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"Coal - Sand Attrition System and Its' Importance in Fine Coal Cleaning"

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Continuous Grinding Tests

As indicated in the last quarterly report, a small grinding chamber similar to that used in the batch tests but fitted with inlet and discharge openings was adopted. A variable speed Masterflex peristaltic pump was placed between the mixing tank, water tank and the grinding chamber inlet port and connected by a system of tubing, as shown in figure 1. The small size of the grinding chamber necessitates the use of a relatively low feed rate in order to keep the residence time of the particles in the mill at a reasonable level. Evidently, this is not enough to ensure that the desired very fine product can be obtained. Hence slurries have to be passed through the mill a number of times. Thereby simulating a grinding circuit consisting of a number of mills in series. Depending on the hardness of the coal, between 3 to 4 passes are sufficient to obtain very fine products as depicted by Tables 1 - 4. The harder the coal, the higher the number of passes required. This is of course influenced by such factors as the initial feed particle size, pulp density, feed rate and stirring speed.

The fact that no media retaining device is employed in the discharge port placed some limitations on the operation. The decision to use an open discharge port was reached as severe clogging problems prevented the use of sieve as a retaining device. Even without the retaining device, the grinding operation has to be carried out in such a manner that most of the media remain in the grinding chamber for it to be effective. This was achieved by exploiting gravitational force or specific gravity difference to effect the separation of coal slurry from the media inside the grinding chamber. The implication is that the mill capacity has to be compromised as less than optimal levels of such factors as feed particle size, feed flow rate and initial solids concentration have to be employed.

With the above restrictions in mind, we set out to explore the range in which the continuous grinding circuit can be used to produce products consisting of very fine particles. In the present investigation, two polydispersed feed with a size designation of minus 50 mesh and minus 100 mesh were chosen as well as initial solids concentration in the range of 20 to 40 weight percent. The term initial solids concentration is used to denote the starting pulp density in the mixing tank. The starting solids concentration is emphasized because the operating procedure adopted

results in a slight dilution of the commencement of grinding.

The procedure involves measuring the desired amount of dry coal and water and mixing in a stirred tank to give the pulp density of interest. Then the stirring mechanism is set in place, the required amount of grinding media measured (which for silica sand is chosen as 250 g) and placed in the mill. Thereafter the mill cover is locked, the water valve is opened and the pump is switched on. Then the mill cover and tubes are checked for leakage and the pump speed is adjusted. After the check up, the grinding mill motor is switched on, the water valve is closed while the slurry valve is opened and further adjustments are on the the pump speed. This procedure appears to be essential for a smooth running of the continuous grinding system. However, when a small volume of slurry is used, a significant dilution may result.

For the four coals employed in this work, it was not possible to effectively grind the minus 50 mesh feed even at the lowest solids concentration range tried. The reason for this is the low feed rate which makes it impossible to obtain a uniform flow as the coarse particles in the feed tend to settle down and form sediment in either the tubing system or the grinding chamber. Besides, only moderate levels of solids concentration could be employed as high solids concentration are also fraught with sedimentation problem. Attempts to increase the flow rate resulted in the grinding media being taken out of the mill together with the slurry. As a result of these limitations posed by the instrument, further tests were restricted to using minus 100 mesh feed size and moderate levels of feed rate and pulp density.

Some of the results obtained are given in Tables 1 - 4 for the different coals used. It can be seen from the tables that the softest coal (Pocahontas #3 in this case) requires about 2 or 3 passes in order to obtain very fine product while the harder coals would require 4 or more passes. The number of passes required for the harder coals can be reduced either by increasing the residence time of the slurry in the mill by decreasing the feed rate or preferably by increasing the stirring speed. Both of these actions will inevitably lead to a slight increase in the media wear. The media wear observed in grinding Pocahontas #3 in three cycles was 1.3% while the corresponding values for grinding both Illinois #6 and Black Creek coals in four cycles were 0.5% and 1.5% respectively. The

above media wear values for the respective coals reflect more about the flow characteristics of the various coal slurries as opposed to the coals hardness. The media wear was determined from the difference in the mass of the media after grinding. The media wear rate is surprisingly quite low. It should, however, be emphasized that the wear value is greatly dependent on the slurry flow characteristics or rheology. This is the reason why the media wear obtained in grinding Pocahontas #3 which is soft in three cycles is of the same magnitude as that observed for Black Creek coal. For the former, most of the media wear occurred presumably during the last cycle of grinding as evident from the change in the sound produced by the grinding chamber.

