A STUDY OF THE FLOCCULS STRENGTH OF POLYDISPERSE COAL SUSPENSIONS TO MECHANICAL INFLUENCES

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Abstract

The effect of the concentration and disperse composition on the flocculation strength to mechanical influence is investigated. It is found that the residual rate of floccules sedimentation after the mechanical influence at a constant rate of flocculant has a maximum value at a concentration of solids in the slime in the range of 7–30 g/dm^3. The best results are obtained in all the experiments at a solids concentration of 10 g/l. It is found that at a concentration up to 7 g/l and more than 30 g/l, the floccules is formed. They have the lowest residual rate after mechanical influences. With increasing content of the solid fraction of 40–100 microns over 15 %, the strength of floccules increases. They retain their shape and relatively high sedimentation rate even after mechanical influence. The obtained data allow to recommend correction of the slime composition before flocculant injection both the concentration close to the optimum, and the content of size fraction of 40–100 mm more than 15 %.

Keywords: flocculation, polydisperse slime, floccules destruction, floccules strength, residual sedimentation rate.

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1. Introduction

Coal slime is formed during coal mining and processing. It is a fine product with high ash content. The solid phase of slime of coal preparation plants is often a valuable mineral raw materials, and the liquid phase should be used in a closed system of water recycling. Local cleaning system of chemically contaminated waste water in order have been developed and implemented in modern coal preparation plants to create closed water and slime system [1]. An efficiency of enrichment operations and reduce of water losses for a plant depend on the quality of suspension separation in the thickener. Therefore, a closed cycle, used in coal preparation, presents particular requirements to the quality of solid-liquid separation in the thickener. In modern conditions one of the pressing problems in the practice of coal preparation is to improve the technics and technology of dewatering of coal polydisperse suspensions of small classes (fine silt, slime, flotation concentrate and others classes with a particle size 0–0.5 mm), formed at the preparation plants [2].

Intensification of clarification processes of the liquid phase due to the use of polymer flocculants is carried out at all stages of slime thickening and dewatering [3]. As a result of the destruction of already formed floccules during slime transportation from thickening to dewatering equipment in modern water and slime schemes reflocculation is carried out before each apparatus. Therefore, an important aspect of improving the economic performance of thickening process is to reduce the consumption of expensive flocculant used for intensification of water clarification process. This leads to the need to establish optimal conditions for flocculation that provide a strong enough aggregates that do not require reflocculation after transportation.

Flocculation efficiency for coal slime depends on many factors that affect the formation of aggregates. To clean coal slime containing fine mineral impurities of clay particles nonionogenic [4], ionigenic (cationogenic and anionogenic) flocculants [5], their combination with each other [6] with coagulants [3] or mineral salts [7] are used. General recommendations for the use of flocculants are reduced to the selection of the type and concentration of flocculant for purification of a particular type of slime with a certain concentration and disperse composition. At the same time still insufficiently studied issues such as the impact of concentration and dispersion composition on the structure of polydisperse slime floccules. It is poorly understood changes of the floccules after mechanical influence, their strength characteristics and strength retention mechanism. According to the theory, destruction of the floccules occurs when the shear stress of the order of 1–10 Pa, with the strength of aggregates increased with increasing dose of flocculant [8]. It is found that slime of coal flotation concentrate without the use of flocculants according to the nature of the flow are near Newtonian liquids, and nucleation does not occur in the slime [9]. Suspension becomes pseudoplastic properties when a flocculant supply [10, 11], and the general guidelines for reduce destruction of the floccules are reduced to reduce the shear deformation [12].

Research results that are described in [13] showed that the sedimentation rate of the floccules at the same flow rate of the flocculant has the highest value at the solids concentration in the slime below 30 g/dm^3. Criterion for evaluating formation of solid aggregates has been proposed, which may be a residual flocculation sedimentation rate after mechanical influence, characterizing the size and structure of the aggregates. These data require further experimental verification of the strength of aggregates that formed at lower concentrations.

Thus, despite considerable study of coal slime flocculation, structure and strength characteristics of the floccules of polydisperse suspensions are enough studied. Knowledge of the laws of the formation of strong aggregates, depending on the concentration and disperse composition of suspension will optimize the flocculation process, as well as to predict the possibility of their transportation, ensuring minimal degradation of the floccules.

