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ROLES OF ADDITIVES AND SURFACE CONTROL IN SLURRY ATOMIZATION

by

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I. ABSTRACT

OBJECTIVES:

- (1) To promote further understanding of the mechanisms and the roles of additives in airblast atomization of coal water slurry (CWS).
- (2) To investigate the impacts of coal particle surface properties and interparticle forces on CWS rheology and coal cleanability.

WORK DONE AND CONCLUSIONS:

This study covers rheology and airblast atomization of micronized coal water slurry. Airblast atomization is carried out in a bench scale unit equipped with a twin-fluid jet atomizer and a Malvern Particle Sizer 2600C for drop size measurement. The coal water slurries are composed of 0.40 to 0.47 volume fractions of micronized 4.4 μm Upper Freeport coal and micronized 3.7 μm Illinois #6 in aqueous solutions containing 20% to 80% glycerol, 42% ethylene glycol, or 50% isopropanol as listed in Table I. We found that all of these slurries are pseudoplastic and the slurry flow behavior index n varies linearly with the nondimensional Hamaker constant A/kT as shown in Fig. 1. Similar correlation for concentrated suspensions of polystyrene spheres and glass beads is also shown in this figure.

The Hamaker constant A/kT , for convenience scaled to the thermal energy at room temperature, is a measure of the interparticular van der Waals attraction force. It is calculated by the Lifshitz equation:

$$A = \frac{3}{4} kT \left(\frac{\epsilon_1 - \epsilon_3}{\epsilon_1 + \epsilon_3} \right)^2 + \frac{3h\nu_e(n_1^2 - n_3^2)^2}{16\sqrt{2}(n_1^2 + n_3^2)^{3/2}}$$

where k is the Boltzman constant; ϵ_1 and ϵ_3 are, respectively, the dielectric constants of particle and the suspending liquid; n_1 and n_3 are the corresponding refractive indices; and ν_e is the absorption frequency. The experimental values for the dielectric constant and the refractive index reported in the literature are used in this calculation. These values for coal are 2.89 and 1.701, respectively. The absorption frequency of graphite, $1.15 \times 10^{15} \text{ s}^{-1}$, is used for coal. The Hamaker constant of coal suspended in a liquid mixture is assumed to be the sum of those for coal in pure liquids multiplied by the liquid volume fractions.

The interparticle electrostatic repulsion, as measured by the zeta potential in deionized water by Malvern zeta sizer IIc, is also seen in Fig. 1 to play an important role in the CWS rheology. The electrostatic repulsion force between neighboring charged particles prevents particle aggregation. Therefore, the CWS at a constant particle volume fraction becomes more Newtonian (greater n) as the absolute value of the zeta potential in deionized water increases. Likewise, the pseudoplastic Upper Freeport CWS at 0.48 volume fraction with a flow behavior index of 0.83 becomes Newtonian as the dispersant concentration increases from 0.36 to 0.74 % by weight of coal. The corresponding zeta potential in deionized water decreases from +4 mV to -35 mV.

The high shear viscosities of the pseudoplastic coal slurries used in airblast atomization range from 2.7 P to 11.2 P. Since the flow field of airblast atomization is unknown, Newtonian liquids with viscosities of 2.9, 3.8, and 9.8 P are also used. We found that the wave mechanism-based model established for the viscous Newtonian liquids can be used for the micronized coal slurries as well. Specifically, the atomized drop sizes, represented by the mass median diameter (MMD), can be described in terms of three dimensionless groups, namely, slurry (or liquid)-to-air mass ratio ($\dot{M}_S/\dot{M}_A$), Weber number (We), and Ohnesorge number (Z) in the simple form:

$$MMD/D = (1 + \dot{M}_S/\dot{M}_A) \{ x_2 \cdot We^{-x_1} + x_3 \cdot Z^{x_1} \}$$

The exponents and coefficients (x_i , $i=1$ to 3) are determined by the best least square fit of the equation to the experimental results using the generalized inverse method. Excellent agreement, with coefficients of correlation of 0.97 - 0.98, has been obtained.

This model depicts the interactions of the aerodynamic force with the liquid surface tension and viscous force. As the atomizing air swirls downstream along the liquid jet, waves form on the surface of the liquid jet. Thus, the liquid jet sheds ligaments which subsequently collapse into small drops. The exponents of the We^{-1} - and Z -dependencies of the drop sizes obtained from airblast atomization of both coal slurries and aqueous glycerol solutions fall between the values, $2/3$ and $1/3$, predicted by the acceleration and the capillary wave mechanism. The exponents of this simple model are in good agreement with those of the empirical models reported in the literature for airblast atomization of low viscosity liquids.

SIGNIFICANCE TO FOSSIL ENERGY PROGRAM:

Coal water slurry (CWS) is potentially the most economical usage of coal, one of the nation's most abundant energy resources. However, it must be broken into fine drops in order to be effectively burned. Understanding the mechanisms of airblast atomization of viscous liquids and the effects of rheology and atomizer design on drop formation and breakup is imperative to development of a physical model for CWS atomization. This model should depict the mechanisms of CWS atomization and serves as a guideline for the design and scale-up of CWS atomizers. Understanding the impacts of coal particle surface properties and interparticle forces on CWS rheology and coal cleanability should improve slurry preparation and coal utilization.

