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CWM의 유변학적 성질에 대한 석탄 입도분포의 영향

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

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1. Introduction

CWM(Coal-Water Mixture) has proved to be a particularly promising alternative fuel since it retains the economic advantages of coal while possessing the handling convenience of a liquid [1-3].

The rheological properties are included in the preparation sector primarily but are directly related to the transportation and storage technology of CWM. Also, they are closely related to atomized droplet sizes and are considered to be one of the principal parameters to improve burner performance and combustion efficiency. Therefore, they occupy a significant position in CWM combustion-related research area. Many studies [4-7] have been carried out extensively since late 1970's on its rheological properties 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 coal PSD(particle size distribution) was studied on the apparent viscosity and non-Newtonian behaviors of CWM. Also, rheological characteristics in the binary and ternary mixture composed of the coal particles with different sizes were investigated,

2. 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 [3, 8]. The amounts of CWM 1002 and NaOH were fixed at 0.4 and 0.1 wt% based

on the CWM weight, respectively.

The experiments on the effect of coal PSD were carried out using 30 coal particle samples with the mass median diameter(MMD) of 13.8 - 97.4 μm. The apparent viscosity was measured by Haake Viscometer (Model RV12) and the non-Newtonian behavior of CWM was evaluated by the simple power-law model.

3. Results and Discussions

3-1. Effect of Mean Particle Size

Fig. 1 represents the apparent viscosities of the CWMs prepared with ten coal samples, the MMD of which ranges from 13.8 to 97.4 μm, It can be seen that the apparent viscosity decreases almost in proportion as the mean size of the coal particles increases and that such tendency is found to be more distinguished as the coal loading in CWM increases.

Fig. 2 shows the effect of coal size on non-Newtonian behaviors. In this figure, all the five CWMs prepared with the particles having MMD below 30.8 μm reveal shear-thickening property 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.

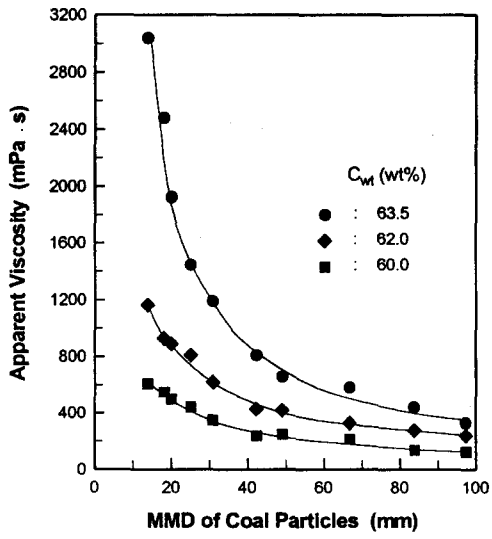

Fig. 1. Effect of MMD of Coal particles on apparent viscosity at 128 s^{-1}.

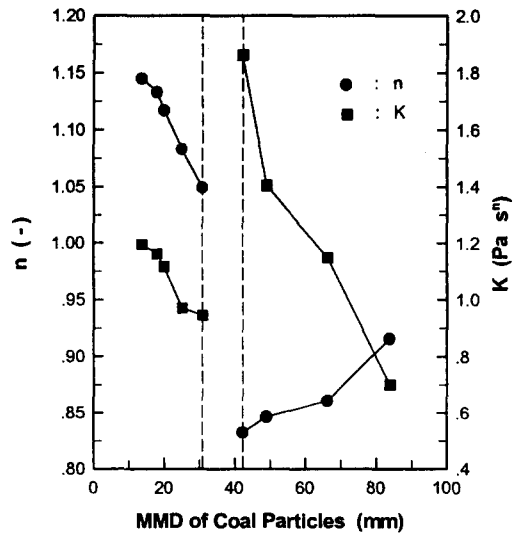

Fig. 2. Influence of coal particle size on the non-Newtonian behavior of CWM.

3-2. Effect of Coal PSD in Binary System

The effect of coal PSD on CWM viscosity was investigated consisting of coarse and fine particles in different portions(Fig. 3). 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. This mixing ratio is nearly the same as that for minimum voidage when mixing spherical solids particles of two sizes [7, 9]. 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.

Fig. 4 shows the viscosity variations when the ratio of mean particle sizes of the fine and coarse components ($d_{f,m}/d_{c,m}$) is varied. The proportion of fine particles was 30.0 - 40.0 wt%, the weight fraction giving the lowest viscosity in Fig. 3. As the mean diameter ratio increases, the viscosity increases for all seven sizes of coarse coal particles and such increase tendency was distinct with increasing coal loading; this finding is partly supported by Fig. 3.

