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RHEOLOGICAL PROPERTIES ESSENTIAL FOR THE ATOMIZATION OF
COAL WATER SLURRIES (CWS).

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OVERALL OBJECTIVE:

The overall objective of this project is to perform experiments to understand the effect of high shear and extensional 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 extensional and high shear 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, further rheological testing of the CWS were performed. The testing included low and high shear measurements. Oscillatory measurements were also planned, but the Haake CV20 accessory needed for this measurement has not yet been delivered. The CWS tested were PSOC-1527 from Middle Kittaning, PSOC-1472 from Lower Banner and PSOC 1475 (Elkhorn #3). The test results indicate that PSOC-1527 coal slurried much better than the PSOC 1472 coal. The rheological data is shown in Table 1.

Rheology as a Function of Temperature

The viscosity as a function of shear rate was measured at 20, 30, and 50°C and 60 °C. From these tests, the effect of temperature on the Newtonian behavior of each CWS was determined. For each coal slurry prepared without a stabilizer, the viscosity decreased under all conditions tested as the temperature was increased. For the slurries containing stabilizers, the decrease in viscosity as the temperature was increased from 20 to 35°C was more significant

than the increase from 35 to 45°C. There was a decrease in viscosity for all the slurries containing xantham gum as the temperature was raised above 45° C. Typical flow behaviors are as shown in Figures 1-5, and the rheological properties are as shown in Table 2.

Low Shear Testing:

The flow behavior exhibited in the shear rate regime of between 0-220 /s indicated that there was very slight settling of the slurries when the concentration was between 58-63%.

High Shear Testing

The high shear behavior of the slurries were studied using a HVA-6 capillary viscometer and 100 mm capillary tubes of 0.8, 1.5 and 3.0 mm inside diameters.

Typical flow data obtained are as shown in Figures 6-8 and Tables 3-5. The data indicate that higher shear rates are obtained with smaller capillary tubes and the viscosity increased with increase in the tube diameter. The data was also used to analyze slippage effects at the capillary walls.

Analysis Of Slippage In Capillary Flow.

Analysis used by Lupton and Tegester [2] to account for slippage in polymer melts gave an expression of the form;

$$\frac{4Q}{\pi R^3} = 4V \frac{1}{R} + \frac{4}{\tau_w} \int_0^{\tau_w} \tau^2 \gamma d\tau$$

A plot of the shear rate at constant shear stress as a function of

$1/R$ (the capillary diameter), should give information about slippage. A horizontal line indicate there is no slippage.

A plot of the shear rate as a function of $1/R$ is shown in Figure 8. The plot shows that there is slippage at the capillary walls.

Further Rheological Characterization measurements are planned for the next quarter.

References

1. Ohene, F. First Quarterly Report, DOE/DE-FG22-91PC91292
2. Lupton, J. M., and Regester, J. W., Poly. Eng. & Sci., 5, 235, (1965)

Table 1

RHEOLOGICAL PROPERTIES OF CWS.

COAL SAMPLE PSOC-1475, pH=9.5

Temp	R ²	n	τ_o	K	Coal Content (%)	η_{100} mPas
25	0.95	1.24	0.3261	.099	63	289
30 C	0.96	1.26	0.774	.0557	63	185
35 C	0.95	1.32	.635	.0326	63	152
45 C	0.98	1.20	.797	.088	63	211
55 C	0.99	1.12	0.381	.123	63	258

TABLE 2

<u>RHEOLOGICAL PROPERTIES OF CWS.</u>						
Coal	COAL SAMPLE PSOC-1527 & 1472 R^2	n	τ_o	K	$\frac{\Phi_{exp}}{\Phi_{th}}$	η_{100} (mPas)
PSOC1472	0.95	0.98	13.41	0.56	82%	484
PSOC1472	0.97	0.93	14.5	0.82	85.3	763
PSOC1472	0.99	0.81	54.34	10.43	78.2	302
PSOC1472	0.97	0.85	37.2	0.06	77.3	286
PSOC1527	0.98	0.92	0	1.18	85.0	502
PSOC1527	0.99	1.12	3.24	0.24	80.2	400
PSOC1527	0.94	0.64	0	1.14	78.8	220
PSOC1527	0.99	0.85	4.02	.35	76.1	214.6

Φ_{th} is the theoretical calculated packing.