Some of the parameters will be investigated further during the next quarter and some tests would be made with steel media.

Fracture Mechanics Tests

In this investigation, four monodispersed and one polydispersed samples prepared from each of the four coal types were used. The so-called uniaxial testing machine manufactured by Tinius Olsen was used to apply the required load on the sample which was placed in a cell made for this purpose.

Preliminary test runs were first made to determine both the amount of sample required to obtain a cylindrical cake of about 4 inches in height and a load which would yield a cake of adequate strength.

It was decided from the trial data to use 240 grams from each of the dry coal samples. In order to obtain a cake following the application of load, an amount of water varying between 34 to 80 ml was used to increase the moisture content of the sample. The variation in the amount of water required is due to the degree of fineness of the particles which make up the samples. A constant pressure of about 12,700 psi was chosen for the test and applied for a duration of one hour. Cylindrical cakes having a diameter of 2 inches and a height varying between 4 to $4\frac{1}{2}$ inches were obtained depending on the coal hardness and initial particle size.

The wet cylindrical cores were weighed and allowed to dry in air for a number of days before being subjected to further uniaxial compression tests. In these tests series, small increments of load were applied on each of the core and the strain release was measured using a dual-sensor strain transducer (supplied by the Measurement Technology Inc.), connected to two strain indicators model P 3500 made by the Measurement Group. The vertical and horizontal strains were measured in this manner when a core was subjected to stress. The results of these tests are given in Tables 5 - 24. It can be seen that there is a strong correlation between the rate of strain release and the property or hardness of the coal. The rate of strain release seems to increase with the hardness of coal. In other words, the harder the coal, the lower the amount of stress a cake can withstand before failure. A similar inference appears to be true for the initial particle size of the sample used to make a cake. That is, the smaller the particle size, the higher the stress a cake made up of such particles can withstand.

The cakes made with the softest coal (Pocahontas #3) tend to exhibit greater resistance to stress. This feature could presumably be attributed to the presence of a significant amount of clay in the coal which have been mentioned in previous reports. While these observations reflect the characteristics expected of the respective cakes, any inference as regards the actual breakage behaviors of the particles require caution.

The particle size distributions resulting from the application of load used to compress the coal samples are given on the basis of the initial particle sizes in Tables 25 - 29. It can be seen from the above tables that an extensive breakage of over 50% occurred in all the feed sizes range used. The high values in Table 29 is partly due to the different sizing device used for the measurement of the particles. While sieves were used for evaluating the particle size distributions given in Tables 25 - 28, the data in Table 29 were determined using Cilas Granulometre because of the very fine nature of the particles. In general, the amount of material broken out of the initial (feed) size intervals appears to be higher for the soft coals compared with the hard coals. However, the hard coals seem to produce a larger amount of fines. More tests would be made at a higher pressure to ascertain whether the enumerated patterns would be maintained.

Verification of Process Parameters

We had reported optimum operating conditions as determined by canonical analysis for Illinois #6 coal in the last quarterly report (sixth). These optimum conditions refer to agitator speed, percent solids and coal particle size. Unfortunately, some of the conditions were outside the feasible region of experimental values. Nevertheless, we decided to conduct experimental verification using the nearest feasible value. For example, agitator speed (3375 RPM) and coal particle sizes (44 mesh, 323 mesh, 54 mesh, and 270 mesh) were substituted using appropriate values.