2. Materials and Methods

Research of polydisperse slime flocculation is carried out using model slimes with controlled parameters of concentration and disperse phase, which are synthesized as follows. Real slime, taken on one of the existing coal preparation plants, passed through a sieve with a size of 40, 60, 80 and 100 microns and coarse fractions were separated. Slime less than 40 microns fraction was thickened by settling and then diluted by clarified liquid to a concentration of 3 to 100 g/dm^3 required to examine the effect of solids concentration on the flocculation process.

For the subsequent series of experiments to study the effect of disperse slime composition was synthesized with solids content from 3 to 100 g/dm^3 and adding medium-sized particles of 40–100 microns in an amount from 5 to 30 %.

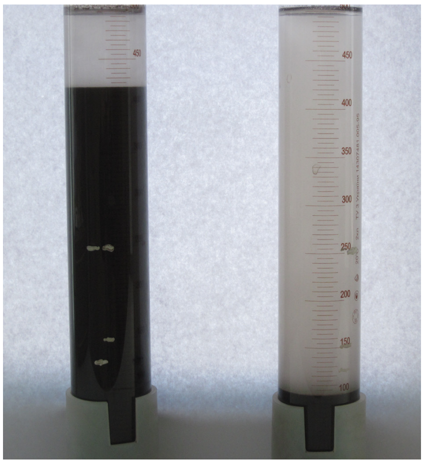
The fraction more than 100 microns was not of interest for further research, because such particles are efficiently sedimented without the use of flocculants. The density of the solid phase of the slime was 1.7 kg/dm^3.

Measurement of flocculants sedimentation kinetics in the mode of free (unconstrained) sedimentation was conducted in a laboratory graduated cylinder of 50 mm diameter and 500 mm height.

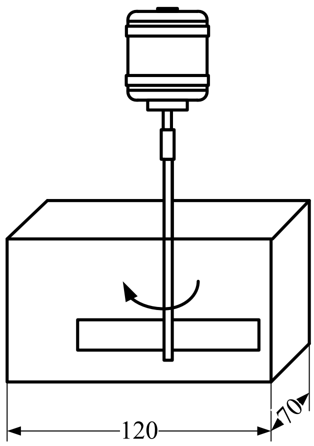
Flocculant type and concentration were selected before experiment. Combination of nonionogenic production (20 % of total amount) and anionogenic (80 % of the total amount) of flocculants were used for this slime. Dosage amounts of flocculant before each experiment recalculated so that the flocculant consumption per weight unit of the solid phase was constant at 200 g/t. This flow provides effective formation of the floccules and flow consistency excludes the effect of flocculant dose of the strength of the floccules at various concentrations of solids in the slime.

3. Experimental procedures

To assess the strength of the floccules to mechanical influences we used the following technological test. In the measuring cylinder (**Fig. 1, *a***) with slime of certain solids concentration slime (from 3 to 100 g/l) and size distribution (from 0 to 30 % of fraction content of 40–100 microns) nonionogenic flocculant was added in an amount of 40 g/t. Anionogenic flocculant after stirring was injected in an amount of 160 g/m by cylinder tilting and was stirred again. After formation of the floccules and their sedimentation, flocculed slime was stirred with a stirrer with a speed at the blade tip about 2 m/s for 40 seconds in a rectangular container 120×70 mm (**Fig. 1, *b***). In our opinion, such mechanical effect simulates the movement of flocculed slime through a pipeline from thickening apparatus to dehydration apparatus. The residual rate of sedimentation after a mechanical influence characterizes the size of the aggregates and, thus, the flocculation strength to mechanical influence.



a



b

Fig. 1. Laboratory equipment for the experiments: *a* – measuring cylinders for investigation of the slime sedimentation rate; *b* – rectangular container with a stirrer for mechanical impact on the floccules

Then the content was poured into a measuring cylinder and determined the sedimentation rate of suspended particles in the sample after mechanical impact. The sedimentation rate of the floccules was calculated using the following formula:

