ANALYSIS OF WAYS TO INTENSIFY FLOCCULATION OF FINELY DISPERSED SLIME

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Abstract: The object of research is the process of the slime cleaning of the coal preparation plant from suspended solids by flocculation. The process of flocculation is multifactorial and depends on the concentration of the solid phase in the slime, the dispersed composition, the salinity, the pH of the medium, the concentration and degree of dilution of the flocculant and many other factors that have not been adequately studied in the current literature. Based on previous studies, it was suggested that the flocculant was introduced into the slime in two portions in an amount of 40 % and 60 % of the total flow. The aim of research is an experimental check of the influence of methods of dispersing and introducing the first portion of the flocculant onto the efficiency of sedimentation of the slime on the real slime. For this, in the diluted slime with water in a ratio of 1:1, the first portion of the flocculant is introduced in two ways: after diluting the slime with water and into the water before mixing it with the slime. It is established that the preliminary dispersion of the flocculant in a large volume of water leads to a significant increase (above 80–85 %) in the sedimentation rate of the formed floccules, as well as their strength to mechanical action.

Keywords: flocculation, polydisperse slime, dispersed composition, floccules strength, sedimentation rate, adsorption efficiency, sedimentation intensification.

1. Introduction

Production activities for the processing of natural raw materials at chemical, metallurgical, food, coal processing enterprises are accompanied by the formation of significant amounts of waste water and slime, which require purification and return of purified water to water circulation. The classic scheme of cleaning the water-slime scheme of the enterprise is clarification of recycled water in thin-layer sedimentation tanks or radial thickeners. Industrial slime water can contain more than 90 % of finely divided fractions (less than 40 μm in size) of a solid phase with a low sedimentation rate. To intensify the purification of highly disperse slimes, the chemical enhancement of the water clarification process using synthetic flocculants and coagulants is used. The complexity and insufficient knowledge of the processes of coagulation and aggregation of particles, the formation of floccules, their destruction under mechanical influences in pipelines and various devices make experimental and theoretical study of these processes relevant to each kind of slime and real equipment.

The phenomenon of aggregation of the solid phase of highly disperse suspensions with the use of polymeric flocculants is widely used in the practice of purification of natural wastewater [1] and industrial origin [2], including slimes and sludge of coal-processing plants [3, 4].

The practice of slime cleaning with the use of coagulants and flocculants is reduced to selecting the right type of reagent and its dosage to obtain the desired effect [5].

According to the theoretical ideas [6], the flocculation process takes place in two stages. In the first stage, the macromolecules (coils) of the polymer diffuse to the surface of the particles of the solid phase and the flocculant adsorption. The kinetics of the flocculant adsorption is determined [7] by the time of diffusion of macromolecules to the particle surface (from several tens of seconds to several minutes). The time of the flocculant diffusion to the particle depends on the concentration of the solid phase in the slime waters, the duration and intensity of mixing, the viscosity of the liquid phase, the concentration and molecular weight of the flocculant, temperature, salinity, the presence of a double electron layer on the surface of the particles, pH of the medium and other factors [8, 9]. In the second stage, the formation of hydrogen bridges and the aggregation of particles into floccules occur on the particles coated with a polymer, the size of which depends on the mechanism of their formation and the size of the particles and coils of the polymer [10].

The variety of factors influencing the flocculation process leads to an increase in its dosage, instead of optimizing the process itself, for example, the stages of the polymer adsorption on the particle surface and the formation of strong aggregates. As noted in [11], to date the problem of optimizing the consumption of flocculants has not been solved and there are no well-developed principles for managing the flocculation process.

Recently, it has been established that the consumption of a flocculant for the formation of certain aggregate sizes and the corresponding rate of their sedimentation is nonlinear. At concentrations of the solid phase in the range of 10–30 g/dm^3, the optimum flocculant consumption is observed [12]. With an increase in concentration of more than 50–60 g/dm^3, the rate of precipitation of floccules significantly decreases at the same flocculant consumption in grams of active polymer per ton of solid phase. It is also found that at concentrations below 10 g/dm^3 and more than 30 g/dm^3, formation of floccules with the least strength to mechanical influences is observed, which leads to their destruction when moving through a pipeline and in dewatering equipment [13]. With an increase in the content of a solid phase fraction of 40–100 μm in size, more than 15 % increases the strength of floccules, which retain their shape and a sufficiently high sedimentation rate even after mechanical effects [14].

