

The size β defined kinetic swelling vulcanizates in various solvents. For system « vulcanizate - chloroform » influence of the contents of a viscose fibre and the size of a fibre for speed of swelling is revealed. So doubling of the contents of a fibre with 0.3 up to 0.7 % of weights. In the length 2 and 5 mm has resulted in increase of size k with 1.07 up to 1.33-1.43 h^{-1}.

Thus, for viscose fibres of essential influence of their size and the contents in vulcanizate for speed of swelling in n-octane and toluene it is not established. Apparently, the reason was weak interphase interaction of a matrix of rubber with fibres, presence of boundary layers because of the big distinctions in ρ_{rubber} and $\rho_{viscose}$, for which $\beta = (\rho_{rubber} - \rho_{viscose})^2$ = 210 (mJ) · (m^{-3}).

Kapron Fibre

For vulcanizates with a kapron fibre, irrespective of the contents in them fibres, with increase of polarity of solvents in a line octan < toluene < chloroform is established growth of size α_{max} accordingly, in intervals 120 ÷ 140, 243 ÷ 276 and 514 ÷ 550 % of weights. The greatest size α_{max}, received in chloroform, specifies increase of polarity vulcanizate and on approach of his parameter of solubility $\rho_{vulc/kapron}$ to size ρ_{ch} = 18.8 $(mJ)^{0.5} \cdot (m^{-1.5})$ in comparison with size r for initial unfilled and nonvulcanized rubber. The reason of it is presence of additives of a polar fibre at a matrix vulcanizate, for which size $\rho_{ПА} = 27.8\ (mJ)^{0.5} \cdot (m^{-1.5})$ [11].

Apparent driving force size α_{max} did not render influence on speed of swelling filled with a kapron fibre vulcanizate.

Distinction in thermodynamic compatibility of solvents and filled with a kapron fibre vulcanizate was defined with its speed of swelling. For system « vulcanizate -octan » with the greater size $\beta = (\rho_{rubber} - \rho_{octan})^2 = 4\ (mJ) \cdot (m^{-3})$ the interval of speed of swelling k = 0.97 – 1.54 h^{-1} is characteristic. For system « vulcanizate - toluene » with smaller size $\beta = 0.64\ (mJ) \cdot (m^{-3})$ the interval of sizes of speed of swelling k has extended (k = 0.84 – 1.73 h^{-1}). For system «vulcanizate - chloroform » with $\beta = 1.96\ (mJ)\cdot(m^{-3})$ depending on size of the contents of a kapron fibre the interval of speed of swelling was displaced up to sizes k = 1.38 – 2.25 h^{-1}. So doubling of the contents of a fibre with 0.3 up to 0.7 % of weights, size 2 and 5 mm, has resulted in increase of size k with 1.38-1.66 up to 2.14-2.25 h^{-1}. Such increase of speed of swelling in chloroform with growth of the contents of a kapron fibre, apparently, speaks the big interphase interaction of a matrix of rubber with filler because of smaller distinctions $\rho_{rubber} = 17.4$ и $\rho_{kapron} = 27.8\ (mJ)^{0.5} \cdot (m^{-1.5})$, for which $\beta = (\rho_{rubber} - \rho_{kapron})^2 = 108\ (mJ) \cdot (m^{-3})$, owing to the high contribution of hydrogen connections at the presence of chloroform [9].

On the contrary, for the toluene which is not forming hydrogen connections**,** decrease of a constant of speed of swelling k is revealed at increase of the contents of fibres of kapron as a result of display of barrier properties by the boundary layers having high polarity.

