Research of rheological properties improvement methods of coal-water fuel based on low-grade coal

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Abstract. Experimental studies of coal-water fuel (CWF) rheological properties based on 3B brown coal have been conducted using different processing methods, such as rotary flows modulation device (RFMD), sodium hydroxide and lignosulfonate. Physicochemical properties of initial solid fuel have been determined using JEOL JCM 6000 microscope. Optimal method of coal-water treatment has been determined based on obtained data considering its influence on viscosity and sedimentation stability of coal-water slurry (CWS).

1 Introduction

The problem solution of catching the sulphur dioxide and nitrogen oxides out of the flue gases from the thermal power plants is connected with the processing of large volumes of gas emissions, exceeding in some cases million cubic meters per hour [1-4]. As a rule, high-quality power plant coals produced in the Russian Federation are exported abroad. Share of coal supplied to domestic TPPs is about 30%, 90% of which are low-quality coals [5].

Thus, domestic power plants are forced to use low-grade coal, which leads to environmental issues that require development and implementation of new efficient technologies that ensure full use of produced fuel and significant economic effect [6].

One of the most promising directions of low-grade coal application in power engineering is coal-water fuel technology (CWF). This technology represents composite dispersed system that consists of solid phase in the form of fine coal, liquid medium (water) and plasticizing agent [7].

2 Experimental setup

3B brown coal from "Balakhtinskoe" deposit was considered as initial sample of solid fuel. After initial grinding, the coal was sieved through a sieve with a mesh size of 80 μm.

Coal structure may vary greatly even within different layers of one deposit [8]. Due to importance of knowledge of coal properties for further evaluation of CWF characteristics [9], micrograph of initial coal (Figure 1) has been obtained with JEOL JCM 6000 microscope. It shows that coal particles have rough porous surface. It is known [10] that coals with such

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structure have higher grindability. In addition, large number of pores leads to an increase in sorption volume, which leads to an increase in moisture capacity and hydrophilicity of the coal, thereby viscosity of CWS increases [11].
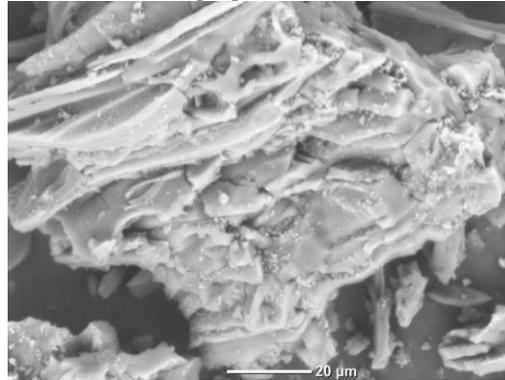

Fig. 1. Microphotograph of initial coal particle.

Application of rotary flows modulation device (RFMD) is proposed in this paper as additional stage of slurry processing prior to combustion for CWF rheological characteristics improvement. There are also proposed ways of chemical influence on coal-water slurry (CWS) - application of sodium hydroxide (NaOH), lignosulfonate (LST) and a mixture of these two additives.

RFMD is a liquid mixer with rotary siren, in which input raw material is subjected to mechanical, acoustic and hydrodynamic influences.

Principle of the device is that during its operation suspension flow is crushed by the rotor into a series of small secondary flows, which enter the gap between the rotor and the stator and are grinded into smaller streams, due to structural features of the stator. Flowing through narrow passages created by holes in the rotor and the stator, the processed raw material undergoes mechanical destruction because of particles impact against lateral surfaces of the rotor and the stator openings. In addition, grinding process occurs when the pressure pulsates due to sudden change of flows direction and frictional forces [12].

Sodium hydroxide is the most common alkali. It represents white solid material. NaOH is highly hygroscopic (it actively absorbs water vapor from the air). It is very soluble in water, during which a large amount of heat is released.

Lignosulfonate is a powder, color of which can vary from light shades of brown to rich brown. It mixes well with water. Lignosulfonate is produced at paper mills during interaction of wood with water, as a result of which wood decomposes and new compounds are formed [13].

After processing, dynamic viscosity of suspension was determined using Brookfield viscometer. To determine true viscosity value, the viscometer operates within confidence interval (10-90%), resulting in shear rate range being limited during examination of various CWF samples due to non-constant rheological properties. Thus, quantitative assessment of CWS viscosity variation has been conducted at equal shear rate (70 rpm), which corresponds to the confidence interval of all considered samples.

Evaluation of sedimentation stability has been conducted by settling of CWF sample in a measuring cup for 24 hours, followed by measuring the height of dense deposit.

