Stabilization of coal-water suspensions

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Abstract. In this paper, the effect of sodium lignosulfonate and sodium carboxymethyl cellulose on the stability of a water-coal suspension was studied. As a result, the viscosity of the water-coal suspension was 0.01-0.08 P·s. The change in dynamic shear rate was considered when adding these plasticizers in different changes. The minimum value of the dynamic shear rate of 13.6 was achieved with the addition of sodium LST plasticizer (SD = 0.1%) in the presence of 40% coal. The influence of alkali on the viscosity of a water-coal suspension was also studied.

1 Introduction

Coal ranks second in importance in the world production of primary energy resources. For this reason it is very important to use the huge reserves of coal in Kazakhstan to the fullest extent possible. The main direction of using coal is the production of thermal and power-generating fuels, which consume more than half of the coal mined.

The biggest problem with using coal is its low environmental acceptability, as its negative impact on the environment outweighs all the benefits of using coal [1].

The solution to this problem is the introduction of liquid fuel. Liquid fuel is a mixture of fine coal sludge, water and a plasticizer. Water-coal suspension (WCS) has a number of advantages:

- reduction of harmful emissions of nitrogen oxides, carbon and sulfur into the atmosphere at all stages of production, storage, transportation and combustion;

- no danger of environmental pollution during storage and incineration;

- prevention of explosions and fire safety in all technological operations;

- no dust during storage and transportation;

- the ability to fully automate the processes of preparation, transportation and use

- the ability to store and transport in conventional fuel oil tanks.

The main problem in the production of WCS is to ensure maximum sedimentation stability at the lowest viscosity. Sedimentation stability provides a long operating period, while a low stability value leads to coagulation, that is, to adhesion of solid particles to each other with further sedimentation. Low viscosity ensures easy transportation of liquid fuels.

2 Methodology and results

The process of WCS manufacturing includes several stages: preparation of plasticizer and coal solutions of the desired fractions, and preparation of a mixture of coal-water suspensions.

Coal fractions consist of 3% – 125 μm, 20% – 63 μm, 77% > 63 μm, since this composition has a stronger structure at lower concentrations of the dispersed phase [2]. Also, the difference in particle sizes in the suspension provides less coagulation of the dispersed phase. This effect is achieved due to the fact that small particles of coal are located between large particles. As a consequence, smaller particles displace water in the aggregates and the viscosity of the suspension decreases, and the degree of filling of the dispersed phase increases [3].

To obtain the desired coal fraction, we used an automatic laboratory knife-type mill, model PRO-02, and a vibrating screen, ANALYSETTE 3 PRO. The content of coal in the WCS is 40% and 50% of the mass of the suspension. The suspension was prepared by adding solutions of modifiers to the crushed mass of coal. The process was carried out at room temperature, followed by stirring until smooth.

Sodium lignosulfonate (LST sodium) and sodium carboxymethyl cellulose (CMC sodium) were chosen as plasticizers. NaOH and KOH were added to the plasticizers to control the concentration of the hydrogen ion in the suspension.

Rheological studies necessarily include the measurement of shear stress. The shear stress is the mechanical forces due to which the system is set in motion. Viscosity is determined from the shear stress data.

The main rheological parameters of the WCS, the viscosity η (Pa·s) and the dynamic shear stress τ (Pa), were determined on an RC-3 rotational viscometer at various shear rates. A 780 pH Meter was used to measure pH.

The rheology of coal-water suspensions is the result of spontaneous diffusion. Which is caused by physicochemical factors or cause external forces of destruction and simultaneous structural of various types. In the same vein (as an effect on contact interactions), the role of the dispersion medium adsorbed on the particles and the plasticizers dissolved in it. The technological efficiency of which is being studied, is also considered.

As can be seen in Fig. 1, with an increase in the concentration of the added plasticizer, the viscosity of suspensions increases. It happens because of LST sodium, like CMC sodium, are high-molecular substances that decrease their own fluidity with increasing concentrations. At the same time, the maximum viscosity value is not more than 0.08, which is a relatively low viscosity value for coal-water slurries [4].

