DOE/PC/88925--T13

CORRELATION OF STABILITY/RHEOLOGY RELATIONSHIP WITH COAL
PROPERTIES AND CHEMICAL ADDITIVES.

Quarterly Progress Report
June 15, 1989- September 15, 1989

DOE/PC/88925--T13

DE93 006075

FRANK OHENE
Department of Chemistry
Grambling State University
Grambling, LA 71245

Technical Project Officer
U. S. Department of Energy
Pittsburgh Technology Energy Center
P. O. Box 10940
Pittsburgh, PA 15236

RECEIVED
JUN 15 1989
U.S. DEPARTMENT OF ENERGY
PITTSBURGH, PA

Work Performed for the Department of Energy Under
Contract #DE-FG22-88PC925

DISCLAIMER

"This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference therein to any specific commercial product, process or service by tradename, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of the author expressed herein do not necessarily state or reflect those of the United States or Government or any agency thereof."

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

INTRODUCTION:

Coal-water slurry (CWS) is being considered as a near term replacement for oil in both industrial and utility applications. Selecting an economical, yet technically compatible feedstock for producing highly loaded CWS is important to the commercialization of CWS technology (1). Previous work has shown that the dispersing additives can represent a significant portion of CWS preparation cost (2).

In an effort to establish a criteria for designing and preparing CWS for utilization, the relationships between coal properties and slurry quality must be determined. These relationships will enable the prediction of potential CWS quality for the particular coal candidate from some characteristic(s) of the coal.

The coal content at a given viscosity varies for different coal(3). Thus, to develop a viable coal selection strategy using chemical surfactants as additives, the adsorption of these surfactants by the coal particle surface must be established. This work therefore, intends to screen a number of chemical surfactants and dispersants which can be used in the preparation of coal water slurry. The information derived from this screening together with the coal properties will be used to help develop a prescription to predict the stability of coal slurries.

OVERALL OBJECTIVE:

The overall objective of this project is to perform experiments to evaluate the necessary boundary conditions in the preparation and utilization of Coal Water Slurries (CWS) and also develop a data base for the conceptual analysis of a prescription to predict slurry quality for a given coal candidate.

SLURRY PREPARATION:

Coal slurries of the samples listed in Table 1, were prepared using the following general specifications:

Slurry:

52-67% by weight of coal depending on

Coal type

Additive type

Packing of the coal particles

Concentration of the Additive

pH of the slurry.

The analysis of the flow properties of the CWS was conducted in the laboratory by :

Measuring the viscosity as a function of shear rate

Viscosity as a function of time

Viscosity as a function of pH

Viscosity as a function of Additive concentration

Viscosity as a function of additive type

Fresh samples were used for each test.

Slurry Preparation

All slurries were made up by mixing weighed amounts of coal and water using a propeller stirrer for times greater than 5 minutes.

Weighed amounts of the additive were added to the mixture prior to mixing.

Rheological Testing

A Haake RV3 concentric cylinder viscometer was used to determine the rheological properties of the CWS. In this device, the slurry is sheared in the annular gap between a rotating bob and a stationary cup. The torque necessary to rotate the bob at a given speed is measured by a torsion spring. The drive unit consists of a driving motor, a tachometer-generator, and a reduction gear. The stator is surrounded by a temperature tempering vessel connected with a constant temperature bath. The temperature can be controlled to $\pm 0.01^{\circ}\text{C}$.

The viscometer is integrated with a Hewlett-Packard HP-87 data acquisition and analysis system. The signals from the viscometer were monitored twice per second and converted to torque and rotational speed values. Viscosity as a function of shear rate was computed using one of the following flow models:

Bingham law

Power law

Modified Bingham law

For this program, a rotor with a radius of 1.511 cm and a

stator with a radius of 2.097 cm were used. The annular gap was 0.586 cm. Since the largest coal particles used were approximately (80mesh), this gap gave adequate clearance so that the readings are not distorted by the effects of large particles. The values obtained are listed in Tables 2 through 7.

Effect of shear on Viscosity:

The CWS, of the four different coal samples listed in Table 1, were evaluated for the effect of shear and temperature. After gently agitating the slurry, it was placed in a constant temperature bath. The rotor and stator of the viscometer were also allowed to come to equilibrium temperature.

Figure 1, shows a typical flow curve for a particular CWS generated in the viscometer. The shear rate, to which the sample was subjected, was continuously increased from zero to a maximum determined by the viscosity of the CWS (curve 1). Curve 2 decreased to zero, curve 3 increased to a maximum and curve four decreased to zero. The viscosity measurements were taken from curve 3, which represents the fluid after it has been sheared and its structure broken down.