Table 30 shows the comparison of predicted values and experimental responses (specific energies, product sizes) for both sand and steel shot system. It is clear from the data that the agreement among product sizes

is far superior than specific energies. Note that optimized value (X_3) is single particle size which is different from the one actually used in the experiments which contain range of particle sizes. This analysis shows that energy consumption is more sensitive to particle size than product median product size.

Fig. 1 Schematic Representation of the Continuous Grinding Test System

Table 1. The product size distributions of minus 100 mesh Pocahontas #3 coal ground in a continuous mode at 2500 rpm, 25% solids and a flow rate of 25 ml/min.

Particle Sizes (μm)	Cumulative Weight Percent Passing		
	1st pass	2nd pass	3rd pass
96	100.0	100.0	100.0
64	98.4	100.0	100.0
48	96.8	100.0	100.0
32	92.7	100.0	100.0
24	90.5	100.0	100.0
16	82.3	97.3	99.6
12	72.9	93.5	99.2
8	56.7	79.1	92.4
6	44.4	65.6	84.9
4	29.0	43.8	62.9
3	20.5	31.6	47.8
2	12.8	19.7	29.4
1.5	8.0	12.8	19.5
1	6.3	10.0	14.9

Table 2. The product size distributions of minus 100 mesh Pittsburgh #8 coal ground in a continuous mode at 2500 rpm, 26% solids and a flow rate of 45 ml/min.

Particle Sizes (μm)	Cumulative Weight Percent Passing			
	1st pass	2nd pass	3rd pass	4th pass
192	100.0	100.0	100.0	100.0
128	99.0	100.0	100.0	100.0
96	96.0	100.0	100.0	100.0
64	88.6	96.9	99.6	99.9
48	85.6	96.9	99.2	99.9
32	76.2	91.9	98.1	99.9
24	68.1	87.4	97.0	99.9
16	53.3	72.9	87.4	93.8
12	40.2	58.2	75.1	84.3
8	26.3	39.0	52.2	61.9
6	18.5	28.2	38.0	45.9
4	12.0	18.2	23.6	28.0
3	8.6	13.2	17.2	20.1
2	6.0	9.1	11.7	13.6
1.5	3.9	5.9	7.7	9.0
1	3.2	4.7	6.1	7.1

Table 3. The product size distributions of minus 100 mesh Illinois #6 coal ground in a continuous mode at 2500 rpm, 24% solids and a flow rate of 40 ml/min.

Particle Sizes (μm)	Cumulative Weight Percent Passing			
	1st pass	2nd pass	3rd pass	4th pass
192	100.0	100.0	100.0	100.0
128	99.0	100.0	100.0	100.0
96	96.1	100.0	100.0	100.0
64	89.9	98.6	99.6	99.8
48	87.5	97.3	99.2	99.6
32	78.8	91.8	97.2	99.3
24	71.7	86.4	95.6	99.1
16	58.3	70.1	83.5	90.8
12	45.7	55.0	68.8	78.5
8	31.6	36.8	46.8	55.3
6	22.8	27.1	34.0	40.3
4	15.2	18.2	21.9	25.2
3	11.1	13.5	16.3	18.5
2	7.5	9.1	10.9	12.0
1.5	4.3	5.3	6.4	7.1
1	3.3	4.1	4.8	5.4

Table 4. The product size distributions of minus 100 mesh Black Creek coal ground in a continuous mode at 2500 rpm, 26% solids and a flow rate of 48 ml/min.

Particle Sizes (μm)	Cumulative Weight Percent Passing			
	1st pass	2nd pass	3rd pass	4th pass
192	100.0	100.0	100.0	100.0
128	98.5	99.9	100.0	100.0
96	94.1	99.7	100.0	100.0
64	85.5	96.9	99.2	99.8
48	82.2	95.8	98.5	99.6
32	70.1	89.7	94.9	97.6
24	60.9	83.4	92.7	97.0
16	46.2	68.6	81.0	88.8
12	33.9	53.7	67.3	77.0
8	21.8	35.6	45.3	54.4
6	15.2	25.1	31.9	38.6
4	9.9	15.8	19.2	22.8
3	6.9	11.1	13.6	16.0
2	4.6	7.5	9.0	10.6
1.5	2.8	4.6	5.6	6.7
1	2.2	3.7	4.4	5.3

