Wetting of Coal by Aqueous Surfactant Solutions

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Synopsis. The rates of wetting of coals of various carbon content by aqueous anionic surfactant solutions were measured. It was found that the rates of wetting increased with increasing concentration of the anionic surfactant in solution and further, the addition of electrolyte significantly promoted the rates of wetting. The presence of the electrolyte on the surface of coal after wetting was confirmed by the zeta potential measurement.

Wettability of coal[1—3)] has been investigated to understand mechanisms of coal flotation, coal dust suppression, and coal–oil mixture. Recently, a coal–water mixture has been receiving attention as a fuel source. Thus, extensive studies have been made of the nature of adsorption of surfactants[4)] on coal to understand stability of coal–water mixture. Glanville and Wightman[5)] have reported that rates of wetting of coal by aqueous surfactant solution are influenced by addition of dipositive metal ions. Acceleration of wettability of coal into aqueous solution is one of the factors necessary to prepare a stable coal–water mixture.

In this note, the wetting behavior of coals of various carbon content by aqueous anionic surfactant solution is discussed by measuring the wetting rates, the zeta potential of the coals and the surface tension of aqueous anionic surfactant solutions.

Experimental

Materials. The coals used in this study were Yallourn, Taiheiyo, Miike, and Hon-gay which were sieved between 60 and 100 mesh. Their pertinent properties have been described elsewhere.[4)]

Sodium 1,2-bis(2-ethylhexyloxycarbonyl)ethanesulfonate (Aerosol OT), sodium 1,2-bis(2-methylpentyloxycarbonyl)ethanesulfonate(Aerosol MA), and sodium 1,2-bis[diamyl(mixture of 2-methylbutyl and 3-methylbutyl)oxycarbonyl] ethanesulfonate (Aerosol AY) were obtained from the American Cyanamid Co. They were used without further purification. The metal salts used were obtained as laboratory grade reagents.

The water used was purified by passing through Milli-Q Reagent-Grade Water Systems until its specific conductivity fell below $10^{-7}\,\Omega^{-1}\,\mathrm{cm}^{-1}$.

Measurements. To estimate rates of wetting of coal, sink times were measured for 0.30 g of coal gently deposited on the surface of the aqueous surfactant solution. Tests were carried out in a room maintained at 25 ± 2 °C. The time taken for the last trace of unwetted coal particles to break through the surface of the aqueous surfactant solution was measured with a stopwatch. The average value of four or five run was taken as the final sink time. The standard deviation was 15%. The rate of wetting of coal was evaluated as the surface area of coal wetted per second.

The zeta potential of coal particles after exposure to the aqueous surfactant solution was measured using a Pen Kem Laser 500 Zeta Potential. The surface tension of the solution was measured using a Wilhelmy-type tensiometer at 25 °C.

Results and Discussion

Figure 1 shows the rates of wetting of coals of various carbon content by the aqueous surfactant solutions. It is seen that the rates of wetting are increased with the concentration of the surfactant. Furthermore, it is noteworthy that the behavior of rates of wetting of coals of various carbon content by Aerosol OT is different from those by Aerosol MA and Aerosol AY. Although it is known that the rate of wetting is a function of surface tension of the solution,[6)] the surface tensions of the three Aerosol surfactant solutions were almost the same at each cmc in this study. Here, each cmc was as follows: Aerosol OT, 2.76; Aerosol MA, 15; Aerosol AY, 34 mmol dm^{-3}. Therefore, the differences among the three surfactants might be explained by diffusion rates and orientation of surfactants at the coal surfaces rather than by a surface tension effect. The surfactants having short-chain hydrophobic groups, such as Aerosol MA and Aerosol AY, are generally[6)] believed to have faster rates of diffusion to and orientation at coal surfaces than that with long-chain hydrophobic groups like Aerosol OT. Especially, such a difference in the rates of wetting is apparent on relatively high carbon content coals, such as Miike and Hon-gay.

Since addition of electrolyte to the aqueous surfactant solution would be expected to have a considerable effect on the wetting of coals, the effect of electrolyte on the rate of wetting of coals was examined. The results are depicted in Fig. 2. In Aerosol OT-electrolyte system, the addition of electrolyte to Aerosol OT promoted the rates of wetting of all the coals tried. In particular, the addition of strontium chloride gave the most effective result. Similar results were obtained for systems of Aerosol MA-electrolyte and Aerosol AY-electrolyte. The addition of a tripositive electrolyte, such as lanthanum nitrate, was not so effective on the rate of wetting of coals as that of

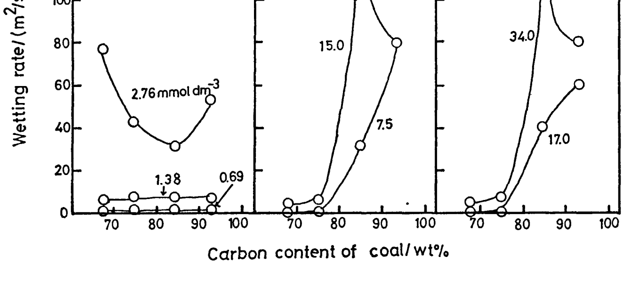

Fig. 1. The rates of wetting of coals with various carbon content by the aqueous surfactant solutions.
(a): Aerosol OT, (b): Aerosol MA, (c) Aerosol AY.