CONCLUSIONS

1. The new technological direction for the successful decision of an environmental problem - problems of recycling of waste products of the fibres, consisting in preliminary mixture of a fibre with acidifying agent before submission of latex on a finishing stage of his coagulation is offered.
2. Scientific bases of the offered approach providing reception of rubbers filled with fibres at a stage of manufacture emulsion of rubber are incorporated.
3. The expediency of the offered approach is experimentally shown:

- the offered approach allows to achieve uniform distribution of a fibre in volume of rubber that is positively reflected in separate properties received vulcanizates;
- the optimum length of a cotton, viscose and kapron fibre makes 2-5 mm, at its contents in rubber in limits from 0.3 up to 0.7 % of weights.;
- introduction of a cotton fibre does not worsen property vulcanizates, and introduction of a viscose and kapron fibre allows to increase such parameters vulcanizates, as stability to thermal ageing, repeated deformations, resistance tear without deterioration of other operational characteristics;
- influence of additives of a kapron fibre differs from influence of additives of cotton and viscose fibres on properties of rubber SKS-30 ARК and rubber mixes because of distinction of a nature of fibres;

- distinction of interphase interaction between a surface of a viscose and kapron fibre and a matrix vulcanizates butadiene-styrene the rubber, reflected for speed of swelling vulcanizate in solvents of a different nature.

4. Deviations реологических, vulcanization properties and physicomechanical parameters vulcanizates are explained at the presence of additives of a viscose and kapron fibre.

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Perspectivity of recycling of waste products of fibrous materials as reception of elastic composite materials is shown by creation of a composition a fibre - latex with the subsequent coagulation and vulcanization of the filled rubber.

Process of allocation butadiene-styrene rubber from latex SKS-30 ARK with use in quality filler a cotton, viscose and kapron fibre is considered. Influence of the contents and lengths of a fibre is established at various charges coagulant on completeness of allocation of rubber from latex. The optimum contents of a fibre and his length is determined.

Influence of a cotton, viscose and kapron fibre on properties of received rubbers, rubber mixes and vulcanizates is investigated.

Perspectivity of the offered approach for recycling fibres is shown.

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Chapter 23

INTENSIFICATION OF PROCESS OF GAS CLEANING IN THE DEVICE WITH COMBINED SEPARATION STEPS

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ABSTRACT

The design of the new device for wet clearing gas is offered. The device contains combined separation the steps executed on a basis vane swirler, set in motion by a rotating rotor. The combination of such elements of a design allows to intensify processes of an interphase exchange and to raise efficiency of clearing of gas.

Results of industrial tests of the device have shown his high efficiency and reliability in operation.

Keywords: gas cleaning, combined separation, vane swirler, rotor, steps.

In the chemical industry devices on a basis vane swirler are one of perspective in engineering of separation water gas systems [1] and are widely used in manufacture at realization of processes wet dust separation [2].

Separators with axial, cylindrical and conic swirler [3] are most distributed.

One of perspective directions of perfection of separators on a basis vane swirler is development combined vorticitys formed various swirler [4]. The basic advantage of such devices in comparison with vane swirler is, that in them various mechanisms of separation

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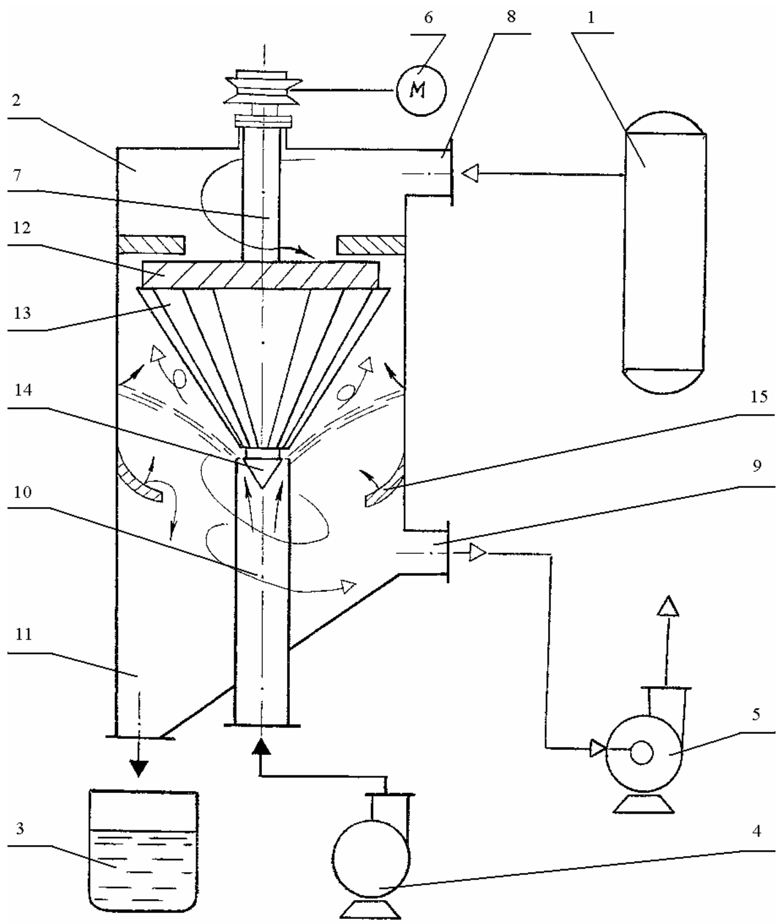
that allows to combine in one device of advantage, for example, centrifugal and inertial separators are simultaneously realized.