TABLE 3

FLOW DATA FOR 63% ELKHORN #3 CWS CONTAINING 0.1% XANTHAM GUM THROUGH 0.80 MM
CAPILLARY TUBE.

* * *

A P P A A R

H V A - 6

* * *

R E S U L T S from 04/04/1994

Operator : Terrance File : OHUNL8A
 Sample : uncleaned Number : 1
 Solvent : 1000
 Density (kg/m3) : 1096 Temperature($\frac{1}{2}$ C): 25
 Capillary-length (mm) : 100.00 Capillary-diameter (mm) : 0.800

HVA 6 - Table 1in (measured)

No.	TAU(Pa)	TAU corr(Pa)	D(1/s)	ETA(Pa.s)	Reynolds	tv(s)
1	1.840E+03	1.834E+03	1.557E+04	0.1178	12	0.0642
2	2.360E+03	2.350E+03	1.990E+04	0.1181	15	0.0502
3	2.800E+03	2.787E+03	2.273E+04	0.1226	16	0.0440
4	3.360E+03	3.340E+03	2.878E+04	0.1160	22	0.0347
5	3.920E+03	3.891E+03	3.419E+04	0.1138	26	0.0292
6	4.680E+03	4.639E+03	4.082E+04	0.1136	31	0.0245
7	5.580E+03	5.522E+03	4.879E+04	0.1132	38	0.0205
8	6.640E+03	6.557E+03	5.798E+04	0.1131	45	0.0172
9	7.860E+03	7.735E+03	7.144E+04	0.1083	58	0.0140
10	9.140E+03	8.937E+03	9.093E+04	0.0983	81	0.0110
11	1.016E+04	9.957E+03	9.093E+04	0.1095	73	0.0110

TABLE 4

FLOW DATA FOR 63% ELKHORN #3 CONTAINING 0.1% XANTHAM GUM THROUGH A CAPILLARY TUBE
OF 3.00 MM DIAMETER.

* * *

A P P A A R

H V A - 6

* * *

R E S U L T S from 04/04/1994

Operator	: Terrance	File : OHUN3A
Sample	: uncleaned	Number : 1
Solvent	: 1000	
Density (kg/m3)	: 1096	Temperature($\frac{1}{2}$ C): 25
Capillary-length	(mm) : 100.00	Capillary-diameter (mm) : 3.000

HVA 6 - Table lin (measured)

No.	TAU(Pa)	TAU corr(Pa)	D(1/s)	ETA(Pa.s)	Reynolds	tv(s)
1	1.125E+03	1.123E+03	1.167E+03	0.9624	1	0.2285
2	1.650E+03	1.647E+03	1.581E+03	1.0419	2	0.1687
3	2.325E+03	2.319E+03	2.107E+03	1.1005	2	0.1265
4	3.000E+03	2.991E+03	2.616E+03	1.1434	3	0.1019
5	3.750E+03	3.739E+03	2.918E+03	1.2814	3	0.0914

TABLE 5

FLOW DATA FOR 63% ELKHORN #3 CONTAINING 0.1% XANTHAM GUM THROUGH 1.5 MM CAPILLARY
TUBE DIAMETER.

* * *

A P P A A R

H V A - 6

* * *

R E S U L T S from 04/04/1994

Operator : Terrance File : OHUN15B
 Sample : uncleaned Number : 1
 Solvent : 1000
 Density (kg/m³) : 1096 Temperature(½C): 25
 Capillary-length (mm) : 100.00 Capillary-diameter (mm) : 1.500

HVA 6 - Table lin (measured)