At low concentrations of the dispersed phase (in our case, coal), in the absence of mutual attraction of particles, hydrodynamic forces act predominantly. If the liquid is Newtonian, then the suspension remains Newtonian. Starting from the average concentration of the solid phase, the viscosity of the suspension increases linearly, but from a certain point it becomes nonlinear. At the same time, with an increase in concentration, the rate of growth in viscosity increases then the nature of the flow becomes non-Newtonian. This phenomenon is explained by the influence of the shear rate of adjacent layers of the suspension [5].

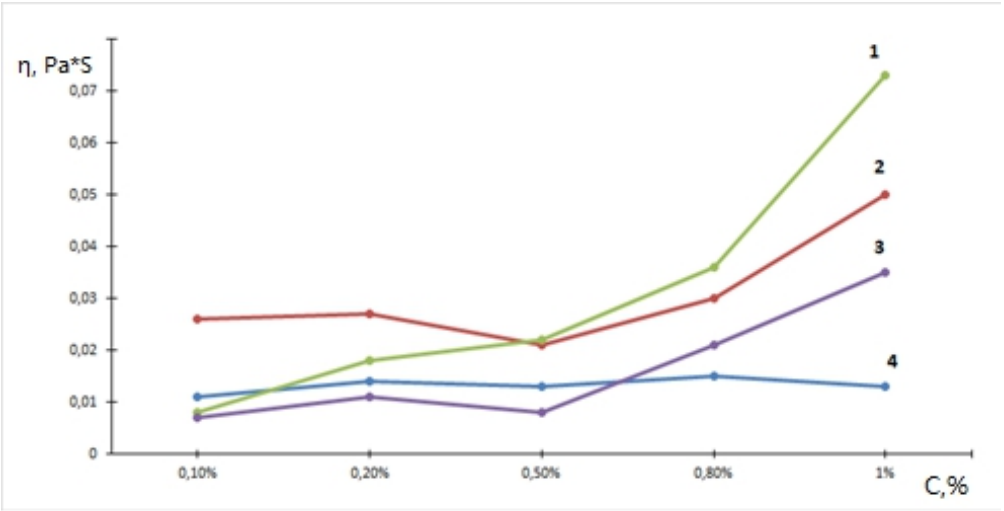

Fig. 1. Dependence of the WCS viscosity on the concentration of added plasticizers LST sodium and CMC sodium: 1-CMC sodium with a coal content of 40%; 2-LST sodium with a coal content of 50%; 3-CMC sodium with a coal content of 50%; 4-LST sodium with a coal content of 40%.

With an increase in the attraction between the solid phase, the viscosity of the suspension increases, since the particles of the dispersed phase form floccules, clusters or a structure. It is leads to the appearance of a pseudoplastic character of the suspension flow and the appearance of thixotropy, since the formation of particles and the structure are sensitive to shear and are subject to destruction [3].

As can be seen in Fig. 2, slurry with a 50% coal content has a higher shearing rate than a slurry with a 40% coal content. All 4 curves have a structure close to linear, which indicates a high sedimentation stability.