Devices with combined separation steps can work in a counterflow mode. It interferes забиванию blocking channels slime at work in conditions of sticking of a dust, that considerably expands their scope [5].

For clearing smoke gases of furnaces of roasting of limestone was applied gas washer with combined separation steps. The technological diagram of clearing of gases is submitted in figure 1.



1 - a furnace of roasting; 2 – gas washer; 3 - the filter a slime pond; 4 - the pump; 5 - the fan; 6 - the electric motor; 7 - a rotor; 8,9 - branch pipes of input-output of gas; 10,11 - branch pipes input -output of irrigating liquid; 12 - cylindrical swirler; 13 - conic swirler; 14 - dissector; 15 – entrainment separator.

Figure 1. The Technological diagram of clearing of smoke gases of the furnace of roasting.

Departing from the furnace of roasting 1 gases at temperature 550ºC feed in gas washer 2 on a tangential branch pipe 8. On an axial branch pipe 10 in the device the solution of limy milk (PH=11,5-12,5) moves on an irrigation.

Installation conic dissector 14 promotes formation of flat radial jets of irrigating liquid which, being reflected from the case of the device, create a high-intensity surface of contact of phases. In gas washer 2 as the first step it is used cylindrical swirler 12, as the second step - conic swirler 13. Swirler are fixed on a rotor 7 which is resulted in rotation by the electric motor 6.

Gas twists in space between swirler 12 and 13 and in a direction twist acts on the blade conic swirler 13 where there is his irrigation and final clearing.

The centrifugal forces arising at rotation of a rotor 7, provide intensive crushing water gas a stream that results in updating a surface of contact of phases and an intensification of processes of an interphase exchange.

Separated slime from the bottom zone of the device flows down on a branch pipe 11 in the filter - a slim pond 3 where there is a cooling and clarification of limy milk then it again moves the pump 4 on washing of acting gas in a branch pipe 10, forming a circulating contour.

The cooled and cleared gas on a branch pipe 9 with the help of the fan 5 is thrown out in an atmosphere.

Industrial tests were carried spent with the following initial data: a degree of a dust content of a gas stream (5÷50) $\cdot 10^{-3}$ kg / m^3, speed of a gas stream in the device 15-20 м/с, density of particles 1000÷2000 kg / m^3, temperature of gas on an input in the device 550 ° With.

As have shown results of researches, gas was cooled up to 62°C, ablation of caught particles did not exceed 0,5 %, the dust content of a gas stream was reduced up to (0,05÷0,2) 10^{-3} kg / m^3. The degree of clearing of gas made 98±1 %

CONCLUSIONS

1. In the device with combined separation steps due to action of centrifugal forces, intensive hashing of gas and a liquid and presence of the big interphase surface of contact, occur effective clearing of gas in a foamy layer.
2. Industrial tests gas washer have shown his high technological efficiency and reliability in operation. The developed device can be used at designing new and reconstruction of the operative equipment for gas cleaning.

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Offered approach for recycling fibres is shown.