Effect of Particle size distribution:

Literature indicates, that the majority of the efforts in the past have been towards enhancing the coal-liquid mixture properties for each utilization phase individually through the use of suitable chemical additives, with not much effort to formulate the basic rheological behavior of highly

concentrated suspensions .

One of the most important parameters influencing the viscosity of CWS is the particle size distribution. In a mixture formed of a broad distribution of particles, the void space between densely-packed coarse particles will be filled by the fluid and fine particles which will act together as a lubricant between the coarse particles . This effect is very important in the resulting viscosity of the mixture, because excess of coarse particles may create an unstable suspension

Flow properties of mixtures will also be affected by the shape of particles, such that the greater the deviation from a uniform spherical shape, the larger the viscosity will be. An important parameter which is closely related to the particle size distribution is the maximum packing of solids.

Packing

size distributions were measured using a microtrac particle size analyzer and the packing efficiencies were determined using a computer program which has been developed at the Adelphi Center for Energy Studies. Tables 9-14 lists the particle size distribution and the packing efficiencies obtained. Viscosity measurements show that as the packing efficiency is varied from 78.5 to 72.5, the coal content at the same viscosity (225 m-Pas), decreased by 3% (Table 7).

Effect of Surfactant Concentration:

Fig. 4 Shows a variation of the viscosity measured as a function of surfactant concentration. There is a gradual

decrease in the viscosity as the surfactant concentration is increased. Beyond a concentration level of 0.25% by weight of surfactant, there was no marked difference in the values obtained.

Types of Additives

Table 2 lists the viscosities of 63% coal slurry of Elkhorn #3 measured at η_{100} in various additives. Among the Igepal series (610-990), the Igepal 990 provided the lowest viscosity. The values obtained are comparable to those obtained using the ammonium sulphonates (a-23, a-23-s,) and the sodium polyanthene and naphthalene sulfonates. Table 2 also compares the values obtained using different surfactants.

COAL CONTENT AND VISCOSITY:

Fig. 3 shows the variation of the coal content as a function of viscosity measured at η_{100} . The plot shows that the Elkhorn # 3 provides the best slurry quality and Illinois # 6 gave the poorest slurry quality.

PLANS FOR NEXT QUATER:

Atomic absorption measurements will be made on the coal samples in order to determine the trace metals present. Also further viscosity measurements will be made using a combination of the additives used during this past quarter, in order to determine the effect on the slurry quality. Stability measurements of the prepared slurries over a period of time will also be made.

Table 1

	PSOC-1494	PSOC-1487	PSOC-1493	PSOC-1475
	Kentucky #9	Adaville#1	Illinois#6	Elkhorn#3
Proximate				
<u>Analysis</u>				
% Moisture	7.12	18.99	9.43	3.37
% Ash	10.97	4.55	13.74	3.22
% Volatile	35.77	34.67	34.34	36.03
% Fixed Carbon	46.14	41.78	42.50	57.38
<u>ULTIMATE ANALYSIS</u>				
% Ash	10.97	4.55	13.74	3.22
% Carbon	65.32	57.96	59.98	78.38
% Hydrogen	3.98	4.09	3.74	5.20
% Nitrogen	1.14	0.84	1.15	1.44
% Total Sulfur	4.50	1.06	4.51	0.95
% Oxygen	6.97	12.50	7.41	7.45
C/O	9.37	4.64	8.09	10.45
FC/VM	1.29	1.21	1.24	1.59
Flotability	47.61	26.01	33.14	68.10
HG Index	72.0	61.1	62.2	58.70
Free Swell.Index	5.0	0.0	3.0	5.0
Predicted				
Coal Content	68.4	56.85	67.7	67.4

Table 2

Rheological Properties of Elkhorn #3 (pH=10)

Additive	Coal Content	ℓ_{100}	PLI	ζ	R^2	ψ_{max}
0.25%						
Igepal 610	63%	557	0.714	250	0.9912	78.5
0.25%						
Igepal 720	63%	460	0.882	150	0.9967	78.5
0.25%						
Igepal 890	63%	305	1.11	90	0.9987	78.5
0.25%						
Igepal 990	63%	224	1.067	30	0.9996	78.5
0% Additive						
	63%	448	0.775	150	.9924	78.5
0.05%						
Igepal 990	63%	350	0.900	65	.9982	78.5
0.10%						
Igepal 990	63%	292	0.793	50	0.9974	78.5
0.15%						
Igepal 990	63%	264	0.898	25	0.9943	78.5

Table 2 (Continued)