The obtained data make it possible to recommend an adjustment of the slime composition prior to the introduction of the flocculant both at a concentration close to the optimum and in terms of the content of a class fraction of 40–100 μm in excess of 15 %. To adjust the concentration before the sedimentation or dewatering equipment, the slime is diluted to specific concentrations.

It is found that the mixing of the flocculant with the slime depends on the methods and time of its mixing and it is expedient to carry out two portions [14, 15]. And in the first portion, maintain the flocculant consumption of 35–40 % of the required dose and hydrodynamically mix for 20–30 seconds, and in the second portion add the remainder of the flocculant with hydrostatic stirring for 10 seconds [15]. This approach ensures the best adsorption conditions (diffusion of the polymer to the surface of the solid phase without the onset of flocculation) and the preservation of the floccules strength. Thus, the two-stage flocculation process requires the best conditions for each stage. It is assumed that the strength of the adsorption of the polymer on the surface of the particles depends on the floccules strength, which is understood as the residual sedimentation rate after mechanical impact. In the literature, methods for improving the adsorption of the polymer in the first stage of the flocculation process are not sufficiently widely described. Let's assume that the efficiency of polymer adsorption, and therefore the residual rate of floccules sedimentation after mechanical exposure, will be higher if the flocculant is previously dispersed in a larger volume, reducing its volumetric concentration. This will provide better conditions for mixing polymer macromolecules in the bulk and effective contact of the interface with the polymer.

Thus, the search for ways to intensify the process of flocculation of polydisperse suspensions will allow to justify the ways to manage the flocculation process and create prerequisites for solving the problem of optimizing the consumption of flocculants and the formation of more durable aggregates.

The aim of this research is experimentally testing the influence of the methods of dispersing and introducing the first portion of the flocculant onto the efficiency of slime sedimentation on real slime.

2. Methods

For the study, a sample of the actual slime, supplied for clarification to the radial thickener, is used as one of the operating coal preparation plants. Before flocculation, the concentration of the solid phase in the slime and its dispersed composition are determined. The concentration of the solid phase (C_s, g/l) was determined by drying the precipitated from 1 liter slime of a wet cake. To determine the dispersion composition, 4 liters of slime is passed through a sieve of size 63, 400 and 1000 microns, the detained phase is dried on sieves, weighed and the mass fraction of each fraction in % is determined. To investigate the flocculation effectiveness, slime with water diluted in a graduated cylinder with a ratio of 1:1 (250 ml of slime + 250 ml of water) is used.

Before conducting the experiments, the types of flocculants, leading to aggregation of the solid phase, are selected. For the flocculation experiments, a nonionic flocculant was used to enter the first point and an anionic flocculant for water at a second point at a concentration of 0.05 %. The total consumption of flocculant in the experiments is 120, 160, 200 and 240 g/t.

Measurement of the kinetics of the floccules sedimentation in the regime of unconstrained settling is carried out in a laboratory measuring cylinder with a diameter of 50 mm and a height of 500 mm. To evaluate the strength of aggregates to mechanical stresses, the following technological test is used [13]. A non-ionic flocculant is added to the graduated cylinder with slime in an amount of 40 % of the total consumption of the flocculant. Two methods of introducing the first portion of the flocculant are investigated:

Method 1. The first portion is introduced into the diluted slime after mixing with water and then 10 is mixed with the cylinder overturning.

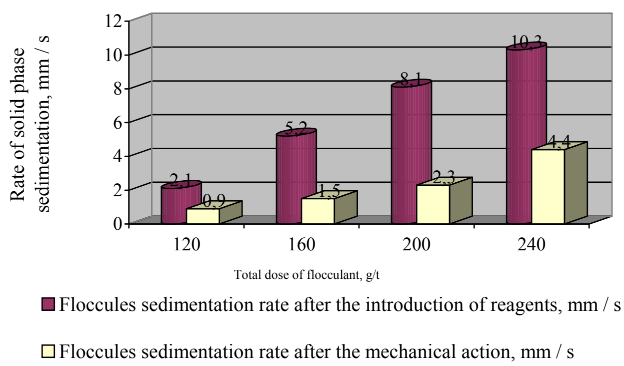
Method 2. The first portion is introduced into water (250 ml), mixed by cylinder overturning to uniform dispersion in the volume, and then an equal portion of the slime is added.