Table 5. The stress, strain and Poisson ratio of a compressed cake made from a 50 x 60 mesh size Pocahontas #3 coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
3.18	570.96		
12.73	1478.88		
19.10	2190.24		
25.47	2995.20		
31.83	3912.48		
38.20	4661.28		
50.93	6430.32		
57.30	7441.20	40.48	5.44×10^{-3}
63.66	8424.00	60.72	7.21×10^{-3}
70.03	9266.40	65.78	7.10×10^{-3}
82.76	11316.24	80.96	7.15×10^{-3}
89.13	11952.72	101.20	8.47×10^{-3}
101.86	13478.40	126.50	9.39×10^{-3}
108.23	14189.76	136.62	9.63×10^{-3}
114.59	14882.40	151.80	10.20×10^{-3}
120.96	15715.44	166.98	10.63×10^{-3}
127.32	16417.44	182.16	11.10×10^{-3}
133.69	17035.20	212.52	12.48×10^{-3}
140.06	17690.40	227.70	12.87×10^{-3}
146.42	18439.20	242.88	13.17×10^{-3}
152.79	19253.52	263.12	13.67×10^{-3}
159.16	19740.24	298.54	15.12×10^{-3}
165.52	20769.84	313.72	15.11×10^{-3}
171.89	21556.08	354.20	16.43×10^{-3}

Table 6. The stress, strain and Poisson ratio of a compressed cake made from a 60 x 100 mesh size Pocahontas #3 coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	1123.20		
47.75	5260.32	25.30	4.81×10^{-3}
63.66	7141.68	30.36	4.25×10^{-3}
79.58	8882.64	45.54	5.13×10^{-3}
95.49	10361.52	60.72	5.86×10^{-3}
127.32	13384.80	101.20	7.56×10^{-3}
143.24	14798.16	116.38	7.87×10^{-3}
175.07	17493.84	166.98	9.55×10^{-3}
206.90	19787.04	222.64	11.25×10^{-3}
238.73	22155.12	283.36	12.79×10^{-3}
254.65	23156.64	318.78	13.77×10^{-3}
286.48	25637.04	414.92	16.18×10^{-3}
318.31	27144.00	516.12	19.01×10^{-3}

Table 7. The stress, strain and Poisson ratio of a compressed cake made from a 150 x 200 mesh size Pocahontas #3 coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	1740.96		
31.83	3238.56	10.12	3.13×10^{-3}
47.75	4286.88	25.30	5.90×10^{-3}
63.66	5840.64	30.36	5.20×10^{-3}
95.49	9126.00	50.60	5.55×10^{-3}
127.32	12055.68	80.96	6.72×10^{-3}
159.16	14854.32	121.44	8.18×10^{-3}
190.99	17316.00	161.92	9.35×10^{-3}
222.82	19787.04	202.40	10.23×10^{-3}
254.65	21902.40	258.06	11.78×10^{-3}
286.48	24204.96	318.78	13.17×10^{-3}
318.31	29016.00	374.44	12.91×10^{-3}

Table 8. The stress, strain and Poisson ratio of a compressed cake made from a 200 x 270 mesh size Pocahontas #3 coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	1460.16		
47.75	3762.42	10.12	2.69×10^{-3}
63.66	4754.88	20.24	4.26×10^{-3}
79.58	5850.00	30.36	5.19×10^{-3}
111.41	8030.88	40.48	5.04×10^{-3}
159.16	11222.64	65.78	5.86×10^{-3}
190.99	13338.00	80.96	6.07×10^{-3}
238.73	16239.60	116.38	7.17×10^{-3}
286.48	18851.04	166.98	8.86×10^{-3}
334.23	21378.24	217.58	10.18×10^{-3}
381.97	23652.72	273.24	11.55×10^{-3}
413.80	24738.48	328.90	13.30×10^{-3}
445.63	26563.68	354.20	13.33×10^{-3}
477.47	28491.84	435.16	15.27×10^{-3}

Table 9. The stress, strain and Poisson ratio of a compressed cake made from a minus 60 mesh size Pocahontas #3 coal.

