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Energy and Ecological Aspects of Coal-water Slurry Utilization

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The opportunity of technological and modified lignosulphonate wastes, process water, oxygenized brown coal with high content huminic acid (to 60 %) with alkali usage as plasticizer agent in the coal-water slurry (CWS) production technological process was checked. The CWS stability scheme in alkali additives interaction was suggested. The bituminous and brown coal mixture (10: 90) CWS was investigated. The anthracite and brown coal relation is from 5 to 95. The discovered regularities demonstrated the slurry properties optimization opportunity in industrial conditions by combined changing of additive quantity and coal physical-chemical composition. The suggested CWS production technology allows solving some questions of ecological safety and resource-saving at the expense of the sources of raw materials assortment expansion. The CWS production industrial scheme on production run equipment without its modernization is developed. The combustion parameters of this fuel are shown. It is established that CW fuel combustion allows reducing the harmful emissions in atmosphere several times.

Keywords: brown coal, coal-water slurry, technological scheme.

The coal-water slurry (CWS) production with its future transportation and usage as energy fuel is one of the perspective ways of conversion of coal into a liquid state for ensuring ecological demands for toxic ejections during solid fuel combustion and also for fuel oil replacement in the industrial heat-and-power engineering installation.

In the process of the CWS production, the possibility of non-quality coal and coal mining and processing wastage and other production usage allows to solve ecological problems and resource-saving.

At present time there are practically no theoretical methods allowing to select CWS formulate and production regimes. Each coal type demands individual approach in CWS production which characterized experimentally.

The creation and improvement technology of the CWS from the different metamorphism stage coal represents highly actual and economically perspective [1].

The CWS introduction allows:

distribute the thermal power station on ecological save distances;

use the dirty mine, opencast mine and residential waste water for the CWS production;

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provide with uninterrupted stable quality fuel in seasonal and daily regimes;

except the coal loss and its self-ignition in transportation and storage;

provide with full technological process automation of fuel production, transportation and usage;

improve the labor conditions;

Coal-water slurry is structural two-phase systems showing non-Newtonian flow. Their properties depend on physical and chemical coal characteristics, chemical additives, flocculation tendency and other factors. The CWS has Bingham liquid properties such as ductility, pseudo- ductility, and swell ability, thixotropic theological time properties.

The main CWS performance properties (ductility, stability, the CWS solid phase, distribution in grain-size) identify the multiple-factor system; the research of that system conduction mechanism in factors changes which influence on that system allows controlling and modeling the system mechanism that permit to decrease the CWS cost price.

The CWS production technology allow to use the run-of-mine coal ridings, concentrating mill coal wastes, coal mining fine fractions as solid phase; different production liquid technological wastes as carrying agent.

The brown coal CWS production characteristic property is metamorphism low degree. At the same time, high reaction ability allows using it as the CWS solid phase simultaneously with more low reaction coal or coal wastes.

The usage opportunity of oxygenized brown coal with high content huminic acid (to 60 %) with alkali as CAA similarity (coal-alkali agent) is researched in the work. In this circuit, the humate natrium which has not only plasticizer effect but stabilizer effect is produced in the CWS production process in grinding apparatus [2]. It allows us to simplify the process of additive production and thus take away the production, transportation and storage processes. The initial components are delivered simultaneously on milling stage in grinding apparatus. The oxygenized coal and alkali usage effectiveness was checked on the bituminous coal mark D CWS. The alkali percentage remains the same as in separate CAA production that is 16–20 % on oxygenized brown coal dry basis or 0,1 % bituminous coal mass. The oxygenized brown coal fraction is 0.5 % on the bituminous coal dry basis. The oxygenized coal with alkali usage reduces the bituminous coal CWS viscosity from 1,1–1,3 to 0,64–0,77 Pa·s. Initial coal ash content doesn’t render significant influence on viscosity decreasing. This shows the opportunity of usage of oxygenized coal additive with alkali for low-ash the bituminous coal CWS production.

The opportunity of production wastes usage as plasticizer agent in the CWS production technological process is checked. In the CWS production process the Krasnoyarsk pulp and paper mill wastes technological (TLS) and modified (MLS) lignosulphonate were used as chemical additives. The LS and MLS characteristics are: MLS 1 – pH = 9,3 C_s = 45 %; MLS 2 – pH = 8 C_s = 52 %; MLS 363 – pH = 6,5, C_s = 50 %; MLS 364 – pH = 5,0, C_s = 50. The additives compositions were also used.