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Chapter 24

RESEARCH OF CRITICAL MODES OF OPERATION OF A SEPARATOR WITH SWIRLER VARIOUS CONSTRUCTION

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ABSTRACT

Experimental researches of separators with swirler various construction are carried spent. Critical modes of their work are investigated, the comparative analysis of size of ablation of a firm phase from researched devices is given.

The major factors influencing for effective work of separators are revealed.

Keywords: separators, swirler, construction, analysis, size of ablation, critical modes.

Now an actual problem, as is known, is clearing of gases of the weighed firm particles and a drop liquid. The variety of the requirements showed to quality of clearing, and also conditions of realization of process, has caused creation of set of designs of separators which principle of work is based on use of various forces (centrifugal, inertial etc.) due to what there is a branch of suspensions from a gas phase.

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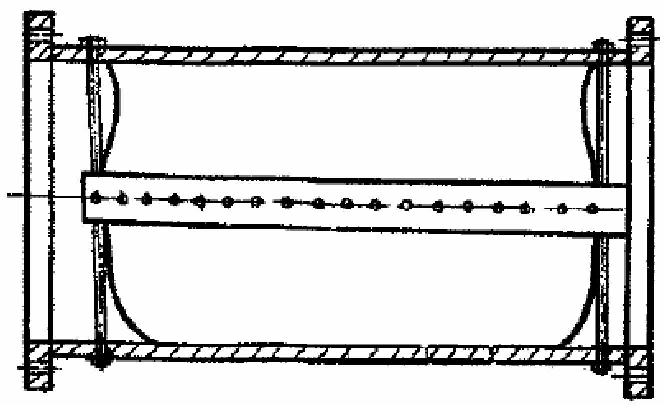
Practice of operation shows, that the most effective and, hence, designs are perspective, the branch of a suspension in which is carried out in a field of centrifugal forces. To such designs it is possible to attribute direct-flow, and counterflow cyclones, vortical devices, rotor separators.[1]

The expediency of use of this or that type of a separator is determined both a required degree of clearing, and technical and economic calculation. So, cyclones with turn of a gas stream have the high hydraulic resistance and a small range of change of gas loadings at which high efficiency of division of phases [2] is observed. In rotor separators the drive is necessary for rotation of a rotor that complicates a design and narrows area of their possible application [3].

On the skilled installation developed by us comparative experimental researches of some designs of the separators were carried spent, allowing to provide highly effective branch of gas from firm particles in a wide range of change of charges of a gas mix at rather small hydraulic resistance.

For clearing a gas mix of firm particles horizontal devices were developed and investigated: the bubbler-vortical device with an axial sprinkler [4]. *(figure 1, a);* the bubbler-vortical device with screw swirler *[5] (figure 1, в);* bubbler-vortical gas washer [6] *(figure 1, c).*



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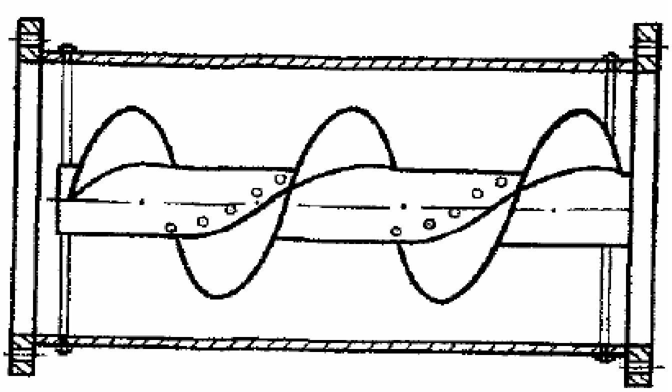