Stress(psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	2742.48		
47.75	5802.20	15.18	2.62×10^{-3}
79.49	10080.72	60.72	6.02×10^{-3}
111.41	13572.00	121.44	8.95×10^{-3}
143.24	16623.36	172.04	10.35×10^{-3}
159.16	17933.76	202.40	11.29×10^{-3}
175.07	19281.60	237.82	12.33×10^{-3}
190.99	20554.56	283.36	13.79×10^{-3}
206.90	21855.60	328.90	15.05×10^{-3}
222.82	23194.08	379.50	16.36×10^{-3}
238.73	24654.24	445.28	18.06×10^{-3}

Table 10. The stress, strain and Poisson ratio of a compressed cake made from a 50 x 60 mesh size Pittsburgh #8 coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	1488.24		
31.83	3060.72		
47.75	4006.08	15.18	3.79×10^{-3}

Table 11. The stress, strain and Poisson ratio of a compressed cake made from a 60 x 100 mesh size Pittsburgh #8 coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
6.37	898.51		
19.10	2517.84		
25.47	3238.56		
38.20	5335.20	10.12	1.90×10^{-3}
44.56	6982.56	20.24	2.90×10^{-3}
57.30	10969.92	80.96	7.38×10^{-3}
63.66	11671.92	121.44	10.40×10^{-3}
76.39	12589.20	253.00	20.10×10^{-3}
89.13	17821.44	379.50	21.30×10^{-3}
101.86	21808.80	379.5	17.40×10^{-3}

Table 12. The stress, strain and Poisson ratio of a compressed cake made from a 150 x 200 mesh size Pittsburgh #8 coal.

Stress (psi)	Strain		Poisson Ratio*
	Vertical	Horizontal*	
6.37	505.44		
19.10	1647.36		
31.83	3369.60		
44.56	5035.68	* Could not record the readings.	
50.93	5821.92		
57.30	6449.04		
63.66	7066.80		
70.03	7684.56		
82.76	9294.48		

Table 13. The stress, strain and Poisson ratio of a compressed cake made from a 150 x 200 mesh size Pittsburgh #8 coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	926.64		
47.75	3032.64		
79.58	6121.44	10.12	1.65×10^{-3}
95.49	8161.92	25.30	3.10×10^{-3}
111.41	10146.24	60.72	5.98×10^{-3}
127.32	12205.44	91.08	7.46×10^{-3}
143.24	14358.24	131.56	9.16×10^{-3}
159.16	16670.16	192.28	11.53×10^{-3}
175.07	18925.92	278.30	14.71×10^{-3}
190.99	20872.80	369.38	17.70×10^{-3}

Table 14. The stress, strain and Poisson ratio of a compressed cake made from a minus 60 mesh size Pittsburgh #8 coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
6.37	1160.64		
25.47	2826.72		
31.83	3538.08		
44.56	5129.28	10.12	1.97×10^{-3}
57.30	6963.84	30.36	4.36×10^{-3}
70.03	9051.12	50.60	5.59×10^{-3}
82.76	11831.04	70.84	5.99×10^{-3}
95.49	14732.64	101.20	6.87×10^{-3}
108.23	18158.40	131.56	7.25×10^{-3}
120.96	22136.40	207.46	9.37×10^{-3}
133.69	26544.96	253.00	9.53×10^{-3}
146.42	36073.44	136.62	3.79×10^{-3}
159.16	42896.88	126.20	2.95×10^{-3}
165.52	45826.56	116.38	2.54×10^{-3}

Table 15. The stress, strain and Poisson ratio of a compressed cake made from a 50 x 60 mesh size Illinois #6 coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
6.37	4558.32		
12.73	7197.84	35.42	7.77×10^{-3}
19.10	10735.92	65.78	6.13×10^{-3}
25.47	13824.72	131.56	9.52×10^{-3}
31.83	17082.00	227.7	13.30×10^{-3}

Table 16. The stress, strain and Poisson ratio of a compressed cake made from a 60 x 100 mesh size Illinois #6 coal.

