Adsorption of Surface Active Agents on Coals

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Synopsis. The interactions between surface active agents and coals with various carbon contents were studied by measuring adsorption isotherms and zeta potentials. A characteristic adsorption behavior was observed for the coals among three different surface active agents, but no correlation was found between the adsorption and the carbon content of the coal.

The surface properties of coal[1,2] have been investigated to understand the mechanisms of coal flotation, coal dust suppression, and coal–oil mixture behavior. Glanville and Wightman[3] studied the wetting rates of powdered coal by alkanol–water solutions; they found that a critical concentration of each alkanol was needed before any wetting occurred and that this critical wetting concentration was lower for alcohols with longer carbon chains. Recently, a coal–water mixture has been found attracting as a fuel source. Although it is important to elucidate the interactions between coal surfaces and surface active agents, there have been few reports on this subject.

In this paper, the interaction between coals of various carbon contents and surface active agents will be reported, using adsorption isotherm and zeta potential measurements.

The coals used in this study were Yallourn, Taiheiyo, Miike, Hon-gay, Tenpoku and Wandoan. They were dry sieved between 60 and 100 mesh screens. The pertinent properties of these coals are given in Table 1.

The surface active agents employed were sodium dodecylbenzenesulfonate (ABS), 1-dodecylpyridinium chloride (DPCl), and polyoxyethylene nonylphenyl ether (NP-7.5) which were supplied by Wako Pure Chemical, Industries, Ltd., Tokyo Kasei, Co. Ltd., and Nikko Chemical, Co., respectively. They were used without purification.

The water used was purified by passing through an ion exchange column followed by filtration from Milli-Q Water Purification System.

The amounts of surface active agents adsorbed on the coals were determined from the difference of the concentration of surface active agents before and after

Table 1. Pertinent properties of coals

	C[a)] (wt%)	H[a)]	H_2O[b)]	Ash[b)]	Specific surface area[c)] $m^2\ g^{-1}$
Yallourn	61.5	4.6	12.2	0.9	1.62
Tenpoku	68.1	5.5	14.3	22.9	4.19
Taiheiyo	74.8	6.0	6.6	8.4	0.68
Wandoan	80.2	6.6	9.3	8.0	2.30
Miike	85.2	6.5	1.2	7.8	0.53
Hon-gay	93.0	3.3	1.7	3.4	0.16

a) From JIS M 8813. b) From JIS M 8812, 60-100 mesh. c) From the nitrogen adsorption at 77 K.

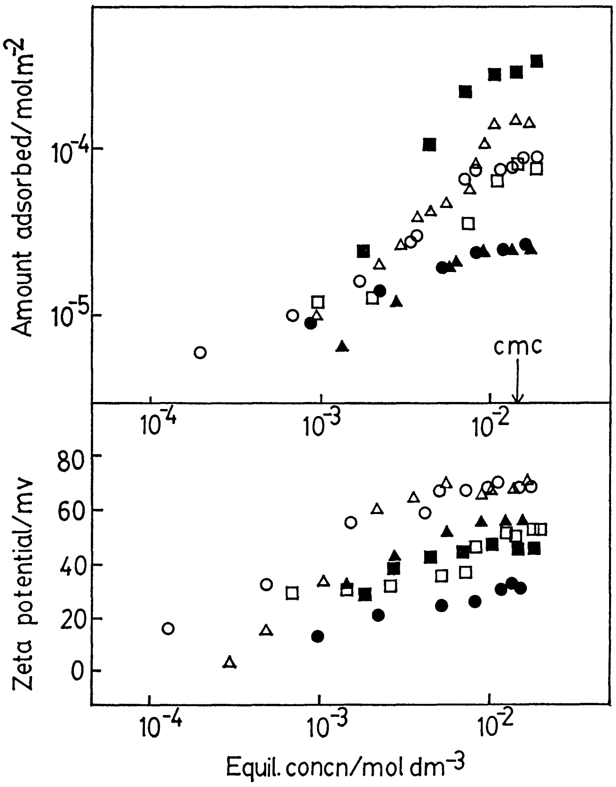

Fig. 1. Adsorption isotherms of DPCl on coals at 25 °C and the corresponding zeta potential result; (○) Yallourn, (●) Tenpoku, (△) Taiheiyo, (▲) Wandoan, (□) Miike, and (■) Hon-gay.

the adsorption by means of UV spectrophotometer (Hitachi ESP-3T). The zeta potentials of the coal surfaces were measured by mean of a Laser Zee Model 500 (Pen Kem Co.). The critical micelle concentration of the surface active agent was determined from the surface tension measurement.

When the coals of various carbon contents shown in Table 1 were dispersed in water, they gave characteristic surface charges. All the coals except Hon-gay coal were found to be negatively charged in electrophoresis, while Hon-gay coal was positively charged. Generally the coal surface is more easily oxidized as the carbon content of the coal decreases. Such an oxidized coal surface would be expected to exhibit a negative charge in water due to dissociation of the carboxyl group. However, in this study, no relation between the carbon content of coal and the surface charge of the coal in water was obtained.