No.	TAU(Pa)	TAU corr(Pa)	D(1/s)	ETA(Pa.s)	Reynolds	tv(s)
1	6.375E+02	6.359E+02	3.145E+03	0.2022	5	0.1696
2	9.750E+02	9.712E+02	4.855E+03	0.2000	7	0.1098
3	1.462E+03	1.454E+03	7.402E+03	0.1964	12	0.0721
4	2.025E+03	2.009E+03	9.789E+03	0.2053	15	0.0545
5	2.513E+03	2.487E+03	1.264E+04	0.1967	20	0.0422
6	3.075E+03	3.026E+03	1.734E+04	0.1745	31	0.0308
7	3.788E+03	3.736E+03	1.785E+04	0.2093	26	0.0299
8	4.387E+03	4.311E+03	2.168E+04	0.1989	34	0.0246
9	5.287E+03	5.164E+03	2.759E+04	0.1872	45	0.0193

FIGURE 1. FLOW BEHAVIOR OF 63% CWS AT 25°C

GSU RHEOLOGY LAB.

Operator:
Caletha

Substance:
Uncleaned

Test No.:
1

Test of:
04-02-1994

System:
M5/MV3

Temperature:
25.0 °C

--- CALUN1.ROT

FIGURE 2. FLOW BEHAVIOR OF 63% CWS AT 30°

GSU RHEOLOGY LAB.

Operator:
Caletha

Substance:
Uncleaned

Test No.:
1

Test of:
04-02-1994

System:
M5/MV3

Temperature:
25.0°C

--- CALUN2.ROT

FIGURE 3. FLOW BEHAVIOR OF 63% CWS AT 35°

GSU RHEOLOGY LAB.

Operator:
Caletha

Substance:
Uncleaned

Test No.:
1

Test of:
04-02-1994

System:
M5/MV3

Temperature:
25.0°C

--- CALUN3.ROT

HAAKE Rot 2.4

FIGURE 4. FLOW BEHAVIOR OF 63% CWS AT 45°

GSU RHEOLOGY LAB.

Operator:
Ohene

Substance:
Unclean coal

Test No.:
1

Test of:
04-03-1994

System:
M5/MV3

Temperature:
25.0°C

--- CALUN4.ROT

FIGURE 5. FLOW BEHAVIOR OF 63% CWS AT 55°

GSU RHEOLOGY LAB.

Operator:
Ohene

Substance:
Unclean coal

Test No.:
1

Test of:
04-03-1994

System:
M5/MV3

Temperature:
25.0 °C

--- CALUN5.R01.

FIGURE 6. HIGH SHEAR FLOW BEHAVIOR OF 63% CWS USING A CAPILLARY SIZE OF DIAMETER 3.00 MM

* * *

A P P A A R

H V A - 6

* * *

lg TAU (Pa.s)

4

3

3

14

R E S U L T S from 04/04/19:

File : OHUN3A.HVA

Number : 1

Operator : Terrance

Sample : uncleaned

Solvent : 1000

Density (kg/m3) : 1096

Temperature ('C): 25

Capillary-length (mm) : 100.00

Capillary-diameter (mm) : 3.000

lg D (1/s)

4

FIGURE 7. HIGH SHEAR FLOW BEHAVIOR OF 63% CWS USING A CAPILLARY SIZE OF DIAMETER 0.8 MM

* * *

A P P A A R

H V A - 6

* * *

lg TAU (Pa.s)

4

3

4

15

5

R E S U L T S from 04/04/1991

File : CHUNLBA.HVA

Number : 1

Operator : Terrance

Sample : uncleaned

Solvent : 1000

Density (kg/m3) : 1096

Temperature (°C): 25

Capillary-length (mm) : 100.00

Capillary-diameter (mm) : 0.800

lg D (1/s)

FIGURE 8. HIGH SHEAR FLOW BEHAVIOR OF 63% CWS USING A CAPILLARY SIZE OF DIAMETER 1.5 MM

* * *

A P P A A R

H V A - 6

* * *

lg TAU (Pa.s)

R E S U L T S from 04/04/199

File : CHUN15B.HVA

Number : 1

Operator : Terrance

Sample : uncleaned

Solvent : 1000

Density (kg/m3) : 1096

Temperature (°C) : 25

Capillary-length (mm) : 100.00

Capillary-diameter (mm) : 1.500

FIGURE 9

A Plot of Shear Rate Vs. $1/R$

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