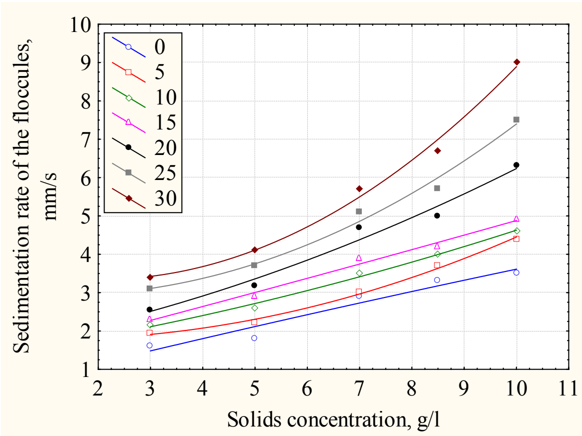
$$V = \frac{0,4H}{t_i}, \quad (1)$$

where H – height of the clarified layer, mm; t_i – free sedimentation time of the floccules (0.4 of the height), s.

Flocculed sediments were sampled after mechanical influence. These samples were studied under the microscope.

4. Results

The study revealed that for the same flocculant concentration residual sedimentation rate of the floccules after mechanical influence depends on the initial concentration and composition of disperse composition of the slime (**Fig. 2**). In the solids concentration range of 3–10 g/l (**Fig. 2, *a***) in all cases of the content of medium-sized class (more than 40 micron) there is an exponential increase of the rate with increasing concentration, with a maximum content at 10 g/l. In the concentration range of 10–50 g/l (**Fig. 2, *b***) in all cases of the content of medium-sized class there is a decrease of residual flocculation rate, having a character close to the line. In the concentration range of 50–100 g/l (**Fig. 2, *c***) in all cases of the content of medium-sized class there is a sharp exponential decrease of the rate.



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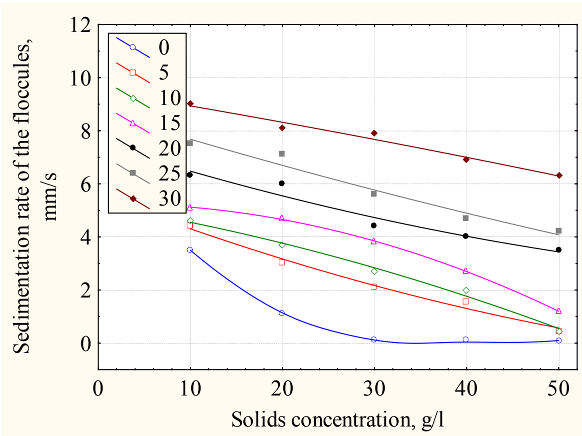

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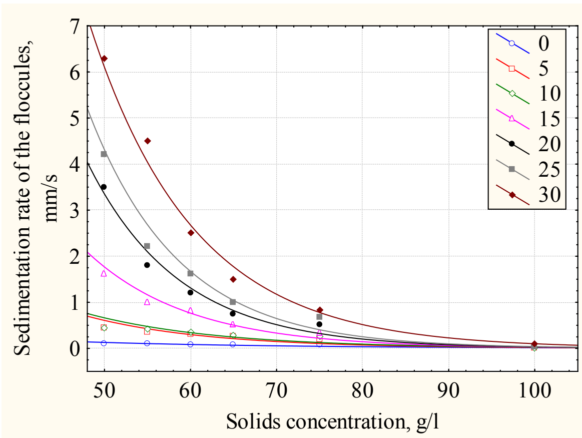

c

Fig. 2. Dependence of sedimentation rate of the floccules undergoing mechanical influence on the concentration (*a* – 3–10 g/l, *b* – 10–50 g/l, *c* – 50–100 g/l) and disperse composition of solids in the slime: the points on the chart – the results of laboratory tests; the lines on the chart – the smoothed line of scatter of experimental values; refer on the lines – the proportion of solids more than 40 micron, %

Investigation of the effect of the disperse composition on the sedimentation rate of the floccules after mechanical influence shown (**Fig. 3**) that with increasing content of the medium-sized class (40–100 microns) the sedimentation rate at all concentrations increases. This is the result of increasing the strength of floccules. Sedimentation rate is reduced with increasing concentration of the solids in the slime and at a concentration more than 50 g/l it is a minimal. At concentrations 75 and 100 g/l sedimentation rate of the slime after mechanical influence is virtually constant, indicating the almost complete destruction of the formed aggregates of the floccules.