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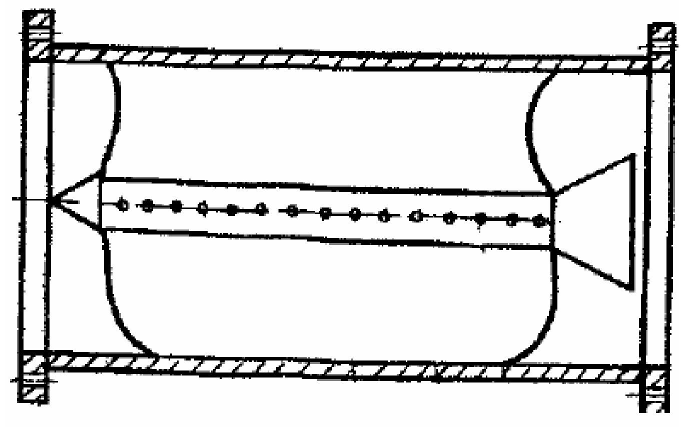
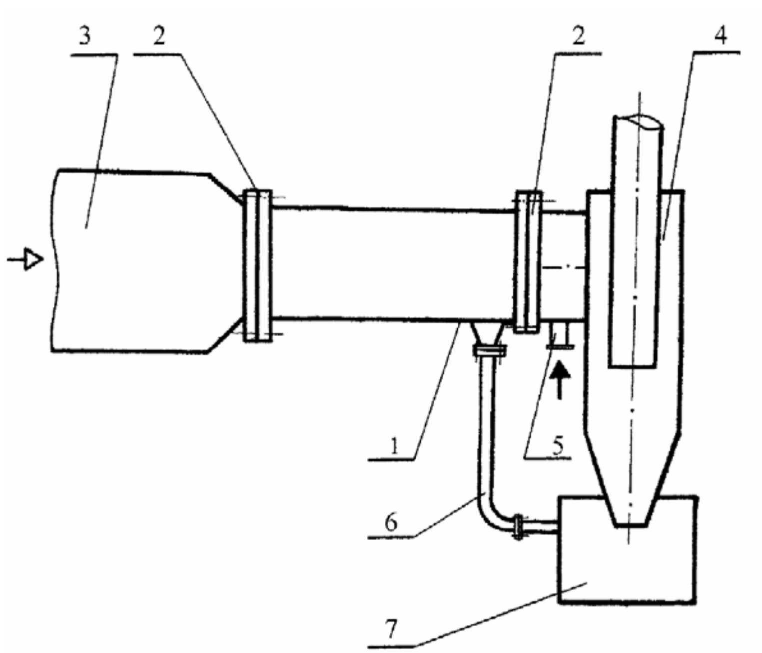


c

a-vane swirler with an axial sprinkler;
в- screw-swirler;
c-vane swirler with conic fairing.

Figure 1. Cylindrical chamber with swirler various construction.

The principle of work of devices is based on use of the centrifugal forces arising about installation static vane or screw swirler. Devices are executed as the cylindrical chamber with swirler variousconstruction. The circuit of skilled installation is submitted in *figure 2.*



The 1-cylindrical chamber; 2-flanges; 3-pipe of input of gas; 4-cyclone; 5-input of irrigating liquid; 6-pipe of a drain slime; 7-slimecollector.

Figure 2. Circuit of experimental installation.

The cylindrical chamber 1 is mounted with the help of flanges 2 in gas duct, connecting a pipe of input of gas 3 with a wet cyclone 4. The liquid on an irrigation moves in the device on a pipe 5.

Separated slime it is washed off by a liquid and by means of an inclination of the cylindrical chamber 1 it is transported on a pipe discharge slime 6 in slimecollector 7. The subsequent division of suspension occurs in a cyclone 4.

Experiences carried spent at atmospheric pressure upon system an air - firm body. As firm impurity used a powder of talc, sand, table salt. Thus fractions of a dust of various dispersiveness prepared a method of sifting on ситах with cells in the size 80-120, 120-160, 200-300 microns. The sizes of particles determined with the help of a microscope. The firm phase moved in a pipe on an input in the device. The degree of a dust content changed within the limits of $(5-50) \bullet 10^{-3}$ kg / m^3, speed of a gas stream in the device ϑ=1,2÷4,5 m/s. For catching firm particles carried away from the device the fabric filter was used.

Ablation expected under the formula

$$e=100-\eta,$$

Where η - a degree of catching, %

$$\eta = \frac{G_2}{G_1} \cdot 100\%,$$

Where G^{-1} quantity of a dust included in the device, kg;

G^{-2} Quantity of the caught dust, kg.