After stirring by the cylinder overturning, an anionic flocculant is introduced in an amount of the remaining 60 % of the total flow rate again mixed by the measuring cylinder overturning for 10 seconds. After flocculation and measurement of their sedimentation rate, the flocculated slime is agitated with a speed at the tip of the blade of about 2 m/s for 40 seconds in a rectangular container of 120×70 mm. In our opinion, this mechanical effect simulates the movement of the flocculated slime through the pipeline from the thickening apparatus to the dehydration apparatus. The residual sedimentation rate after mechanical action characterizes the size of the aggregates, hence the strength of the floccules to the mechanical action. Then the sedimentation rate is again measured.

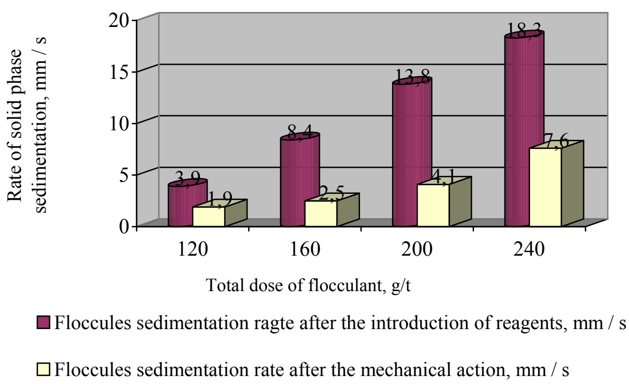
3. Results

According to the recommendations of [13], slime flocculation of such concentration and dispersed composition will lead to an uneven distribution of the polymer on the surface of the particles, the convergence of which will lead to the beginning of the second stage - aggregation of particles. Insufficient adsorption of the flocculant on a part of the solid phase leads to the formation of unstable bonds and, accordingly, unstable floccules, which break down under mechanical influences. Therefore, in order to reduce the concentration to the optimum value of 10–30 g/dm^3 [12], for further investigation, the slime sample is diluted two-fold and the effect of changing the method of introducing the first portion of the flocculant on the adsorption quality of the polymer is studied.

The results of measuring the sedimentation rate of the slime at various doses of the flocculant (with the introduction of 0.05 % of the flocculant solution in 250 ml of water in the second method there will be a different degree of dilution of the active polymer) in an amount of 120–240 g/t and a method for introducing the flocculant and into water before diluting the slime) are shown in **Fig. 1**.



a



b

Fig. 1. Regularities of the change in the sedimentation rate of floccules from the concentration and method of introducing the flocculant:
a – the introduction of flocculants according to the method 1,
b – the introduction of flocculants according to the method 2

An analysis of the results obtained in **Fig. 1** shows that the sedimentation rate of flocculates both after formation and after mechanical effects is significantly different. According to the second method, with a preliminary dispersion of the flocculant in a considerable volume of water, the sedimentation rate in all cases is higher by almost 80–85 % at the same flocculant consumption, which indicates a possible reserve of reagent economy.

4. Discussion

The obtained results can be explained by the fact that mixing of the flocculant pre-dispersed in the bulk with the slime leads to the best conditions for the adsorption of the polymer on the surface of the solid phase due to more efficient diffusion. Due to the uniform distribution, the probability of sticking together polymer coils and microflora is reduced, the polymer consumption for aggregate formation is eliminated until the adsorption of macromolecules on the particles of the solid phase occurs.

The second explanation may be a change in the structure of the polymer coil of the macromolecule of the flocculant, which, with a high dilution degree, can be untwisted in the filament, possibly more favorable and mobile for the adsorption process on the particle surface.

Thus, the obtained data allow to reduce the consumption of the flocculant due to the qualitative carrying out of the polymer adsorption process. At the same time, it is necessary to further investigate the causes and features of this process, which will form the basis of our further research.

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