PLANS FOR THE COMING YEAR:

The studies on rheology and airblast atomization mechanisms will continue, emphasizing the effects of particle size and additive type and concentration. Extensive characterization of coal particle surface, modified by additives, will also be carried out in the coming year. Specifically, the zeta potential will be measured as a function of pH value and additive concentration. The corresponding particle surface charge will be calculated using the Electrical Double Layer Theory. The particle floatability will also be determined by film flotation and its correlation with the particle surface charge will be evaluated.

II. HIGHLIGHT OF ACCOMPLISHMENTS

1. We developed a wave mechanism-based model for airblast atomization and a Pascal program for the best least squares fit of the model to experimental results using the generalized inverse matrix method. This model depicts the interactions of the aerodynamic force with the liquid surface tension and viscous force, and gives excellent correlation with the measured drop MMD from atomization of micronized coal slurries using a twin-fluid jet atomizer.
2. We found that the flow behavior index of a micronized coal slurry varies linearly with its interparticular van der Waals attraction as represented by the Hamaker constant. We also found that the interparticle electrostatic repulsion force plays a very significant role in CWS rheology, particularly when ionic dispersants are used or when the coal surface is highly oxidized.

III. ARTICLES AND PRESENTATIONS

1. S.C. Tsai, "Staged Froth Flotation of Fine Coal," ACS Industrial and Engineering Chemistry Research, 27, 1699-1674, (1988)
2. Q.Y. Song and S.C. Tsai, "Flotation of Ilmenite Using Benzyl Arsonic Acid and Acidified Sodium Silicate," Int. J. of Mineral Processing, 26, 111-121, (1989)
3. S.C. Tsai, B. Viers, and D. Botts, "Effects of Pseudoplastic Behavior on Airblast Atomization of Viscous Liquids", Proceedings of 3rd International Symposium on Liquid-Solid Flows, ASME, FED-75, 225-231, (1988)

231, (1988)

4. S.C. Tsai, B. Viers, and D. Botts, "Airblast Atomization of Viscous Newtonian Liquids", presented at the 3rd Annual Conference on Liquid Atomization and Spray Systems, ILASS-Americas, May 16-17, (1989)
5. S.C. Tsai, B. Viers, and D. Botts, "Effects of Liquid Viscosity on Rheology of Suspensions," presented at the Annual Meeting of the Fine Particle Society, and published in Pariculate Science and Technology, 7, 87-95, 1989.
6. S.C. Tsai, B. Viers, and D. Botts, "Airblast Atomization of Viscous Liquids," to appear in Fuel (accepted for publication).
7. S.C. Tsai, K. Ghazimorad, and B. Viers, "Correlation between the Hamaker Constant and the Folw Behavior Index of a Concentrated Suspension," to appear in J. of Rheology, November 1990.
8. Q.Y. Song and S.C. Tsai, "Selective Flocculation and Magnetic Seeding Flocculation of Weakly Magnetic Iron Minerals," submitted to Int. J. of Mineral Processing for publication.
9. S.C. Tsai and B. Viers, "Airblast Atomization of Viscous Newtonian Liquids Using Twin-fluid Jet Atomizer," submitted to J. of Fluid Eng. for publication.
10. S.C. Tsai, K. Ghazimorad, and B. Viers, "Airblast Atomization of Micronized Coal Water Slurries Using Twin-fluid Jet Atomizer," submitted to Fuel for publication.

TABLE I

Dimensionless Hamaker Constant A/kT for van der Waals Interaction Across Various Suspending Liquid

Solid/liquid	Polystyrene	Glass	Coal
Silicone oil	1.1	0.2	2.0
Glycol	1.3	0.6	2.1
Glycerol	0.9	0.6	1.7
Water	--	1.2	3.7
80/20 w/w glycerol/water			2.2
40/60 w/w glycerol/water			3.0
20/80 w/w glycerol/water			3.3
50/50 w/w isopropanol/water			3.1
42/58 w/w ethylene glycol/water			3.1

TABLE II

Semi-empirical Models for Airblast Atomization of Coal Slurries and Aqueous Glycerol Solutions

$MMD/D = (1 + \dot{M}_S/\dot{M}_A) \{x_2 \cdot We^{-x_1} + x_3 \cdot Z^{x_1}\} 10^{-2}$				
	x_1	x_2	x_3	c.o.c.*
(a)	0.47	8.5	1.4	0.93
(b)#	0.60	12.0	1.1	0.93
(c)	0.33	11.7	1.4	0.98
(d)	0.31	9.7	0.2	0.97

* Coefficient of correlation

MMD is replaced by volume mean diameter (VMD)

(a) Atomization of Newtonian liquids at inlet air pressures below the threshold value

(b) Atomization of Newtonian liquids at inlet air pressures above the threshold value

(c) Atomization of coal slurries at inlet air pressures below the threshold value

(d) Atomization of coal slurries at inlet air pressures above the threshold value

Fig. 1. Correlation between flow behavior index n of a concentrated suspension in aqueous solutions (except circles) and its Hamaker constant (solid circles are data for 0.55 and 0.45 volume fractions from Gadala-Maria and Acrivos, 1980. ϕ : particle volume fraction.)

Fig. 2 Correlation between Experimental and Calculated Dimensionless Drop Sizes, $10^2 \text{MMD}/D$ for Atomization of Coal Slurries at Inlet Air Pressure a) below and b) above the Threshold Pressure. (Diagonal lines represent perfect correlation with coefficient of 1.0. D is diameter of the central opening for liquid or slurry passage).

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