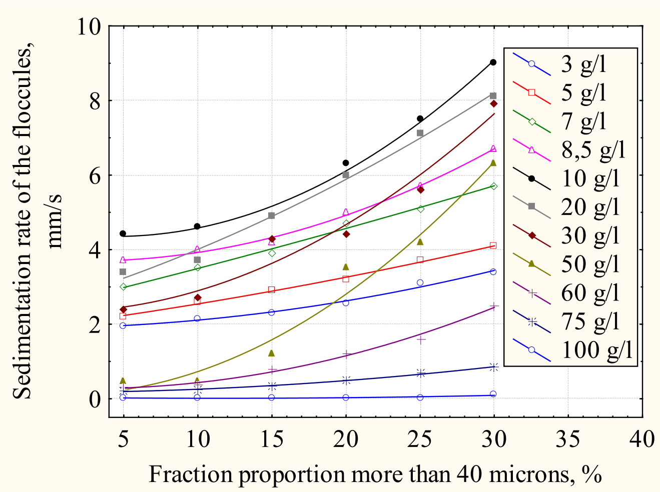

Fig. 3. Dependence of sedimentation rate of the floccules undergoing mechanical influence at different concentrations on the content of fraction proportion of 40–100 microns of the solids in the slime

For content of fraction proportion of 40–100 microns up to 15 % there is a slight increase of the residual rate, and more than 15 % – an increase of the rate becomes significant, particularly in the concentration range of solids in the slime of 7–30 g/l (more than 1 mm/s for every 5 %).

5. Discussion

Research results, presented in **Fig. 2, 3**, show that the concentration and disperse composition of the slime have a significant impact on preserving the strength of floccules to mechanical influences. It is interesting that at low concentrations of solids (up to 7 g/l, **Fig. 2, *a***) and high (more than 50 g/l, **Fig. 2, *c***) there is formation of floccules unstable to mechanical influences. Mechanical influences lead to the destruction of the floccules and a sharp reduction of the residual sedimentation rate. This is confirmed by photos of the floccules shown in **Fig. 4**. At a concentration close to 10 g/l (**Fig. 4, *c***) after mechanical influence floccules are stored with clear contours at a low (**Fig. 4, *a, b***) and high (**Fig. 4, *d, e, f***) concentrations aggregates are visible. They are divided into microfloccules.

Analyzing the obtained data, we can recommend to conduct the slime flocculation at a concentration of the solids close to 10 g/l (the optimal concentration) or in the concentration range of 7–30 g/l (conditions close to optimal). The most resistant to mechanical stress floccules are formed in these concentrations. They retain a sufficiently high sedimentation rate.

Growth of the coarse particles content in the slime (fractions more than 40 microns) leads to the formation of more stable flocculation structures under all concentrations. Moreover, for slimes at a concentration of solids in the range of 7–30 g/l (upper curves in **Fig. 3**) fraction share growth more than 40 microns has significant influence, when a for low (less than 7 g/l) and high (more than 30 g/l) solids concentration there is a slight increase of the residual rate. Floccules hardening increases significantly (by a residual rate) at a fraction proportion of 40–100 microns in the slime more than 15 %. This is clearly seen in the photos of the floccules and presented in **Fig. 5**. Sufficiently coarse floccules are formed with a clear outline and transparent liquid phase at a fraction proportion of 40–100 microns in the slime more than 15 % (**Fig. 5, *d, e, f***), then with the less content of medium-sized particles (**Fig. 5, *a, b, c***).