Table 1. The surface tensions of aqueous aerosol surfactant solutions with and without electrolyte

Sample(concn/mmol dm^{-3})	Surface tension dyn cm^{-1} (at 25 °C)
Aerosol OT(0.69)	39.0
Aerosol OT(0.69)-$SrCl_2$(0.26)	25.5
Aerosol OT(0.69)-$La(NO_3)_3$(0.26)	26.5
Aerosol OT(0.69)-$ZnCl_2$(0.26)	27.6
Aerosol OT(0.69)-$CaCl_2$(0.26)	27.7
Aerosol OT(0.69)-$MgCl_2$(0.26)	28.0
Aerosol MA(7.5)	41.7
Aersol MA(7.5)-$La(NO_3)_3$(0.26)	31.4
Aerosol MA(7.5)-$SrCl_2$(0.26)	37.5
Aerosol AY(34)	32.6
Aerosol AY(34)-$La(NO_3)_3$(0.26)	28.0
Aerosol AY(34)-$SrCl_2$(0.26)	32.3

a dipositive electrolyte. The surface tensions of Aerosol surfactants with and without electrolyte are tabulated in Table 1. The addition of electrolyte, particularly strontium chloride, reduced the surface tension of Aerosol OT surfactant significantly. Thus, the electrolyte that decreased the surface tension of the surfactant solution increased its rate of wetting of coal. In Aerosol MA and Aerosol AY systems, the rates of wetting of coals were promoted by the addition of electrolyte, although the ratio of electrolyte to surfactant is different for each system.

Further, to elucidate the interaction of coal surfaces and the surfactant with and without the electrolyte, the zeta potentials of coal particles after their exposure to the solutions were measured. The results are shown in Fig. 3. The zeta potential of coal particles after the exposure to the Aerosol surfactant solution containing electrolyte was less negative than that in the Aerosol surfactant solution alone. This implies that dipositive or tripositive ions are present on the coal surface. Accordingly, it follows that the adsorption of dipositive or tripositive ions promotes the rate of wetting of coal by Aerosol surfactant solution.

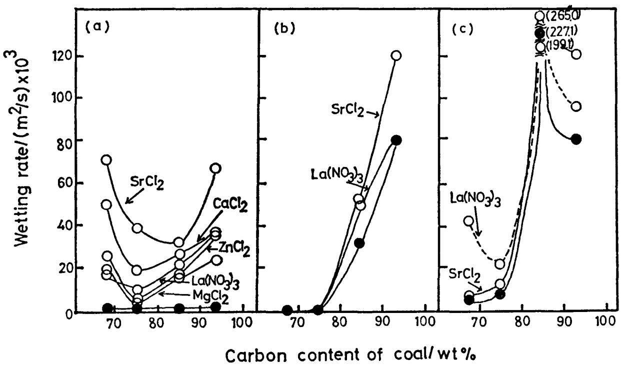

Fig. 2. The rates of wetting of coals with various carbon content by the aqueous surfactant solutions with (○) and without (●) electrolyte. The concentration of electrolyte is 0.26 mmol dm^{-3}.
(a): Aerosol OT, 0.69 mmol dm^{-3}, (b): Aerosol MA, 7.5 mmol dm^{-3}, (c): Aerosol AY, 34 mmol dm^{-3}.

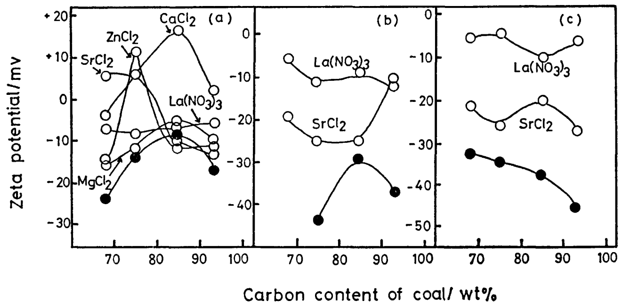

Fig. 3. The zeta potentials of coal samples shown in Fig. 2.

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