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The effect of anionic dispersants on the moisture distribution of a coal water slurry

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ABSTRACT

Coal water slurry (CWS) was prepared from lignite washery tailings. Its moisture content can be subdivided into two forms: free water (surface adsorption water) and bound water, i.e., interparticle, capillary, adhesion and internal adsorption water. The effect on moisture distribution of three distinct dispersants was studied through thermal drying and TG–DSC analysis. A new test method combining thermal drying and bond strength analysis was put forward for a thorough moisture distribution. The new method showed reasonable results and arrives at the same conclusion as the TG–DSC method. The addition of dispersants increased the free water content and decreased the bound water content, in particular those of interparticle and capillary water. Also there was a slight decrease in total moisture, compared to CWS prepared without dispersant. The moisture distribution showed its biggest change with dispersant CLS (calcium lignosulfonate), followed by dispersant NDF (a co-polymer of methylene naphthalene sulfonate, styrene sulfonate and maleate), and ended up with NNO (sodium methylene bis-naphthalene sulfonate).

1. Introduction

Coal water slurries (CWSs) have been regarded as a promising coal-based fuel with high solid concentration, and thus saving transport, storage and dewatering costs [1–5]. A typical CWS consists of 60–75% coal and about 1% chemical additives, with water as the balance [1]. Already in 1981 CWS fuel was successfully proposed by Zhejiang University as a key R&D project in China. Till now, CWS fuel has been used in over 20 power plants, over 300 industrial furnaces and several hundreds of various kilns in China [6]. CWSs prepared from lignite washery tailings are commonly used as a clean energy application for its transport possibility by pipes, its disposal ability of solid waste and its inflammability with high volatile content. High concentration and rheological properties are the two most important parameters in preparing CWSs. Thus, studies in this area have drawn increased attention from researchers in recent years.

According to our experimental result, the moisture content of CWSs prepared from lignite washery tailings was reduced after dispersant is added. Investigations have been conducted in order to explain the reason. The effect of dispersants on viscosity and rheological property was found to be generally discussed [7–12]. However, very few studies were launched on how dispersants affect the moisture distribution of CWSs. The inherent moisture of coal is reported as one of the most important factors affecting the moisture distribution of CWS [13,14]. Also the porosity of coal is a function of inherent moisture, which plays an important role in the rheological properties of CWS [15,16]. All the signs indicated the necessity to study the moisture distribution of CWSs as well as the changes between each kind of water after dispersant is added.

The different water forms need to be studied before measuring the moisture distribution. Water in lignite exists in many states, due to its complicated pore structure and the presence of polar groups, which is similar to sewage sludge. Therefore, the moisture distribution in sludge was taken as a reference in this study. Usually, two main types of water are considered, the free water, which is not influenced by the solid particles and the bound water, whose properties are modified due to the presence of the solids [17]. However, this simple classification is insufficient to fully understand the condition of water in CWSs. It is also difficult to figure out the influence mechanism of the dispersant on the properties of CWSs. Many different methods were reported for water classification. Vaxelaire and Cezac [17] reviewed the different definitions of water distribution. Tsang and Vesilind [18] classified the water into free, interstitial, surface, and bound water. Smollen [19] classified the water into free, immobilized, bound, and chemically bound water. There is no clear classification of water in wet material.

More rationally, Karthikeyan et al. [20] classified water depending on its location in lignite (Fig. 1): 1. Surface adsorption water, forming

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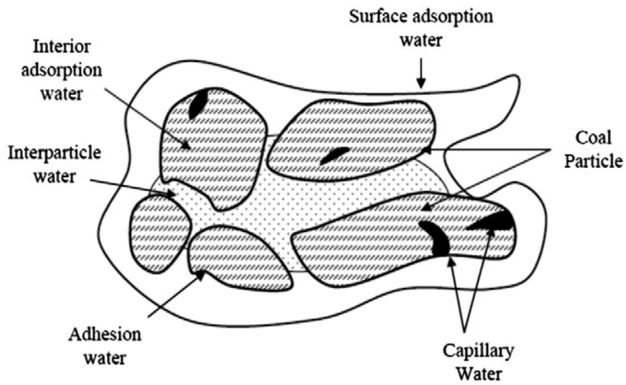

Fig. 1. Different forms of water associated with coal [20].

a layer of water molecules adjacent to the coal molecules but only on the particle surface. 2. Interparticle water, present between two or more particles. 3. Capillary water, contained in capillaries and small crevices of each particle. 4. Adhesion water, forming a layer or film around the surface of individual or agglomerated particles. 5. Interior adsorption water, contained in micropores and microcapillaries within each coal particle, deposited during formation.