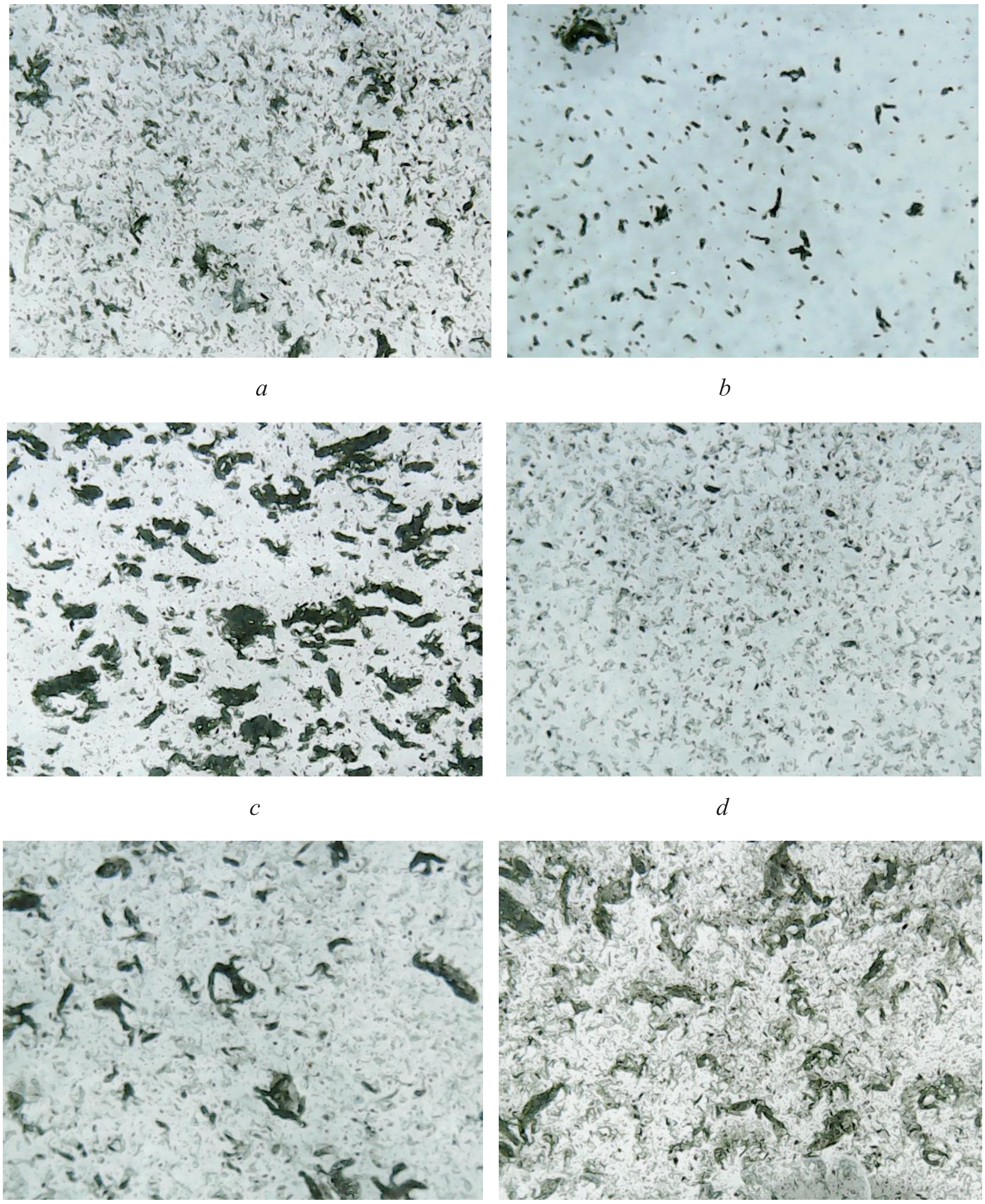

Fig. 4. Photos of the floccules after mechanical influence at solids concentrations in finely divided (less than 40 microns) slime, g/l: *a* – 3, *b* – 5, *c* – 8.5, *d* – 50, *e* – 75, *f* – 100

An ability of the slime correction has a practical interest to achieve the most favorable conditions for the formation of strong aggregates of the floccules. For example, by dilution or thickening of the slime it can adjust the solids concentration in the range of the best values (7–30 g/l). The second way of the intensification of strong aggregates formation can be adding of coarse slime particles more than 40 microns. Compliance with the optimum ratio of the concentration and disperse composition of the slime at the stage of aggregate formation (slime flocculation) provides to obtain fairly strong floccules that are resistant to mechanical influences, and to minimize the destruction of the floccules during transportation and dehydration.