3 Results

Figure 2 presents obtained results of coal-water fuel viscosity using various methods of its processing.
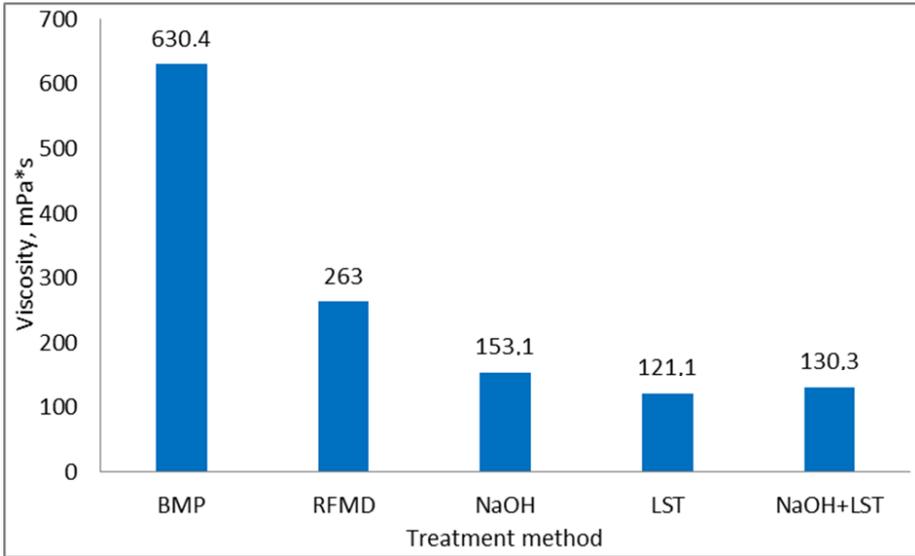
Fig. 2. Viscosity of coal-water fuel depending on treatment method.

As can be seen from Figure 2, maximum effect of suspension viscosity reduction has been obtained using lignosulfonate. Application of mechanical treatment has not showed the expected results, but this type of treatment can be used as an additional stage of CWF processing, since it significantly reduces viscosity of the suspension (more than 2 times).

Figure 3 presents results of coal-water fuel sedimentation stability using various methods of its processing.
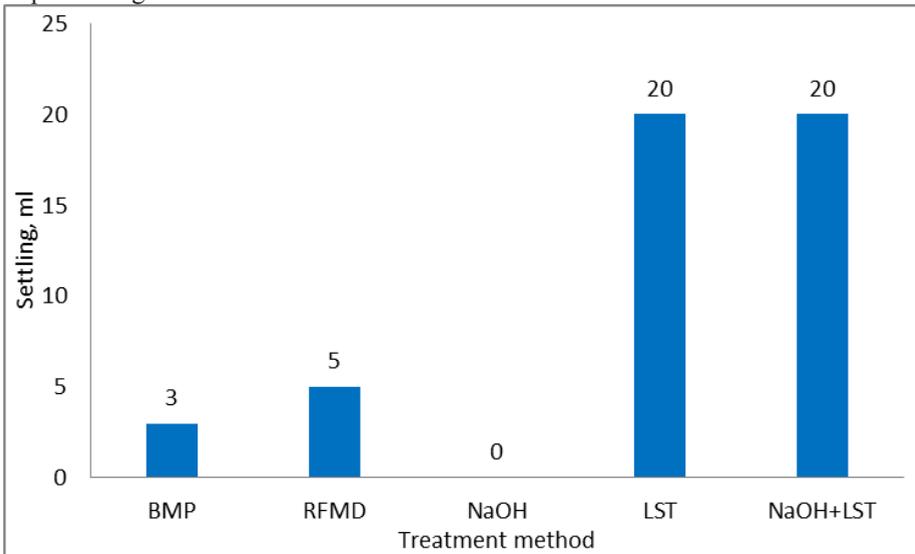

Fig. 3. Sedimentation stability of coal-water fuel depending on treatment method.

It follows from diagram 3 that sodium hydroxide has maximum effect on sedimentation stability. However, despite this, application of NaOH and lignosulfonate mixture causes formation of dense layer (about 20 ml), as in the case of using only lignosulfonate. Hence, it can be concluded that lignosulfonate has a much greater effect on CWF sedimentation stability than sodium hydroxide.

Conclusion

Thus, effect of chemical and mechanical treatment on rheological characteristics of coal-water fuel (viscosity and sedimentation stability) was evaluated. It has been found that maximum decrease of viscosity is observed with lignosulfonate application. However, this additive adversely affects sedimentation stability, which makes its use relevant only if the facility is able to install CWF storage tanks with a stirring mechanism.

Application of mechanical treatment (an additional step in the form of rotary flows modulation device) significantly reduces viscosity of the slurry, which makes it possible to use it in power engineering.

It has been determined that optimal treatment is application of sodium hydroxide, which significantly reduces viscosity of the suspension and does not cause sedimentation.

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