TECHNICAL PROGRESS REPORT #6

Title: Non-Intrusive Measurement of Particle Charge: Electrostatic Dry Coal Cleaning (DE-FG22-91PC91290)

Organization: Center for Applied Energy Research
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Report Period: 10/1/92 - 12/31/92

Grant Period: 8/29/91 - 8/28/94

1. **Grant Objective:** No change
2. **Technical Approach Changes:**

To date, charge data has been collected on 3 minerals, two coals, and 1 mineral/coal mixture. This data has addressed the originally proposed variables of particle size, separator voltage, and to some extent, gas composition. In addition, the effect of tribocharger gas velocity on particle charge has been extensively evaluated. While the scope has expanded somewhat by adding variables and by performing some computer modelling, the project is on schedule. During the next quarter, charge evaluations on coal, mineral, carbon, and carbon/mineral mixtures will continue. Additionally, the data analysis procedure for non-spherical particles will be further refined. Also, the gas temperature control system will be constructed in preparation for work in the following quarter.

3. **Progress Report by Task:**

Task 1. Sample Acquisition and Preparation

Spherical silica particles, in diameters ranging from 10 - 120 microns, were acquired to investigate the size effect on particle charge. Also, an approximate 50-50 percent weight mixture of similar diameter silica and glassy carbon particles was prepared to function as a two component synthetic coal. Chemical analysis of the six coals previously acquired has been completed.

Task 2: PDPA - Charge Measurement

Summary of Work

Triboelectric charging/electrostatic separation experiments were performed using mineral pyrite, spherical silica, two coals (Elswick seam from Pike Co., KY and Leatherwood seam from Harlan Co., KY.) and a carbon-silica spherical particle

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mixture. Two dimensional particle velocities in the separation chamber, as well as the number density distribution, were measured by a laser Phase Doppler Particle Analyzer (PDPA) for different tribocharging loop velocities (6-15 m/s). Particle deposition on the separation chamber's cathode and anode as well as the material passing through the separator were collected, weighed and analyzed to determine the separation efficiency.

Typically, for a feed coal with 11% ash, the coal recovery was around 70-95% with an ash content of about 4%. Deposits on the anode accounted for approximately 20% of the total feed weight and contained about 20% ash, while the cathode depositions accounted for 70-90% of the total feed and contained less than 4% ash. Approximately 10-15% of the feed did not accumulate on either electrode and was collected at the bottom of the separation chamber. The net electric current induced in the copper charging loop when transporting coal particles (size range 38-45 microns) was much less than that for single component particles such as silica. This may be due to a charge cancellation effect as a result of mineral matter and coal charging oppositely.

Two diameter ranges of silica spheres were investigated (37-45 and 52-78 microns). It was observed, by visualization with a helium-neon laser light sheet, that the smaller silica particles had a greater deflection in the electric field due to their increased charge-mass ratio, even though their measured absolute charge value was lower.

The mineral pyrite, which was ground to 200x325 mesh, would induce a corona when the electric field exceeded 300 kv/m. One reason for this could be that since the pyrite particles were conductive and very angular, their deposition on the electrodes created sharp electrical discharge points.

Experimental Results

With spherical particles, the PDPA can be used to measure diameter, two component velocities and record the time when each particle passes through the optical probe. With this information for each particle, the charge can be calculated and a charge distribution histogram can be plotted. For non-spherical particles, the diameter can no longer be measured by the PDPA and must be determined by a Scanning Electron Microscope (SEM) with image processing software. However, the SEM size distribution cannot be directly correlated to the PDPA velocity data since the particle size and velocity were not determined simultaneously. As a first approximation, an average size can be assumed for all the particles which would yield an approximate charge distribution. Realizing that the particle number distribution in the separation chamber is affected not only by charge, but also by the size distribution, the size variance should be taken into account for a better interpretation of the experimental data. Therefore, a comprehensive computer program is being developed which considers both size and charge distribution by applying statistical methods. It solves

an inverse problem of particle distribution and utilizes the mathematical library IMSL, located on the main frame computer at the University of Kentucky Computing Center.

During PDPA measurements, the optical probe traversed the separation chamber at a predetermined rate, (2-4 minute data collection time), continuously collecting data. A typical data plot is shown in Figure 1. The left column of figures shows data collected without an electric field while the right column shows data with the specified electric field. The X-axes are all relative positions across the horizontal axis of the separation chamber. The first row of figures show particle number density distributions. It is clear that the particle distribution shifts to the right (anode side of the separation chamber) when an electric field is applied. Particle vertical velocity is shown in the second row. It should be noted that this is not the charging velocity (the velocity inside the copper tribocharging loop) which is usually larger than the velocity in the separation chamber. The curves indicate an average vertical velocity distribution with some variation along the edges because of the limited number of particles in these areas. The horizontal velocity distributions, mainly caused by the electric field, are shown in the third row of figures.