Adsorption isotherms of the surface active agents on coals from water and the corresponding surface charge of the coals are shown in Fig. 1. In Fig. 1, the amount of DPCl adsorbed increased with increasing the concentration of DPCl. Especially, in the case of Yallourn coal, the adsorption isotherm was similar to those which

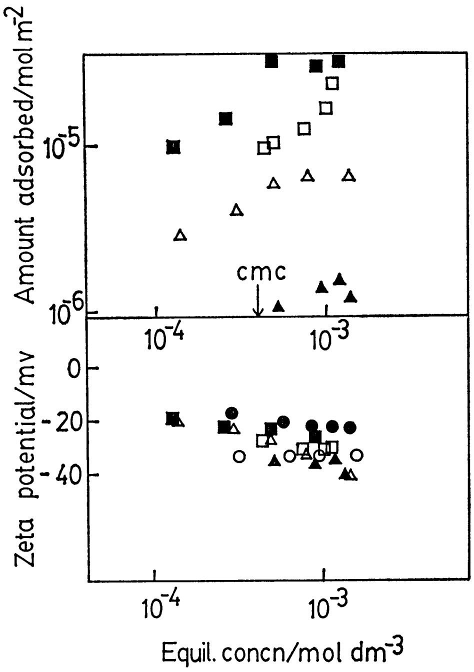

Fig. 2. Adsorption isotherms of ABS on coals at 25 °C and the corresponding zeta potential result; (○) Yallourn, (●) Tenpoku, (△) Taiheiyo, (▲) Wandoan, (□) Miike, and (■) Hon-gay.

Somasundaran and Fuerstenau[4] established in ionic surfactants–alumina system. That is, at low concentration, the adsorption obeyed Henry's law. The adsorption increased rapidly with the concentration of DPCl, but later increased more slowly. Finally, above the cmc, the adsorption reached a plateau. The zeta potential of coal by adsorption of DPCl increased positively on increasing the concentration. Two mechanisms are proposed for the orientation of DPCl on the coals. One is that DPCl molecules are adsorbed on the nonpolar surface of coal with the polar groups outward. The other is that the positively charged group of the DPCl molecule is oriented towards the negatively charged sites on the coal. Further, it is expected that near the cmc, a bimolecular layer of DPCl is formed on polar sites of the coal.

Figure 2 gives the adsorption isotherms of ABS on coals and the corresponding zeta potential measurements. In case of Yallourn and Tenpoku coals, the amount of ABS adsorbed was so small that it could hardly be estimated. The adsorption increased with increasing concentration of ABS and reached plateaus above the cmc for Hon-gay and Taiheiyo coals. On the other hand, the amount of ABS adsorbed on Wandoan and Miike coals increased even above the cmc. The zeta potential of the coals after the adsorption of ABS increased negatively with the concentration. This indicates that ABS molecules are adsorbed on nonpolar surface of coal with their polar groups outward.

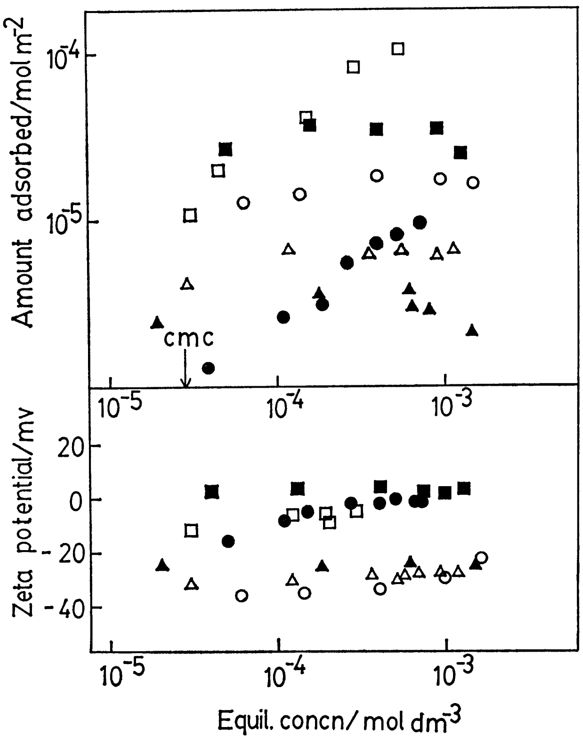

Fig. 3. Adsorption isotherms of NP-7.5 on coals at 25 °C and the corresponding zeta potential result; (○) Yallourn, (●) Tenpoku, (△) Taiheiyo, (▲) Wandoan, (□) Miike, and (■) Hon-gay.

Adsorption isotherms of NP-7.5 on coals and the corresponding zeta potential result are shown in Fig. 3. At above the cmc of NP-7.5, the adsorption increased with the concentration for Tenpoku and Miike coals, whereas for the other coals, the adsorption was almost constant. On the other hand, the zeta potential of the coals was almost constant in spite of different amounts adsorbed, because NP-7.5 is a nonionic surface active agent.

Comparing with the amount adsorbed of surface active agent on coals, the amount of DPCl adsorbed was much larger than that of ABS for all the coals. The amount of NP-7.5 adsorbed was intermediate between those of DPCl and ABS for all the coals. Furthermore, no correlation was observed among the amount of surface active agent adsorbed, the zeta potential of the coal after the adsorption, and the carbon content of the coal.

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