Additive	Coal Content	η_{100}	PLI	η	R^2	ϕ_{max}
0.21%						
Igepal 990	63%	243	1.061	10	0.9955	78.5
0.25% A-23	63%	236	0.991	0	0.9989	78.5
0.25% A-23-S	63%	213	0.991	0	0.9900	78.5
0.25% sodium polyanthane sulfonate	63%	198	0.9924	0	0.9986	78.5
0.25% sodium naphthalene sulfonate	63%	235	0.986	0	0.9966	78.5
0.25% Armogard 6000	63%	292	0.888	35	0.9912	78.5
0.25% Lignin Sulfonate	63%	264	1.023	25	0.9896	78.5
0.25% Nopcosperse	63%	225	0.881	25	0.9803	78.5

Key: PLI -Power Law Index, η_{100} -viscosity at 100 , ϕ Yield Stress, R^2 Regression coefficient, ϕ_{max} = Packing Efficiency

Table 3

Rheological properties of Elkhorn #3 as a Function of pH

	η_{100}	PLI	η_0	R^2	pH
0.25 % Igepal 990					
in 63% of coal					
Slurry	224	1.067	30	0.9996	10
	300	0.774	65	0.9969	7.65
	226	0.873	35	0.9962	8.45
	359	0.776	75	0.9886	4.80

Table 4
Rheological Properties of Elkhorn #3 (pH=10) as a Function of
Coal Content.

	ζ_{100}	PLI	ζ_0	R^2	pH
0.25% Igepal 990 in 70% Slurry	720	0.9864	250	0.9866	10
0.25% Igepal 990 in 67% Slurry	432	0.880	15	0.9990	10
0.25% Igepal 990 in 65% Slurry	319	0.868	15	0.9991	10
0.25% Igepal 990 in 64% Slurry	266	1.007	20	0.9886	10
0.25% Igepal 990 in 63% Slurry	224	1.067	30	0.9996	10
0.25% Igepal 990 in 62% Slurry	161	1.221	0	0.9900	10
0.25% Igepal 990 in 61% Slurry	142	1.112	0	0.9968	10
0.25% Igepal 990 in 60% Slurry	121	1.012	0	0.9938	10

Table 5

Rheological Properties of Kentucky #9

	η_{100}	PLI	η_0	R^2	pH
0.25% Igepal 990					
in 64 % Slurry	252	0.741	80	0.9995	10
0.25% Igepal 990					
in 62 % Slurry	234	0.916	90	0.9984	10
0.25% Igepal 990					
in 60% Slurry	165	0.992	70	0.9977	10
0.25% Igepal 990					
in 59% Slurry	121	0.900	30	0.9976	10
61% Slurry					
(No additive)	289	0.948	225	0.9946	10
0.25% A-23					
in 61% slurry	286	0.784	100	0.9988	8.65
0.25% Igepal 990					
in 56% Slurry	95	1.150	35	0.9940	10
0.25% A-23					
in 64% Slurry	324	0.661	90	0.9982	10
64% Slurry					
(No Additive)	485	1.045	220	0.9953	10
0.125% Igepal 990					
+ 0.125% M-133 in					
64 % Slurry	188	1.153	200	0.9845	10

Table 6

Rheological Properties of Adaville #1

Description of <u>Slurry.</u>	η_{100}	PLI	η_0	R^2	pH
61% Slurry					
(No Additive)	587	0.714	20	0.9996	10
0.25% Igepal 990					
in 66% Slurry	680	0.778	235	0.9886	10
0.25% Igepal 990					
65% Slurry	414	1.042	30	0.9996	10
0.25% Igepal 990					
in 61% Slurry	236	1.009	45	0.9980	10
0.25% Igepal 990					
in 64% Slurry	325	0.851	30	0.9990	10
0.25% Igepal 990					
in 60 % Slurry	158	0.921	20	0.9990	10
0.25 % Igepal 990					
in 63% Slurry	292	0.941	0	0.9965	10
62% Slurry					
(No Additive)	364	1.026	45	0.9984	10
60% Slurry					
(No Additive)	194	1.017	15	0.9991	10
0.25% A-23					
in 65% Slurry	337	1.025	15	0.991	10

Table 7

Rheological Properties of Illinois #6

Description of <u>Slurry</u>	η_{100}	PLI	γ_0	R^2	pH
0.25% A-23					
in 60% Slurry	180	0.973	20	0.9989	10
0.25% A-23S					
in 58% Slurry	110	1.160	50	0.9954	10
0.75% Lig. Sulfate					
in 64% Slurry	314	1.249	80	0.9987	10
0.25% A-23 in					
63% Slurry	438	0.700	25	0.9994	10
0.25 A-23S in					
64% Slurry	186	1.202	100	0.9967	10
0.25% Igepal 990					
in 63% Slurry	450	1.212	180	0.9881	10
0.25% Igepal 990					
in 61% Slurry	291	0.981	75	0.9960	10
0.25% Igepal 990					
60% Slurry	212	0.881	45	0.9886	10
0.25% Igepal 990					
in 59 % Slurry	186	1.075	55	0.9866	10
0.25% Igepal 990					
in 58% Slurry	154	1.012	30	0.9920	10
0.25 % Igepal 990					
in 57% Slurry	127	1.032	65	0.9951	10