With the introduction of researched additives the brown coal CWS fluidity is increasing. Characteristic flux index *(n)* < 1 for each CWS shows that used chemical additives didn’t change the slurry flow pseudo-plastic character (Fig.1).

The liquid phase alkalinity shows significant influence on the brown coal CWS rheological properties, so turn-down pH of the used lignosulphonate additives (from 5 to 10) – the brown coal CWS structural viscosity reduces twice is determined. The (amount, quantity) natrium hydroxide depend on coal ash content is determined (Fig. 2).

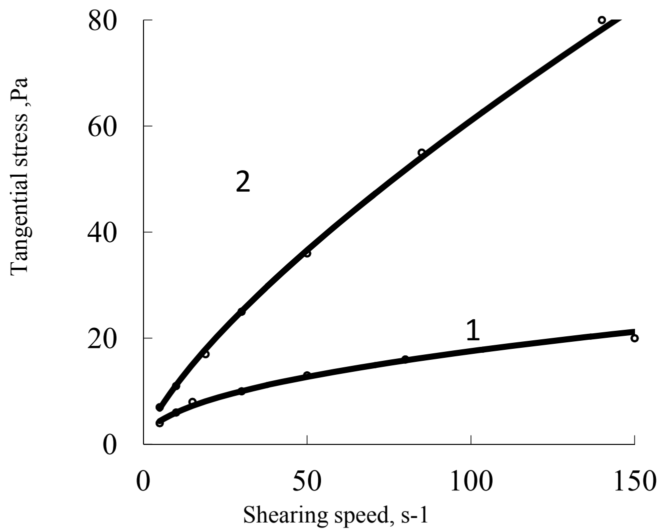

Fig.1. The CWS flow rheogram: 1 – C_s = 40,5 %, 2 – C_s = 37 %

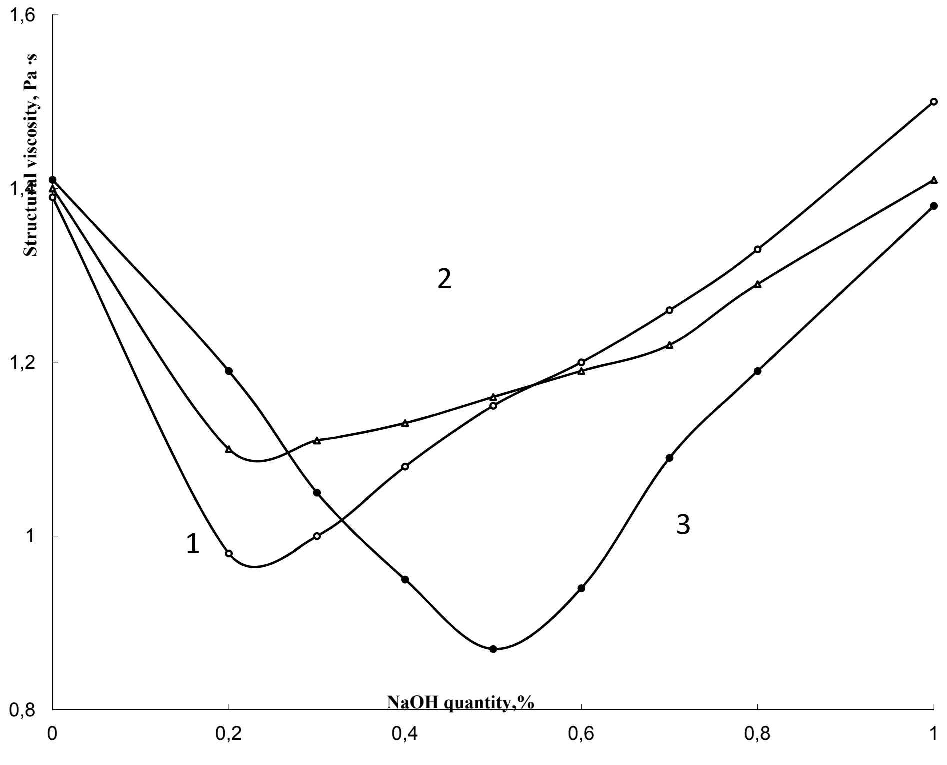

Fig. 2. Plot CWS structural viscosity against putting natrium hydroxide quantity (C_s – 46 %). (Coal ash content 1 – 4,6; 2 – 5,3; 3 – 7,6 %)

It is necessary to raise the hydroxide natrium from 0,2 to 0,5 %, with the increasing of the solid phase mineral matter percentage from 4,6 to 7,6 %. The CWS stability is decreasing due to ash content reduction.

