Effect of cavitation treatment of coal-water and composite liquid fuels on their characteristics

L I Maltsev* and Yu S Podzharov
Kutateladze Institute of Thermophysics SB RAS, 1 Lavrentyev Ave., Novosibirsk, 630090, Russia
*E-mail: maltzev@itp.nsc.ru

Abstract. The effect of mechano-cavitation treatment of coal-water and artificial composite liquid fuels, based on brown coals and anthracite, on particle size distribution of their coal mass and dynamic viscosity is studied experimentally. It is shown that the treatment of both fuels leads to significant regrinding of their coal mass and a noticeable increase in viscosity.

1. Introduction
To date, almost all mined coal is subjected to sorting and enrichment during primary processing; as a result, the large volumes of small coal fractions with high humidity and ash content (screenings, coal sludge, cake) are formed. To use such coal wastes for energy production by traditional technologies, it is necessary to dehydrate them. However, thermal drying of flooded coal sludge is not economically feasible. The technology of their combustion in the form of coal-water suspension (CWS) or artificial composite liquid fuel (ACLF) is more effective. These types of fuels allow using low-grade, waterlogged coals along with coal waste. The technology of burning coal in the form of liquid fuels has several advantages: it increases completeness of fuel combustion and combustion at lower temperatures, which reduces emissions of soot, benzopyrene and nitrogen oxides, etc. The disadvantage of CWS is its low calorific value, therefore, when preparing the composite fuels with a higher calorific value, waste oil components and oil refining, pyrolysis resins of various industries, alcohols, and spent motor oils (heating oil) are used. Currently, to prepare CWS and ACLF, the methods based on mixing coal powders obtained by dry or wet grinding of coal on a ball mill with water and other (combustible) components and subsequent processing of the resulting mixture with the help of disintegrators, vibration and planetary mills, cavitators, homogenizers, etc. are used [1]. As a rule, the technology of fuel preparation includes a long list of operations using relatively complex and expensive devices.

In this work, we used the method of CWS and ACLF preparation, which includes two operations: wet grinding of coal to a particle size of 200-300 µm using a ball drum mill or other similar devices and subsequent processing of a suspension-emulsion mixture containing all components of the produced fuel using a rotary hydrodynamic cavitation generator (RHDCG) [2]. Processing via the RGDK includes three mechanisms of coal particle destruction: shock, abrasion, and cavitation; this device is an effective dispersant and homogenizer. The calorific content of composite fuels can be calculated knowing the calorific value of fuel components and their content. However, such characteristics as viscosity, particle size distribution of the coal mass, sedimentation stability of CWS and ACLF depend significantly on the stage of coal metamorphism, the type of additives, and the method of fuel preparation. According to experiments, the water-soluble components slightly affect
the above characteristics. A more prominent role is played by liquid products that are immiscible with water. In this work, we used brown coal of grade B2 or anthracite cake to prepare CWS. Brown coal, oil of grade M8 and fuel oil of grade 100 were also used in ACLF preparation. The solid/liquid ratio was 50/50. Coal granules were measured using a SALD-2101 Laser Diffraction Particle Size Analyzer (SHIMADZU, Japan). The viscosity of suspensions was determined using a REOTEST 2 rotational viscometer.

2. Results

The granulometric composition of the coal mass in a coal-water suspension obtained by mechanical mixing of coal powder produced by dry grinding of brown coal of grade B at the ball-drum mill and water is presented in Fig. 1 before cavitation treatment and after a 2-minute treatment at RHDCG. As we can see, significant regrinding of coal occurs due to cavitation. However, the total mass of coal with a particle size of less than 10 µm remained virtually unchanged, whereas in our similar experiments with coal and anthracite this fraction increased from 2 - 3% to 25 - 30%. Apparently, brown coal, as more plastic, is less susceptible to cavitation destruction on a microscale, and, moreover, it is possible that brown coal particles of submicron sizes stick together more intensively after cavitation treatment than particles of coals of higher stages of metamorphism.

![Figure 1. Granulometric composition of the coal mass in CWS before ▲ and after ● cavitation treatment.](image-url)
Data on dynamic viscosity of a coal-water suspension with oil additives are presented in Fig. 2. As we can see, introduction of oil into the suspension leads to an increase in its viscosity. Moreover, the oil content of about 4%, from the point of view of mixture fluidity, becomes almost critical.

In another series of experiments, the CWS viscosity was measured, when fuel oil of grade 100 was introduced instead of oil. It turned out that oil additives have even more significant effect on suspension viscosity than oil. The one-percent content of fuel oil in suspension is already close to critical. It is known that the viscosity of fuel oil decreases with increasing temperature. However, in this case, the viscosity of CWS with a small addition of fuel oil even increased with increasing temperature. The joint introduction of equal amounts of fuel oil and diesel fuel into CWS did not result in viscosity increase.

Data on granulometric composition of the coal mass and dynamic viscosity of CWS prepared on the basis of cake obtained by flotation enrichment of anthracite powder at OJSC “Siberian Anthracite” are shown in Figs. 3 and 4. First of all, we should note a high degree of anthracite grinding in suspension. Two-minute cavitation treatment of suspension led to additional grinding of coal. As for viscosity, the two-minute treatment of suspension with cavitation changed it little.
Conclusions
As a result of experiments performed with a coal-water suspension based on brown coal of grade B2, it has been found that a) cavitation treatment of CWS at the rotary hydrodynamic cavitation generator (RHDCG) leads to significant regrinding of the coal mass and has a little effect on the suspension viscosity; b) with addition of technical oil of grade M8 to suspension in small portions, the processing
allows obtaining a homogeneous mixture that does not stratify within a week, c) the dynamic viscosity of the emulsion-suspension mixture increases with increasing oil content. Moreover, even with an oil content of about 5%, the viscosity of suspension takes supercritical values, which will cause difficulties in spraying and burning fuel.

A more noticeable increase in viscosity occurs when fuel oil is introduced into CWS. Here the viscosity takes the critical values even when the fuel oil content is about 1%.

In the case of CWS based on the use of anthracite cake, cavitation treatment also leads to noticeable reduction of coal particle size (especially in the range of particle sizes of up to 10 μm), and does not affect the viscosity of suspension.

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