Figure 2 is a similar plot for the same coal at a different charging gas flowrate. Because the flow rate is higher the vertical velocity is increased. The shift in the particle number density distribution is more obvious for silica particles of small size (37-44 μm), Figure 3. Visualization with a helium-neon laser indicated a very effective deflection toward the cathode. A calculated charge distribution for the small silica particles is plotted in Figure 4. Although the absolute value of charge was not as large as that of larger silica particles (52-75) reported earlier, a greater deflection in the separation chamber was observed, probably due to its higher charge-mass ratio. This can also be explained by the fact that the smaller particles had larger surface area per unit volume and the charge is proportional to surface area.

The coal samples deposited on the cathode and anode, as well as the coal passing through the separation chamber, were collected and weighed. These samples, and a sample of the coal before separation, were subjected to proximate analysis to determine the separation efficiency. The results are shown in Tables 1 and 2 for the two coals at different charging gas flow rates. Tables 1 and 2 show that, regardless of the charging velocity, the total solids collected on the electrodes remains approximately constant. This means that the effect of decreased particle residence time in the separation chamber (as a result of increased charging velocity) is offset by the higher magnitudes of particle charge resulting from the same increased charging velocity.

Results of the glassy carbon/silica mixture test are shown in Table 3. The cathode deposit was almost 95% carbon while the anode was about 95% silica. This degree of separation was high, considering the possibilities of particle agglomeration and discharging. PDPA measurement of this sample will be used to calibrate the charge calculation method for coal, which has a more complex particle size distribution.

Task 4. Reports/Publications

An abstract was submitted to the International Conference on Coal, September 12-17, 1993, Banff, Alberta Canada. Another abstract was sent to the 1992 Pittsburgh Coal Conference, September 20-24, 1993, Pittsburgh, PA. Also, a paper entitled "Non-Intrusive Measurement of Particle Charge Relating to Electrostatic Dry Coal Cleaning" is in preparation for the journal Fuel.

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Figure 1: Data Plots - Elswick Seam
200 x 325 mesh; Flow=30

Figure 2: Data Plots - Elswick Seam
200 x 325 mesh; Flow=40

Figure 3: Number Density Distribution - Silica Spheres
37-44 μ ; Flow=20

Figure 4: Charge Distribution - Silica Spheres
37-44 μ ; Flow=20

Table 1: Separation Efficiency - Elswick Seam
200x325 mesh (45-75 μm) E=200 kv/m

Flow = 10	Feed	Cathode	Anode	Center
Weight %	----	65	22	13
Moisture	0.85	0.89	0.61	0.74
Ash	11.78	3.57	22.03	10.24
Volatile	52.9	39.24	38.41	39.68
Carbon	34.47	56.3	38.9	49.3
(C+V)/A	7.42	26.8	3.51	8.69

Cathode coal recovery: 71.1%, Anode ash removal: 41.1% (19.5% coal)

Flow = 20	Feed	Cathode	Anode	Center
Weight %	----	70	14	16
Moisture	0.85	0.93	0.75	0.88
Ash	11.78	3.74	19.00	7.74
Volatile	52.9	39.63	33.61	35.87
Carbon	34.47	56.0	46.6	55.5
(C+V)/A	7.42	25.7	4.22	11.8

Cathode coal recovery: 76.6%, Anode ash removal: 22.6% (12.9% coal)

Flow = 30	Feed	Cathode	Anode	Center
Weight %	----	87	4.7	8.3
Moisture	0.85	0.37	0.94	0.71
Ash	11.78	4.69	25.02	14.65
Volatile	52.9	40.52	36.32	38.32
Carbon	34.47	54.4	37.7	46.3
(C+V)/A	7.42	20.2	2.96	5.78

Cathode coal recovery: 94.5%, Anode ash removal: 9.98% (3.98% coal)

Table 2: Separation Efficiency - Leatherwood Seam
200x325 mesh (45-75 μ m), E=200 kv/m

Flow = 10	Feed	Cathode	Anode	Center
Weight %	----	62	25	13
Moisture	1.73	1.18	.99	1.00
Ash	10.73	4.83	22.89	7.85
Volatile	33.85	35.56	28.31	33.18
Carbon	53.7	58.4	47.8	58.0
(C+V)/A	8.16	19.5	3.33	11.6

Cathode coal recovery: 66.5% wt, Anode ash removal: 53.3%wt (21.7% coal)

Flow = 20	Feed	Cathode	Anode	Center
Weight %	----	65	22	13
Moisture	1.73	1.62	0.97	1.19
Ash	10.73	5.19	29.40	8.87
Volatile	33.85	35.22	26.89	32.25
Carbon	53.7	58.0	42.7	57.7
(C+V)/A	8.16	18.0	2.37	10.1

Cathode coal recovery: 69.2%wt, Anode ash removal: 60.3% (17.5% coal)

Table 3: Separation Efficiency - Purified Carbon-Silica Mixture
48-75 μ m, E=200 kv/m

Flow = 20	Feed	Cathode	Anode	Center
Weight %	----	45.5	9	45.5
Silica	52.68	6.87	95.65	90
Carbon	47.32	93.13	4.35	10
C/S Ratio	0.898	13.6	0.0455	0.111

Cathode carbon recovery: 89.5%, Anode silica recovery: 16.3%

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