석탄의 입도분포가 CWM의 유변학적 성질에 미치는 영향

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Effect of Coal PSD on the Rheological Behaviors of CWM(Coal-Water Mixture)

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Introduction

The CWM(Coal-Water Mixture) fuel that comes to the front recently as one of important coal utilization technologies enables coal to be burned in a liquid-state to settle a lot of inconveniences and disadvantages that coal has as a solid-state fuel. It is assessed as a technology by which high economics and short-term commercialization might be realized in comparison with the gasification or liquefaction technologies of coal [1, 2].

Characterization of rheological behavior in highly loaded coal-water mixture is one of the most important fields in utilizing coal as an easy-handling liquid state fuel. Since the idea of utilizing highly loaded CWM as a substitute fuel for oil has received worldwide attention again from late 1970's, numerous studies [3, 4] have been carried out extensively on its rheological properties over the past decade in an effort to obtain highly loaded mixtures with acceptable fluidity while maintaining sufficient stability against sedimentation of coal particles.

In order to add to the understanding of the factors governing the rheological properties of CWMs, the influence of size and its distribution of coal particles was studied on the apparent viscosity and non-Newtonian behaviors of CWM. Also, rheological behavior in the binary and ternary mixture composed of the coal particles with different mean size were investigated, using anionic surfactant as additive.

Experiment

CWM was prepared with seven bituminous coals using dry-grinding method; a commercialized anionic surfactant(CWM 1002) was adopted as an additive to prepare CWM; and NaOH was employed as an electrolyte. The amounts of CWM 1002 and NaOH were fixed at 0.4 and 0.1 wt% based on the CWM weight, respectively. Also, The experiments on the effect of coal particle size were carried out using 30 coal particle samples with the MMD of 13.8 - 97.4 μm. The apparent viscosity of CWM was measured by Haake Viscometer(Model RV12) and the non-Newtonian behavior of CWM was evaluated by the power-law model.

Results and Discussions

Effect of Mean Particle Size Fig.1 represents the effect of coal particle size on non-Newtonian behaviors of CWM. In this figure, all the five CWMs prepared with the coal particles having MMD below 30.8 μm reveal shear-thickening property, which is n > 1, and other CWMs prepared with the coal particles having the MMD over 42.3 μm display shear-thinning behavior. Also, both the dilatant and pseudoplastic property of CWM increase as the MMD of coal particles decreases. Further, in case of dilatant CWMs, n and K decrease with increasing MMD, but for the CWMs showing pseudoplastic property, n is increased and K is decreased with the increasing MMD of coal particles.

Effect of Coal PSD in Binary System It is of interest to note that CWM viscosity is the lowest at a fine: coarse blending ratio of 35±5 : 65∓5, regardless of the ratio of the mean diameters of the fine and coarse particles(Fig. 2). This mixing ratio is nearly the same as that for minimum voidage when mixing spherical solids particles of two sizes [5, 6]. This figure also implies that a CWM prepared with an appropriate blending ratio of two types of coal particles of different fineness is lower in viscosity than one prepared with single-sized particles, and that the lower the mean diameter ratio, the lower the viscosity. Some of the results in Fig. 2 coincide qualitatively with other findings [6, 7] concerning the effect of coal PSD on packing fraction or voidage of solids particles and viscosity variation of coal slurries.

Fig. 3 represents the variation of power-law model constants with the mixing ratios of two different coal samples showing shear-thinning and shear-thickening characteristics, respectively, when each of them is independently used to prepare CWM fuel. From this figure, we observe that the variation of K value with the mixing ratios of two coal particles is very similar to that of apparent viscosity and that the values n also display a linear proportionality with the blending ratios. Therefore, it is supposed that if CWM is prepared by blending coarse coal particles with pseudoplastic property and fine coal particles with dilatant property, non -Newtonian property of CWM moves from the pseudoplastic to the dilatant as the fraction of fine coal particles is increased.

Solid Volume Fraction at Maximum Packing Fig. 4 shows the variation of apparent viscosity, η, and maximum packing density, ϕ_m, with the fraction of fine coal particles. From this figure, it is clear that the blending ratio of fine coal particles indicating minimum value of η is exactly in agreement with the blending ratio of fine coal particles accompanying maximum value of ϕ_m.

Effect of Coal PSD in Ternary System Fig. 5 shows the apparent viscosity for the ternary mixture consisting of the same three coal particles. From these figures, it is shown that the apparent viscosity of CWM is considerably reduced even in the case of adding only 20 - 30 wt% of coarse coal particles(X), compared to the case of blending only medium-size(Y) and fine-size coal particles(Z). Also, the variation of apparent viscosity is found to be the largest when coarse-size particles are added to the binary mixture composed of medium-size and fine-size coal particles.

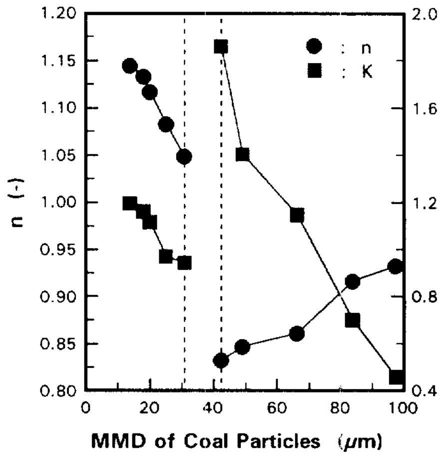

Fig. 1. Influence of coal particle size on the non-Newtonian behavior of CWM.

