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EFFECT OF COAL BENEFICIATION PROCESS ON
RHEOLOGY/ATOMIZATION OF COAL WATER SLURRIES.

Quarterly Progress Report
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OVERALL OBJECTIVE:

The overall objective of this project is to perform experiments to understand the effect of coal beneficiation processes and high shear rheological properties on the atomization of coal-water slurries (CWS). In the atomization studies, the mean drop size of the CWS sprays will be determined at various air-to CWS. A correlation between the high shear rheological properties, particle size distributions and the atomization will be made in order to determine the influence of these parameters on the atomization of CWS.

Work Done

During the past quarter, several experimental studies on pressure dependent atomization of Coal-water slurries and simulated fluids were performed. Surface tension, elastic, high and low shear viscosities were performed prior to the atomization tests.

In the previous quarter, theoretical analysis of the physical process governing atomization was proposed by considering an energy balance across a control volume that extended from the nozzle exit plane to the line of spray measurement. The inlet conditions were calculated using a two phase flow technique and the outlet conditions calculated by using conservation of momentum and assuming that the final velocities of the air and liquid are equal.

The final expression is of the form:

$$SMD/L = 1/3 \rho_A/\rho_F We^{-1}(1+M_F/M_A) + 1/3 \rho_A/\rho_F CK \gamma^n (1+M_F/M_A) \quad (1)$$

This expression has a term dependent on viscosity and a term

independent on viscosity.

Based on this relationship, several rheological evaluations on CWS and glycerine-water mixtures were performed. Atomization studies as a function of the variables; surface tension of the mixtures, injection air pressure, ratio of mass of fuel to mass of air (M_F/M_A), and mixture density were performed. The results obtained are represented in Tables 1 and 2.

Rheological Properties

The Rheological properties of the glycerine solutions with and without the xantham gum, were determined using a Haake RV-20 rheometer and HVA-6 capillary viscometer. The glycerine solutions without the xantham gum, were found to be Newtonian and the viscosities ranged from 384 mPas.s to 598 mPas.s, depending on the concentration. The flow behavior of the glycerine solutions containing the xantham gum exhibited a dilatant flow behavior. Also, rheological measurements of the glycerine-water mixtures were carried out as a function of temperature. This was to determine the temperature at which the onset of gelation takes place. The result of this study will be reported in the next quarter.

Atomization Studies

Atomization studies were performed at Adelphi University. The initial tests were performed to compare and optimize conditions necessary for the CWS atomization. A Malvern 2600 particle size analyzer and a Dalavan Airo Nozzle were used to provide information about the spray characteristics, including drop size

distribution, mean median size distribution and spray velocity. The source of atomizing air used was the house air system, which delivers air at pressures up to a maximum of 85 psig. The atomizing air passes through a filter and a flowmeter before it enters the atomizer.

Calibration of the fluid flow were performed by collecting and weighing a definite amount of the sample per unit time. The calibration of the air flow was done using a rotameter. Air pressurized to 85 psig was passed through the rotameter where the volume displaced per unit time was measured. The calibration in both cases proved to be linear. Spray recirculation was minimized by exhausting the atomized fluid via a cylindrical duct of diameter 65 cm and a centrifugal blower whose volume was sufficient to draw all the atomizing air.

The atomization study began with simulated fluids-(mixtures of glycerine-water mixtures or corn syrup-water mixtures). This was done to minimize the experimental variables, optimize the experimental conditions for subsequent CWS atomization studies and also, simplify the analysis. The atomization data obtained for the simulated fluids are as shown in Table 1 and 2. The Air/Fuel ratio was varied from 0.12-0.40 in this study.

Variation of SMD as a Function of Viscosity

The SMD of glycerine-water mixtures at high Air/Fuel and low Air/Fuel data are plotted in Figures 5 and 6. The data show that at high Air/Fuel ratio, there is no significant change of the SMD as the viscosity is varied. However, at low Air/Fuel ratio the

SMD shows a strong dependence on the viscosity. This is due to the fact that entrainment losses become more severe as A/F increases. In the high A/F regime, there is very little variation between the SMD and the viscosity of the glycerine-water solutions. This is probably due to the fact that the relative velocity between the droplets and the air is very high and this produces high pressure forces on the droplets to the same extent. Considerable dispersion of the droplets was also observed at high A/F ratios. This effect is minimized in the low A/F regime.

Figures 5-8 show plots of SMD as a Function of Air/Fuel ratio. The plots show a linear dependence of SMD on the air to Fuel ratio. A fit of the experimental data to equation 1 in order to determine the necessary coefficients will be reported during the next quarter.

TABLE 1
ATOMIZATION DATA
GLYCEROL-WATER SOLUTION

VISCOSITY (mPas)	A/F	SURFACE TENSION dynes/cm	DENSITY g/ml	SMD μM
384	.387	63	1.23	19.1
384	.367	63	1.23	22.8
384	.364	63	1.23	21.8
384	.361	63	1.23	29.9
384	.356	63	1.23	34.2
384	.305	63	1.23	40.8
384	.274	63	1.23	64.2
384	.246	63	1.23	80.0
384	.186	63	1.23	105
384	.127	63	1.23	149
410	.392	65	1.26	22.8
410	.381	65	1.26	25.3
410	.361	65	1.26	32.8
410	.312	65	1.26	45.8
410	.288	65	1.26	67.3
410	.212	65	1.26	91.2
410	.174	65	1.26	131.2
598	.412	66	1.26	20.6
598	.392	66	1.26	24.3
598	.366	66	1.26	38.2

TABLE 2
ATOMIZATION DATA

CORN SYRUP-WATER SOLUTION

VISCOSITY (mPas)	A/F	SURFACE TENSION dynes/cm	DENSITY g/ml	SMD μM
350	.401	65	1.25	18.1
350	.387	65	1.25	20.8
350	.373	65	1.25	21.9
350	.368	65	1.25	26.9
350	.360	65	1.25	30.1
350	.344	65	1.25	36.3
350	.312	65	1.25	48.2
350	.289	65	1.25	72.4
350	.212	65	1.25	92.6
350	.167	65	1.25	132
460	.434	66	1.26	24.6
460	.381	65	1.26	33.5
460	.361	65	1.26	42.8
460	.302	65	1.26	55.8
460	.274	65	1.26	108.2
460	.242	65	1.26	119.6
460	.164	65	1.26	161.2
620	.434	66	1.27	29.6
620	.414	66	1.27	38.2
620	.398	66	1.27	44.2

Fig. 1. A Plot of SMD Vs. Air/ Fuel.
 (Glycerol-Water Mixture, Viscosity = 384 mPas.s)

Fig. 2. A plot of SMD Vs. Air/Fuel
(Glycerol-Water Mixture, Viscosity = 410 mPas.s)

Fig. 3. A Plot of SMD Vs. Air / Fuel
(Corn Syrup - Water Mixture, Viscosity = 350 mPas.s)

Fig. 4. A Plot of SMD Vs. Air/ Fuel
(Corn Syrup--Water Mixture. Viscosity = 460 mPas.s)

FIG. 5. A PLOT OF SMD VS VISCOSITY

FIG. 6. A PLOT OF SMD VS VISCOSITY

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