As have shown results of researches, ablation of a dust for the device (figure 1, a) is higher, than at others. Especially appreciable increase of ablation is observed for devices with vane swirler at speeds of gas, big 4 m/s.

The sharp increase of ablation also occurs at diameter of particles d < 80 microns. At d > 80 microns ablation practically remains a constant which is not exceeding 2 % at speeds of gas in the device within the limits of 1,5÷3,0 m/s. It is established also, that the more hardly a particle, the there is their branch more effectively.

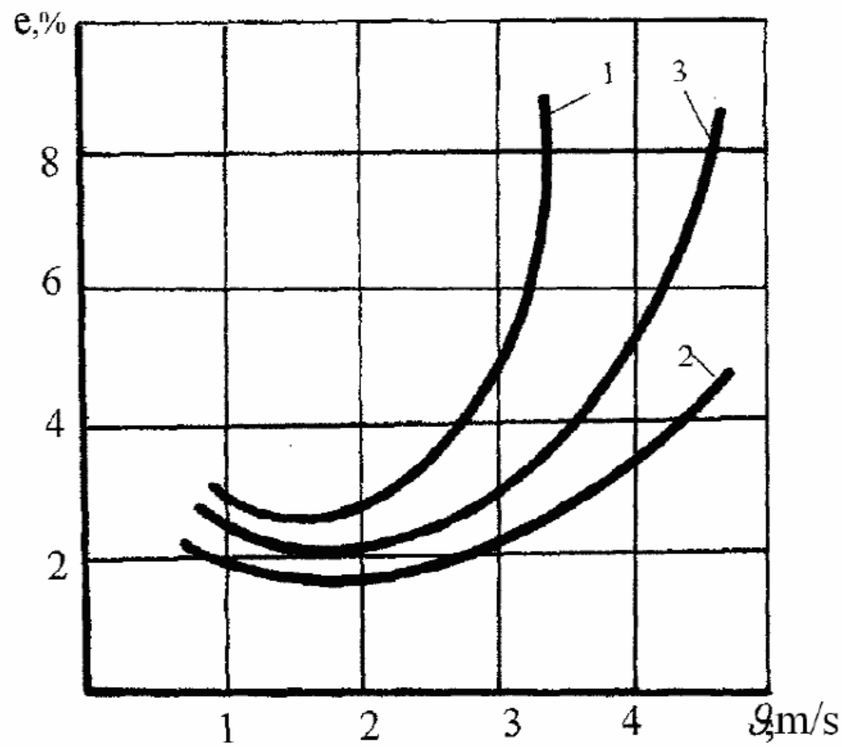
For the device (figure 1, в) the size of ablation is insignificant, however occurs blocking screw channels screw products of clearing that limits use such swirler at work in conditions sediment environments. The diagram of influence of speed of gas in the device on ablation of a dust is submitted on *figure 3.*

In parallel with measurement of quantity of a firm phase carried away from the device determined hydraulic resistance of devices and expected factor hydraulic resistance ξ on speed of gas in the device.

The following results for devices with various swirler are received:

figure 1, a ξ=31,12; figure 1, b ξ=83,71; figure 1, e ξ=22,25.

It was established, that besides influence of speed of gas and the size of particles, occurrence of ablation is influenced significally with a field of centrifugal forces. So, with growth of a tangent of a corner of an inclination of a screw line шнека tg α influence of centrifugal forces decreases, and the increasing influence on size of ablation renders Re_g and, at tg α > 0,74 account characteristics of a liquid phase, and also centrifugal forces already have a little an effect for occurrence of ablation. And, on the contrary, at tg α < 0,3 prevailing influence on process rendered Re_e and centrifugal forces.



1- for swirler fig. 1, a;
2- for swirler fig. 1, в;
3- for swirler fig. 1, c.

Figure 3. Influence of speed of gas in the device on ablation of a dust.

Conclusions

Thus, the carried spent complex of experimental researches has allowed to reveal the major factors influencing for effective work of separators.

Results of researches were used at calculation and designing of the devices found practical application for branch of weighed impurity from a gas stream.

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