Wetting of Coal by Nonionic Surfactant and Mixtures of Nonionic and Anionic Surfactants

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Synopsis. The rates of wetting of coals with various carbon contents by aqueous nonionic surfactants and mixtures of nonionic and anionic surfactants were examined. It was found that the wetting rate of each coal decreased with an increase of the length of oxyethylene chain in the nonionic surfactant. Further, the wetting rate of coal by anionic surfactant was enhanced by the addition of nonionic surfactant. This enhancement was most effective for coals with relatively low carbon content.

Wettability of coal allows us to understand mechanisms of coal flotation, coal dust suppression, and coal–water mixing. A number of techniques[1–3] have been used to measure the wettability of coal. Glanville and Wightman[4] have employed a wetting time method. They have reported that rates of wetting of coal by aqueous surfactant solution are accelerated by addition of dipositive metal ions. Esumi *et al.*[5] have studied the effect of dipositive metal ions on wetting of coals with various carbon contents by anionic surfactant solutions. They have demonstrated that the rates of wetting of coals are enhanced more effectively by anionic surfactants with long-chain hydrophobic groups than those with short-chain ones, in the presence of dipositive metal ions.

In this work, effects of nonionic surfactants and mixtures of nonionic and anionic surfactant solutions on the wetting of coals were investigated by measuring the wetting rates and the zeta potential of wetted coal particles.

Experimental

Materials. The coals used in this work were Yallourn, Taiheiyo, Miike, and Hon-gay coals, whose carbon contents were 61.6, 74.8, 85.2, and 93.0 wt%, respectively. They were sieved between 60 and 100 mesh. The other physical properties for them have been described elsewhere.[6]

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. Poly(oxyethylene)nonylphenyl ethers (NP-*n*, where *n* indicates the average mole number of oxyethylene units) were supplied by Nikko Chemicals Co., Ltd. These surfactants were used without further purification.

The water used was purified by passing through Milli-Q Reagent-Grade Water Systems until its specific conductivity fell below 10^{-7} Ω^{-1} 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 in a 100 ml beaker at 25 °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. Here, the rate of wetting of coal was expressed as the surface area of coal wetted per second to compare the wettability of coals with different surface area.

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

Results and Discussion

Figure 1 shows the wetting rates of coals with various carbon contents as a function of the concentration of nonionic surfactants. It can be seen that the wetting rate of each coal is enhanced with an increase of the concentration of nonionic surfactant. Further, the wetting rates of coals are influenced by the length of the oxyethylene chain in the nonionic surfactant; the wetting rate of each coal decreases with an increase of the length of oxyethylene chain from 7.5 to 50. In this study, the optimum oxyethylene chain at which a maximum wetting rate of all the coals except Hon-gay coal is attained is located at 7.5—15 mol. Glanville and Haley[7] have also studied the wetting rates of coal obtained from the Pocahontas No. 3 Seam of McDowell County, West Virginia by using a series of polyethoxylated alkylphenol and have reported that there is an optimum degree of ethoxylation for a maximum wetting rate of coal dust. Thus, the above results can be interpreted by considering the surface tension of the nonionic surfactant and the diffusion rate to the coal surfaces: as the surface tension of nonionic surfactant

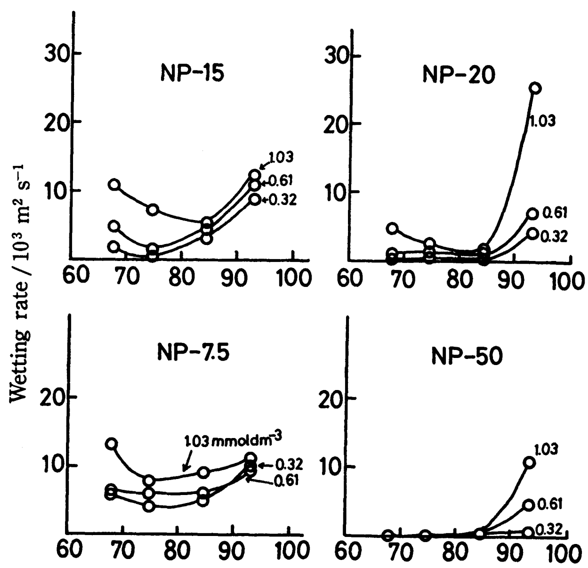

Fig. 1. The rates of wetting of coals with various carbon content by nonionic surfactant solutions.