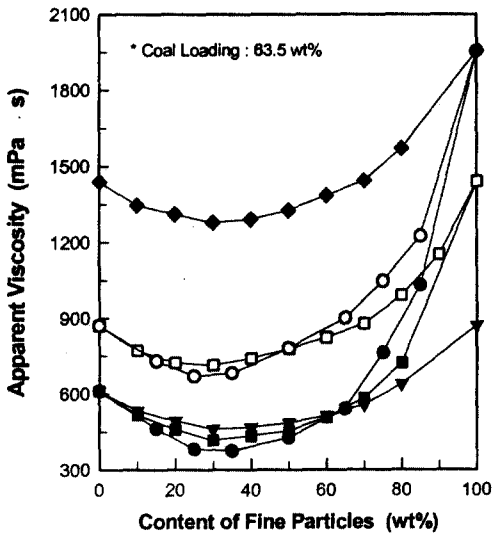

Fig. 3. Variation of apparent viscosity with mixing ratio of fine coal particles. $d_{f,m}/d_{c,m}$ (μm) : ◆, 20.0/25.1; ○, 20.0/ 42.3; □, 25.1/42.3; ●, 20.0/ 83.9; ■, 25.1/83.9; ▼, 42.3/83.9.

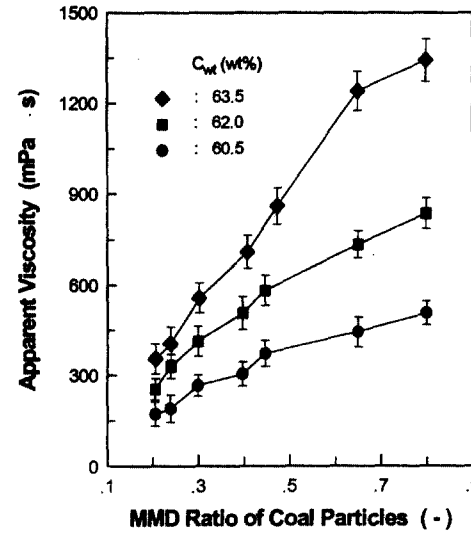

Fig. 4. Variation of apparent viscosity with ratios of mean diameters of fine to coarse coal particles. MMD of fine coal particles ($d_{f,m}$) : 20 μm.

Two coal samples of different sizes were blended to prepare CWM, each of which displayed pseudoplastic property when independently used to prepare CWM. The variation tendency of n and K in this case were presented in Fig.

5 as a function of fine particle content. The variations of n values can be expressed as a straight line formed by connecting two points at which the fraction of fine coal particles is 0.0 and 100 wt%, respectively. The variation pattern of K with the fraction of fine particles is very analogous to that of the apparent viscosity of CWM and shows minimum value at a fine : coarse blending ratio of 35±5 : 65±5.

Fig. 6 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.

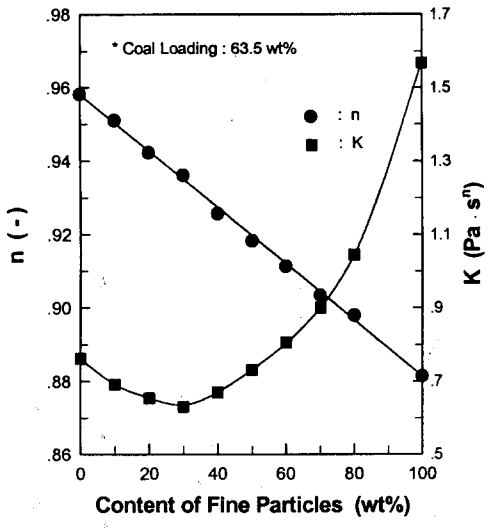

Fig. 5. Variation of non-Newtonian behavior of CWM with mixing ratio of fine coal particles. $d_{f,m}/d_{c,m}$ (μm) : 42.3/83.9.

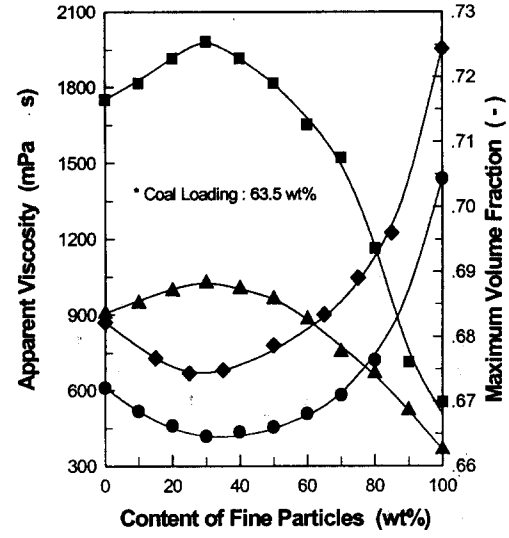

Fig. 6. Influence of fine particle content on the maximum solid volume fraction and apparent viscosity of CWM (● &◆ : η, ■&▲ : Φ_m). $d_{f,m}/d_{c,m}$ (μm) : ●&■, 25.1/83.9; ◆&▲, 20.0/42.3.