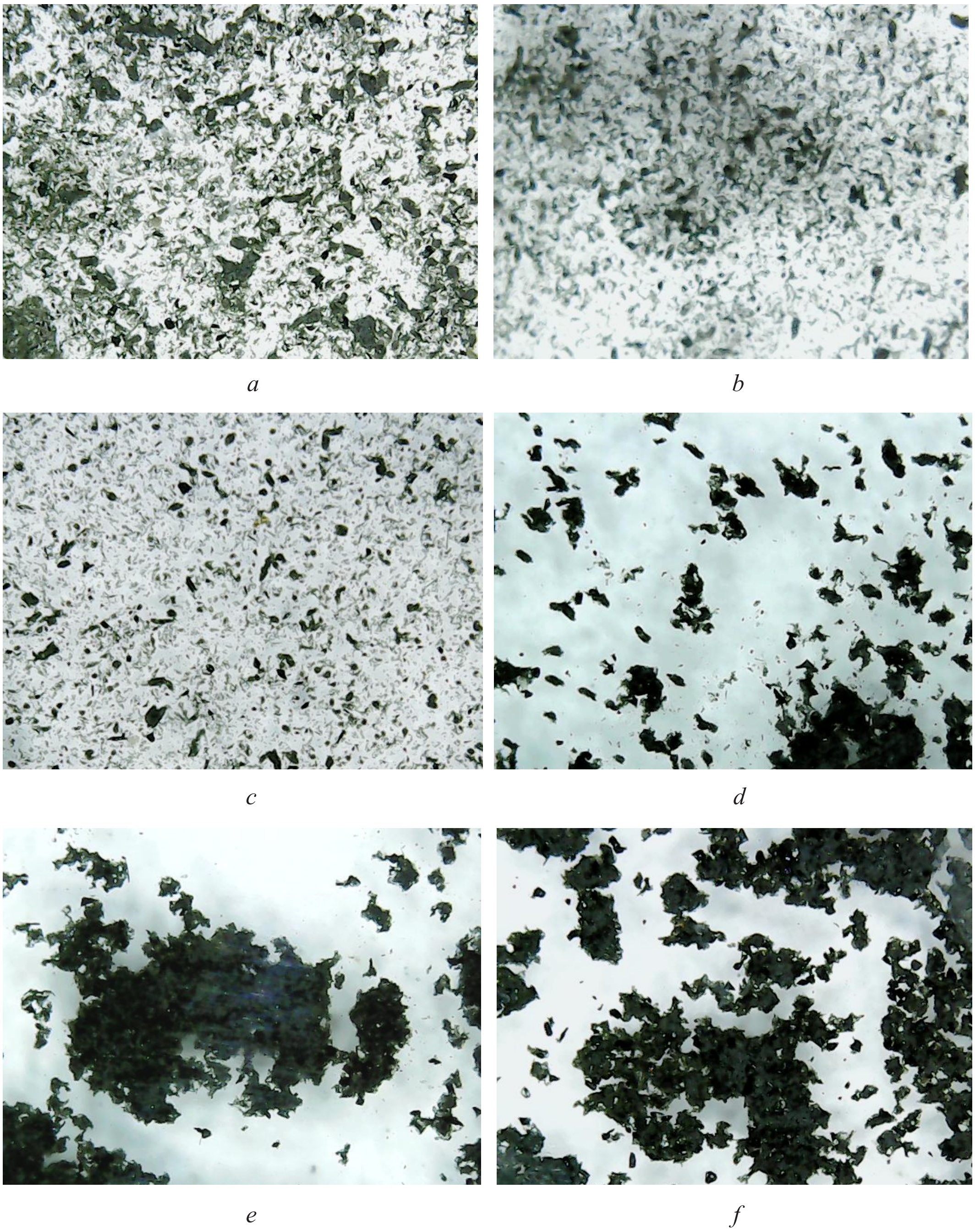

Fig. 5. Photos of the floccules after mechanical influence at
a concentration of 10 g/l and the content of the medium-sized fraction in the slime, %:
a – 5, *b* – 10, *c* – 15, *d* – 20, *e* – 25, *f* – 30

6. Conclusions

The studies allow to formulate the following conclusions:

1. Investigation of the influence of solids concentrations show that the most stable to mechanical stress aggregates formed when the concentration of solids in the slime of 7–30 g/dm^3 (the best conditions for flocculant adsorption).

2. Investigation of the influence of content of the medium-sized class (particle size 40–100 microns) showed that stronger aggregates form in the presence of the fraction of 40–100 microns in the slime more than 15 %.

The results allow to control the process of formation of solid aggregates by correction of the concentration and composition of the slime by dilution or adding of fraction of the solid phase before flocculant injection.

The resulting experimental dependencies can be used to optimize the process of flocculation and getting aggregates resistant to mechanical influences. This will control the slime treatment process with minimal degradation of the floccules, and hence saving flocculant consumption at the stage of dehydration.

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