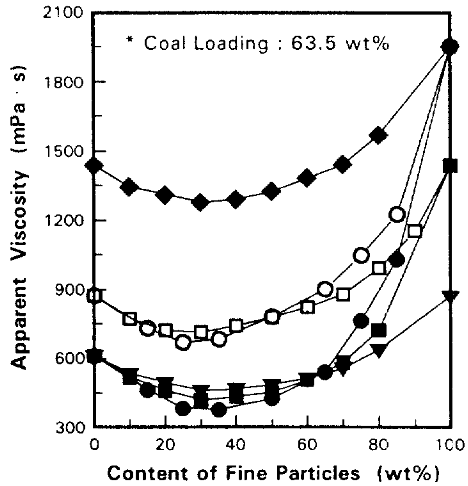

Fig. 2. Variation of CWM apparent viscosity with mixing ratio of fine coal particles. $d_{f,m}/d_{c,m}$ (μm) : ◆, 20.0/25.1; ○, 20.0/42.3; □, 25.1/42.3; ●, 20.0/83.9; ■, 25.1/83.9; ▼, 42.3/83.9.

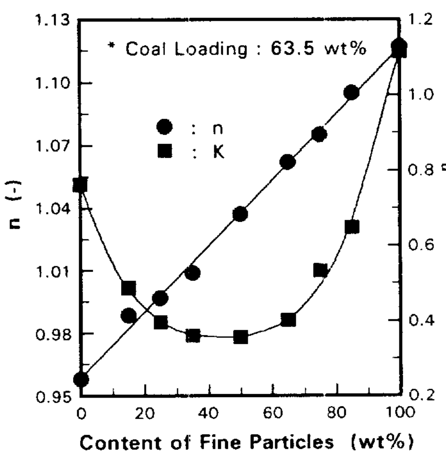

Fig. 3. Variation of non-Newtonian behavior of CWM with mixing ratio of fine coal particles. $d_{f,m}/d_{c,m}$ (μm) : 20.0/83.9.

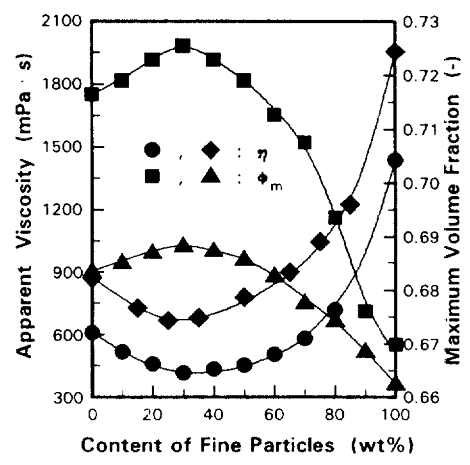

Fig. 4. Influence of fine particle content on the maximum solid volume fraction and apparent viscosity of CWM. $d_{f,m}/d_{c,m}$ (μm) : ● & ■, 25.1/83.9; ◆ & ▲, 20.0/42.3.

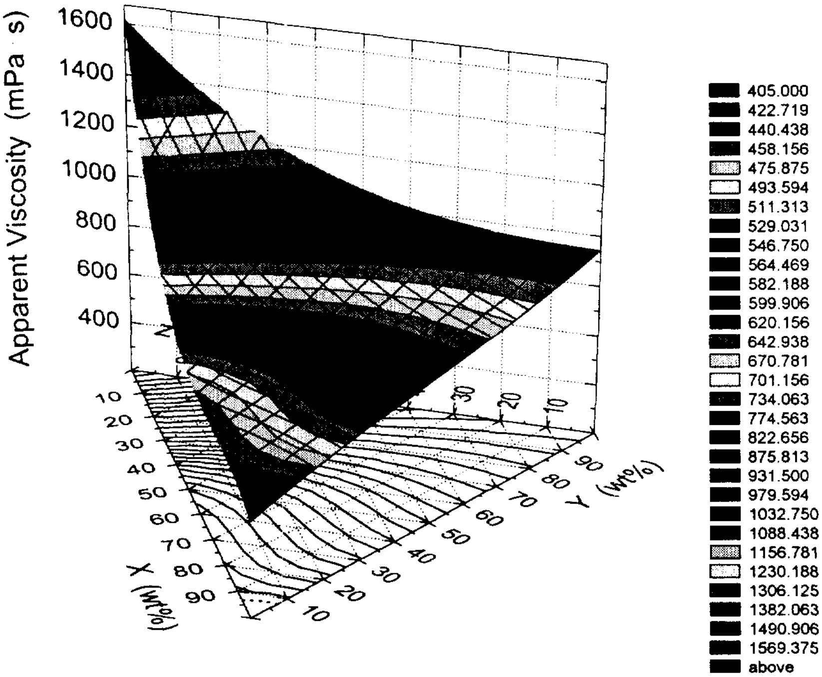

Fig. 5. Change in the apparent viscosity of CWM with mixing ratio of three coal particles of different mean diameters (X, coarse size; Y, medium size; Z, fine size). Coal loading : 63.5 wt%. Coal sample no./d_{50} (μm) : X, B-2/83.9; Y, B-5/42.3; Z, B-8/20.0.

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