Until now, no accurate method was reported to measure the moisture distribution of CWSs prepared from lignite washery tailings. Such a moisture distribution is mostly discussed for wet materials like sewage sludge and oil sludge, with methods such as thermal drying method, dilatometric method, TG–DTA and TG–DSC [21]. There are advantages and disadvantages in each method. Considering the complicated pore structure and the polar groups of lignite, the CWSs prepared from lignite washery tailings show similar properties to those of sewage sludge. In this study thermal drying and the TG–DSC method were used to examine the moisture distribution. The thermal drying method has good repeatability and the moisture distribution can be subdivided into three forms: free water, middle water and bound water. However, the middle water can hardly be subdivided any more. The coal water binding energy can be calculated by TG–DSC as a function of the changing moisture percentage. But representative sampling is needed.

In this study, a new method is put forward to determine the moisture distribution of CWSs. Indonesian lignite washery tailings (LWT) was used to prepare CWS. A lignite (LIG) sample from Indonesia was also used as a reference sample, in addition to the lignite washery tailings. This paper demonstrates the effect of three anionic dispersants on the moisture distribution of CWSs prepared from Indonesian lignite washery tailings.

2. Experimental

2.1. Samples

Both the lignite washery tailings (LWT) and the lignite (LIG) were obtained from South Sumatra, Indonesia. The results of proximate and ultimate analysis of the LWT and LIG are presented in Table 1. Two conventional anionic dispersants were selected in this study: sodium methylene bis-naphthalene sulfonate (NNO) and calcium lignosulfonate (CLS). Besides, another dispersant (NDF) is a co-polymer of methylene naphthalene sulfonate, styrene sulfonate and maleate. It was first

Table 1
Proximate and ultimate analysis (wt.%) of LWT and LIG.

Sample	Proximate analysis			Ultimate analysis (daf)				$S_{t,d}$
	M_{ad}	A_d	V_{daf}	C	H	N	O	
LWT	10.12	18.84	55.34	66.95	5.41	1.45	>25.89	0.21
LIG	11.57	21.36	58.12	65.00	4.80	0.66	>29.19	0.14

daf is the dry and ash-free base; M_{ad} is the moisture (air dried base); A_d is the ash (dry base, i.e., moisture-free base); and V_{daf} is the volatile matter (dry and ash-free bases).

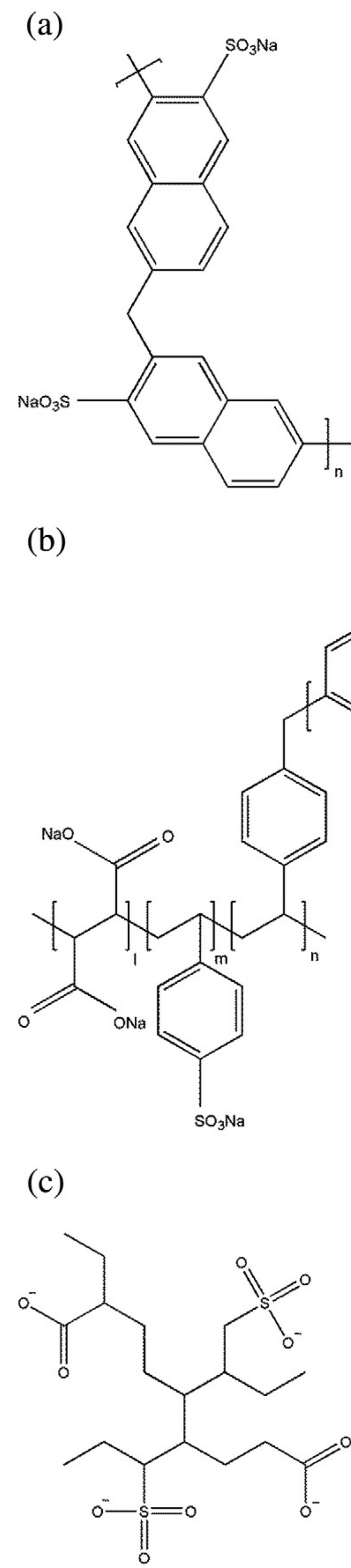

Fig. 2. Schematic drawings of the molecular structures of (a) NNO, (b) NDF [22], and (c) CLS.