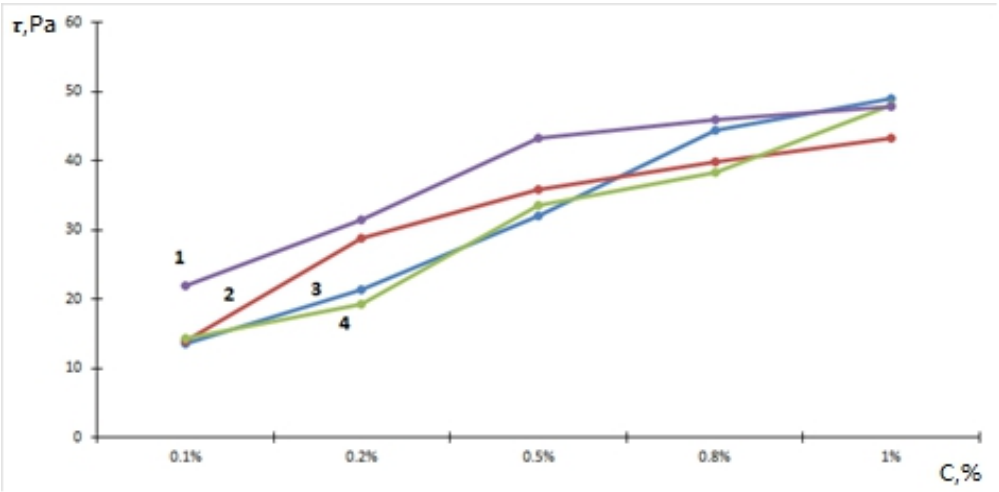

Fig. 2 Dependence of the dynamic shear stress of WCS on the concentration of added plasticizers LST sodium and CMC sodium: 1-CMC sodium with a coal content of 50%; 2-LST sodium with a coal content of 50%; 3-LST sodium with a coal content of 40%; 4-CMC sodium with a coal content of 40%.

To achieve lower viscosity values of the suspension, the pH level was adjusted to study the effect of the concentration of hydrogen ions on the viscosity of coal-water suspensions [6]. As can be seen in Fig. 3, the effect of plasticizers is most effective at high pH values (11-12) where the viscosity reaches 0.02 (Pa·s). As we know, pH > 7 corresponds to an alkaline environment in which high-molecular compounds have an optimally expanded configuration. And the maximally hydrophilize of the surface of coal particles, thereby protecting coagulation-vulnerable parts of their surface [7].

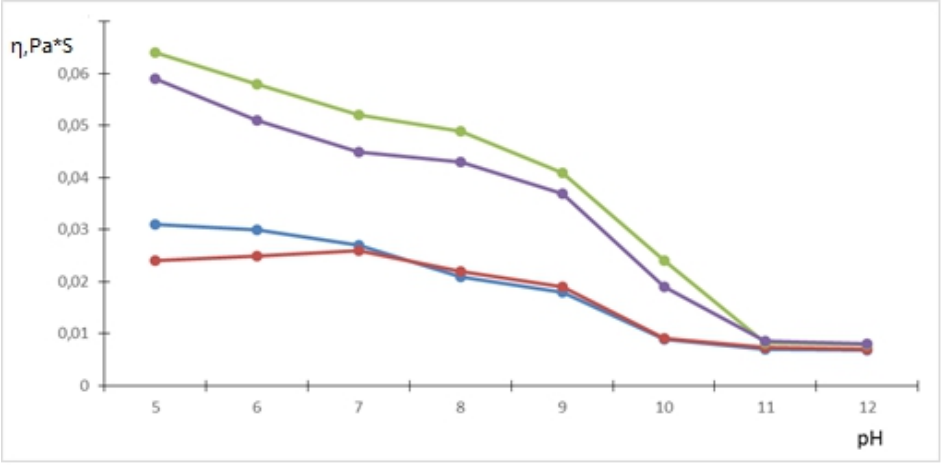

Fig. 3 Dependence of the WCS viscosity on the pH level: 1-CMC sodium with a coal content of 40%; 2-CMC sodium with a coal content of 50%; 3-LST sodium with a coal content of 40%; 4-LST sodium with a coal content of 50%.

At low pH values, due to an increase in the ionic strength of the solution, the electrostatic interactions of ions are screened. The macromolecules can again fold into relatively dense coils leading to a decrease in the force of interaction between the plasticizer and the surface of the coal [8].

3 Conclusions

The use of LST sodium and CMC sodium in the form of WCS plasticizers (SD = 0.1-1%) makes it possible to achieve a suspension viscosity of 0.01-0.08 Pa·s. It was found that the minimum value of the dynamic shear rate of 13.6 Pa is achieved with the addition of the LST sodium plasticizer (SD = 0.1%) in the presence of 40% coal. The presence of alkali significantly increases the stability and reduces the viscosity of the WCS, which indicates a combination of electrostatic and steric effects and a more complete adsorption of the plasticizer.

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