The additive influence on slurry properties on different circuit introduction was examined and so it could considerably influence on additive effectiveness. The additives were added both on wet crushing stage simultaneously on aqueous phase and beforehand received slurry on homogenization stage.

In the lignosulphonate usage the greater viscosity decrease is attained on homogenization stage. In the mechanical-chemical break-down process the additive polymeric structure destruction is taken place and additive effectiveness is receding. It is necessary to use these additives on homogenization stage.

The significant part of the CWS plasticizer additives has alkaline medium (lignosulphonate additives, coal-alkali agent and other). The alkali influence nature on brown coal CWS stability isn't practically researched and discussed. Formally, alkali is a simple CWS plasticizer additive.

The dependence of the CWS structure viscosity from injecting alkali concentration has extreme character with minimum in the alkali concentration value interval from 0,2 to 0,5 % (Fig.2). With coal ash content increasing from 4,6 to 7,6 % it is necessary to raise the natrium hydroxide from 0,2 to 0,5 % for viscosity support and slurry stability. The alkali content raise to 1 % leads to slurry separation with hard sediment formation.

The extreme dependence nature could be explained as alkali concentration and its influence on the CWS viscosity. The aqueous alkali reacting with brown coal on the first stage transport the huminic acid in aqueous phase in natrium salt form:

$$\mathrm{NaOH + (HO\text{-}Humin)_{coal} \rightarrow (NaO\text{-}Humin)_{water} + H_2O}, \qquad (1)$$

where $\mathrm{(HO\text{-}Humin)_{coal}}$ – huminic acid in coal, $\mathrm{(NaO\text{-}Humin)_{water}}$ – dissolved natrium salt of huminic acid.

The natrium salt of huminic acid is in true solution form in aqueous solution and exactly this composition has the CWS aqueous phase with high alkali concentration (more than 0,5 %,(Fig. 2) providing full transition of huminic acid to corresponding salt.

In small alkali concentration its first interaction with coal is on the equation (1), then comes the stage of natrium salt of huminic acid hydrolysis and sodium ions migration from solution to coal solid phase:

$$\mathrm{(NaO\text{-}Humin)_{water} + (HO\text{-}Humin)_{coal} \rightarrow} \\ \mathrm{\rightarrow (HO\text{-}Humin)_{gel} + (NaO\text{-}Humin)_{coal}} \qquad (2)$$

The process (2) can only proceed on small alkali concentration and that leads to huminic acid coagulation, conversion from natrium salt of huminic acid true solution to colloidal solution, huminic acid gel. Formed in such way gel stabilizes the CWS and decreases its viscosity. The process (2) couldn't be proceed on high alkali concentration because all himin acid groups are deprotonated and that leads to hard sedimentation at alkali concentration about 1 % (Fig. 2).

The alkali optimum consumption for CWS plasticization grows with the used coal ash content increasing. This has as minimum two conditions: (*a*) the active alkali binding by coal ash content components, e.g. in sodium silicate and (*b*) at the same time with the huminic acid content in coal the ash content frequently increasing; and all this in accordance with suggested slurry stabilization mechanism leads to alkali quantity increasing which is necessary for its dissolution and coagulation.

The alkali usage as additive on experimental-industrial level showed stable decreasing of brown coal mixture structural viscosity from 1,88 to 0,77-0,80 Pa·s.

The initial wet coal predrying allows raising the CWS solid phase content on average 10 %. The highest CWS coal content meanings were received in B2 coal predrying to 6–14 % and B1 coal to 8–13 % humidity, which is equilibrium moisture content.