3-3. Effect of Coal PSD in Ternary System

Fig. 7 shows the apparent viscosity for the ternary mixture. The apparent viscosity 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.

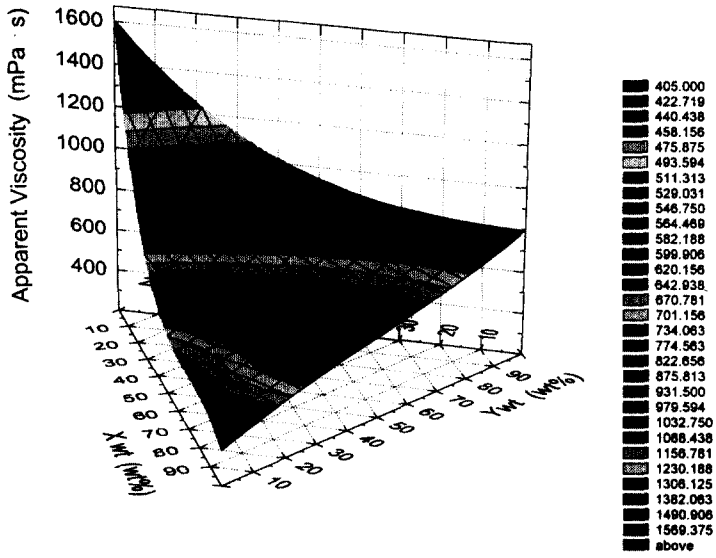

Fig. 7. Change in the apparent viscosity of CWM with mixing ratio of three coal particles of different mean diameters (X, coarse size; Y, medium size; Z, fine size). Coal loading : 63.5 wt%. d_{50} (μm) : X, 83.9; Y, 42.3; Z, 20.0.

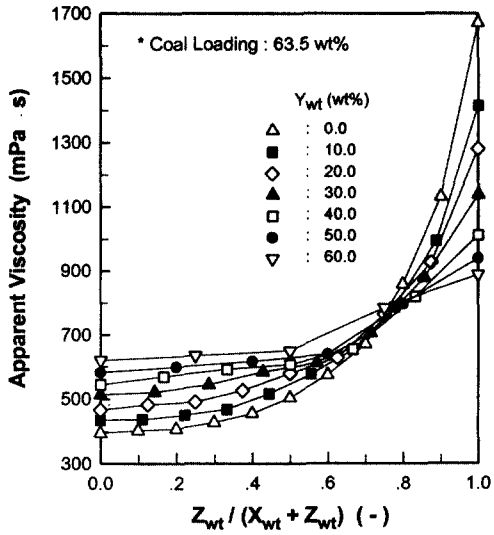

Fig. 8. Effect of addition of medium size particles on the apparent viscosity of the CWM composed of coarse and fine size particles. d_{50} (μm) : X, 83.9; Y,42.3; Z, 20.0.

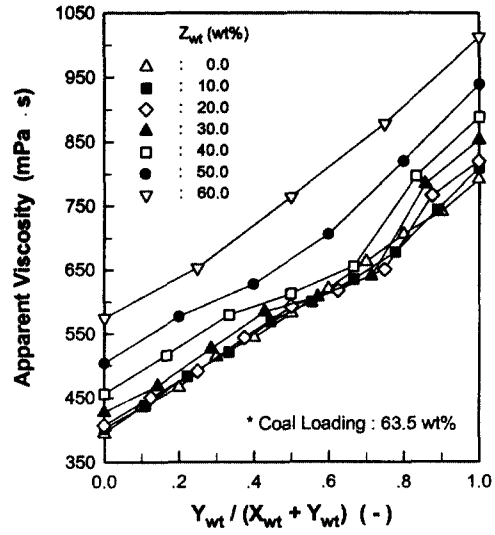

Fig. 9. Effect of addition of fine size particles on the apparent viscosity of the CWM composed of coarse and medium size particles. d_{50} (μm) : X, 83.9; Y, 42.3; Z, 20.0.

The effect of medium-size coal particles on apparent viscosity was shown to have mutually opposed results, based on the point where the fraction of fine-size coal particles is about 80 wt% on the basis of binary mixture (Fig. 8). Also, if fine-size coal particles are added to the binary mixture of coarse-and medium-size particles, the spread of PSD is increased, as well as the mean diameters of ternary mixture is reduced. Therefore, the increase rate of apparent viscosity was increased with increasing addition amount of fine-size coal particles (Fig. 9).

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