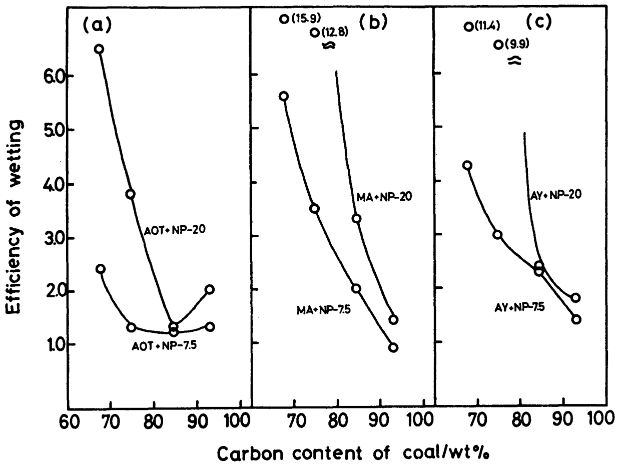

Fig. 2. The efficiency of wetting of coals with various carbon content by addition of nonionic surfactant in the presence of anionic surfactant.
(a): Aerosol OT, 1.38 mmol dm^{-3}, NP-*n*, 0.61 mmol dm^{-3}, (b): Aerosol MA, 7.5 mmol dm^{-3}, NP-*n*, 0.61 mmol dm^{-3}, (c): Aerosol AY, 14 mmol dm^{-3}, NP-*n*, 0.61 mmol dm^{-3}.

at a same concentration increases from NP-7.5 to NP-50, the wetting rate of coal by the nonionic surfactant is accelerated from NP-50 to NP-7.5 and the nonionic surfactants with longer oxyethylene chains are believed to diffuse more slowly than those with shorter ones. Compared with anionic surfactants[5] such as Aerosol OT, MA, and AY, the addition of the nonionic surfactants is less effective on the wetting rate of coal.

As the addition of nonionic surfactant has been shown to increase the wetting power for textile[8] by some anionic surfactants, a similar effect will be expected for the wettability of coal. So, the effect of nonionic surfactants on the wetting rate of coal by anionic surfactant solution was examined. Here, the efficiency of wetting rate of coal by the addition of nonionic surfactant can be evaluated by the ratio of the wetting rate of coal by the addition of nonionic surfactant in the presence of anionic surfactant to the sum of wetting rates of coal in each surfactant. The results are given in Fig. 2. In Aerosol OT–NP-*n* system, the efficiency of wetting decreases with an increase of carbon content and shows a minimum at 85.2 wt%, then increases for both NP-7.5 and NP-20. On the other hand, the efficiency of wetting decreases gradually with an increase of carbon content until 74.8 wt%, then rapidly for Aerosol MA–NP-*n* and Aerosol AY–NP-*n* systems. Particularly, the wetting rates of Yallourn and Taiheiyo coals are enhanced most effectively by the addition of NP-20 in the presence of Aerosol MA and AY, respectively. Since the surface tensions of these systems are not so different, this enhancement might be attributed to an increase caused by the nonionic surfactant in the mobility of the anionic surfactant, resulting in more rapid diffusion to the surface of coal particles.

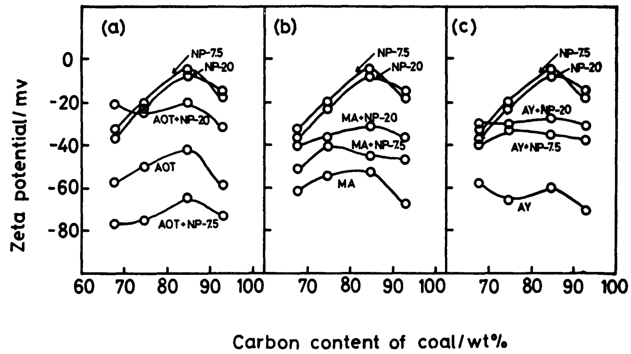

Fig. 3. The zeta potentials of coals shown in Fig. 2.

To elucidate the interaction of coal surfaces and the anionic surfactant by the addition of the nonionic surfactant, the zeta potentials of coal particles after their exposure to the aqueous surfactant solution were measured. The results are depicted in Fig. 3. The magnitudes of zeta potentials of coal particles after the exposure to the anionic surfactant–NP-*n* systems are located between that of anionic and of nonionic surfactants alone, except for the Aerosol OT–NP-7.5 system. The above results imply that co-adsorption of anionic and nonionic surfactants occurs on the coal surface and weakens the repulsion forces between anionic surfactant molecules, resulting in the promotion of the wetting rates of coal.

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