The bituminous and brown coal mixture (10: 90) CWS was investigated. The anthracite and brown coal relation is from 5 to 95. On high-ash riddling basis anthracite and brown coal the high concentrated slurry with solid phase percentage 49–62 % and combustion specific heat 11,7–15,6 MJ/kg could be prepared. The 25 % anthracite content the solid phase percentage 50–60 % and the 12–15,3 MJ/kg heat value CWS is more rheological indexes appropriating and fuel calorific value.

In large-capacity production the technology control was carried out on processing line shown on Fig.3. The CWS production regimes were developed on run-of-mine coal in 90–150 TPH production ball mill. The CWS production water discharge is 65–110 cubic meter/h.

The pH = 8,2–9,4 and high alkali (2,0–2,8 milligram-equivalent per litre) process water was used as liquid phase for the CWS production. The result of water and coal mixing in mill is humate which are the plasticizer additive of analogous alkali.

The Beryozovskii coal-field run-of-mine brown coal was used. The slurry was received in two-stage grinding regime. The production fluctuates from 4 to 12 TPH.

In experimental-industrial scale the CWS production on mixture base was held on scheme without classifier usage and recirculation in two stages. The mixture with relation Bituminous coal: Brown 80:20 was used for CWS production as solid phase.

Thus, the Kansk-Achinsk brown coal CWS production opportunity with salvages and dirty production water is shown in large-capacity production.

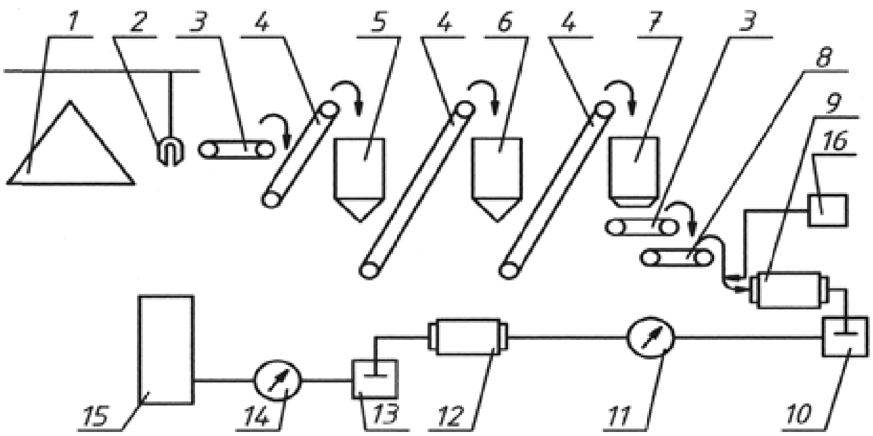

Fig. 3. The brown coal CWS production technological scheme on industrial equipment: 1 – raw-material storage; 2 – crane; 3 – apron feeder; 4 – belt conveyor; 5 – primary crushing grinding-mill; 6 – fine crushing grinding-mill; 7 – loading bin; 8 – belt weigher; 9 – ball grinder; 10,13 – mixer; 11,14 – pump; 12 – rod mill; 15 – storing tank; 16 – additive measurer

The discovered regularities demonstrated the slurry properties optimization opportunity in industrial conditions by combined changing of additive quantity and coal physical-chemical composition.

The suggested CWS production technology allows solving some questions of ecological safety and resource-saving at the expense of the sources of raw materials assortment expansion. The CWS production industrial scheme on production run equipment without its modernization is developed.

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Энергетические и экологические аспекты сжигания водоугольных суспензий

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Показана технологическая возможность применения лигносульфонатов, технической воды и других отходов при производстве водоугольных суспензий. Предложен механизм стабилизации ВУС. Исследованы водоугольные суспензии, полученные на основе угольных смесей: «каменный – бурый» в соотношениях от 10 до 90, «антрацит–бурый уголь» – от 5 до 95. Установлено, что на основе высокозольных отсевов антрацита и бурого угля можно приготовить высококонцентрированные суспензии с массовой долей твердого 49–62 %. Предложенная технология получения ВУС позволяет решить ряд вопросов экологической безопасности и ресурсосбережения за счет расширения ассортимента источников сырья. Разработана промышленная схема получения ВУС на серийном оборудовании без дополнительной модернизации последнего. Установлено, что сжигание водоугольного топлива позволяет снизить эмиссию вредных выбросов в атмосферу в несколько раз.

Ключевые слова: бурый уголь, водоугольные суспензии (ВУС), технологическая схема.