Table 7 Continued

0.25% Igepal 990

in 55% Slurry	105	1.10	60	0.9948	10
---------------	-----	------	----	--------	----

0.25 % A-23 in

62% Slurry	338	1.088	150	0.9993	10
------------	-----	-------	-----	--------	----

Table 8

Coal Slurry Content as a Function of Packing Concentration

<u>Packing</u> <u>Concentration</u>	Coal Content	η_{100}	PLI	η_0	R^2	pH
80.5	68.6	480	0.886	225	0.9899	10
78.5	67	432	0.880	15	0.9990	10
72.5	60	225	1.012	10	0.9886	10
78.5	63	224	1.067	0	0.9996	10

Table 9

Particle Size Distribution of Elkhorn #3

Size Microns	Weight Under
564	100
261.6	99.9
160.1	88.6
112.8	81.0
84.8	74.5
64.6	68.2
50.2	61.3
39.0	55.1
30.3	49.6
23.7	45.0
18.5	41.1
14.5	36.3
11.4	30.1
9.1	23.9
7.2	17.5
5.8	10.1

Packing Efficiency is 78.5

Table 10
Particle Size Distribution of Adaville #1
(PSOC-1487)

Size Microns	Weight Under
564	100
261.6	100
160.1	100
112.8	99.8
84.8	93.8
64.6	88.8
50.2	78.2
39.0	66.0
30.3	55.7
23.7	47.9
18.5	41.7
14.5	31.3
11.4	22.6
9.1	18.6
7.2	15.2
5.8	9.5

Packing Efficiency is 75.5

Table 11
Particle Size Distribution of Illinois #6
(PSOC-1493)

Size Microns	Weight Under
564	100
261.6	97
160.1	71.4
112.8	57.4
84.8	51.4
64.6	48.2
50.2	42.7
39.0	38.0
30.3	34.6
23.7	31.4
18.5	28.3
14.5	23.8
11.4	18.1
9.1	14.2
7.2	10.8
5.8	6.50

Packing Efficiency is 80.01

Table 12
Particle Size Distribution of Adaville

Size Microns	Weight Under
564	100
261.6	100
160.1	100
112.8	99.8
84.8	93.8
64.6	88.8
50.2	78.2
39.0	66.0
30.3	55.7
23.7	47.9
18.5	41.7
14.5	31.3
11.4	22.6
9.1	18.6
7.2	15.2
5.8	9.5

Packing Efficiency is 72.1

Table 13
Particle Size Distribution of Kentucky #9
(PSOC-1494)

Size Microns	Weight Under
564	100
261.6	87.1
160.1	65.7
112.8	65.7
84.8	61.8
64.6	49.4
50.2	46.6
39.0	43.8
30.3	36.3
23.7	32.5
18.5	31.0
14.5	29.1
11.4	24.7
9.1	19.0
7.2	16.4
5.8	9.2

Packing Efficiency is 82.6

Table 14
Particle Size Distribution of ELKHORN #3
(PSOC-1475)

Size Microns	Weight Under
564	100
261.6	96.9
160.1	70.1
112.8	55.3
84.8	49.3
64.6	46.5
50.2	41.0
39.0	36.7
30.3	33.2
23.7	30.4
18.5	27.7
14.5	23.2
11.4	17.4
9.1	13.8
7.2	11.1
5.8	6.9

Packing Efficiency is 81

ADELPHI UNIVERSITY

07/25/89

TEST #: 1475-8

FUEL: 0.25% POLYANTHANE IN 63 % PSOC 1475

RHEOLOGY DETERMINATION

TEMPERATURE: 20

MEASURING SYSTEM: MV11150

INSTRUMENT CONSTANTS:

R1= 1.511 R2= 2.097

L1= 6.007

ACCELERATION: 200 rpm/min

CURVE #1 —————
CURVE #2
CURVE #3 - - - - -
CURVE #4 - - - - -

FIGURE 1

ROTOR SPEED (rpm)

Fig. 4 A VARIATION OF VISCOSITY AS A FUNCTION OF SURFACTANT CONCENTRATION.

Fig. 2 A VARIATION OF VISCOSITY AS AFUNCTION OF pH

Fig. 3 VARIATION OF VISCOSITY AS A FUNCTION OF COAL CONTENT.

- 1 ELKHORN # 3, PSOC 1475
- 2 KENTUCKY # 9, PSOC 1494
- 3 ADAVILLE # 6, PSOC 1487
- 4 ILLINOIS # 6, PSOC 1493

**DATE
FILMED**
3/19/93