Stress(psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
6.37	5110.56		
12.73	5335.20	15.18	2.85×10^{-3}
19.10	9921.60	35.42	3.57×10^{-3}
25.47	12467.52	50.60	4.06×10^{-3}
31.83	16351.92	80.96	4.95×10^{-3}
38.20	19974.24	126.50	6.33×10^{-3}
44.56	23783.76	227.70	9.57×10^{-3}
50.93	26994.24	288.42	10.69×10^{-3}
57.30	30026.88	348.56	12.81×10^{-3}
63.66	33546.24	480.70	14.33×10^{-3}
70.03	37093.68	571.78	15.41×10^{-3}
76.39	41052.96	688.16	16.76×10^{-3}

Table 17. The stress, strain and Poisson ratio of a compressed cake made from a 150 x 200 mesh size Illinois #6 coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	2208.96		
31.83	5054.40	25.30	5.01×10^{-3}
47.75	8555.04	55.66	6.51×10^{-3}
63.66	12963.60	111.32	8.59×10^{-3}
79.58	18439.20	202.40	10.98×10^{-3}
95.49	23212.80	333.96	14.39×10^{-3}
111.41	27892.40	480.70	17.23×10^{-3}
127.32	32198.40	672.98	20.90×10^{-3}
143.24	34856.64	890.56	25.55×10^{-3}

Table 18. The stress, strain and Poisson ratio of a compressed cake made from a 200 x 270 mesh size Illinois #6 coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
6.37	1956.24		
12.73	3388.32		
25.47	5990.40		
44.56	8424.00	30.36	3.60×10^{-3}
57.30	9912.24	50.60	5.11×10^{-3}
63.66	10801.44	60.72	5.62×10^{-3}
82.76	14657.76	80.96	5.52×10^{-3}
89.13	15724.80	91.08	5.79×10^{-3}
95.49	17128.80	111.32	6.50×10^{-3}
108.23	19936.80	151.80	7.61×10^{-3}
127.32	25234.56	263.12	10.43×10^{-3}
140.06	28744.56	394.68	13.73×10^{-3}
152.79	34070.40	617.32	18.12×10^{-3}

Table 19. The stress, strain and Poisson ratio of a compressed cake made from a minus 60 mesh size Illinois #6 coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
6.37	2227.68		
19.10	5035.68	30.36	6.03×10^{-3}
31.83	8480.16	60.72	7.16×10^{-3}
44.56	12823.20	126.50	9.87×10^{-3}
57.30	16791.84	227.70	13.56×10^{-3}
63.66	18897.84	293.48	15.53×10^{-3}
76.39	22538.88	430.10	19.08×10^{-3}
89.13	25646.40	617.32	24.07×10^{-3}
95.49	26956.80	708.40	26.28×10^{-3}
101.86	28360.80	885.50	31.22×10^{-3}

Table 20. The stress, strain and Poisson ratio of a compressed cake made from a 50 x 60 mesh size Black Creek coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	12055.68	75.90	6.30×10^{-3}
31.83	22464.00	318.78	14.19×10^{-3}

Table 21. The stress, strain and Poisson ratio of a compressed cake made from a 60 x 100 mesh size Black Creek coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
6.37	2040.48		
12.73	4680.00	15.18	2.24×10^{-3}
19.10	8611.20	75.90	8.81×10^{-3}
25.47	13665.60	151.80	11.11×10^{-3}
31.83	17849.52	268.18	15.02×10^{-3}
38.20	21556.08	379.50	17.61×10^{-3}
44.56	24672.96	506.00	20.51×10^{-3}
50.93	27087.84	667.92	24.66×10^{-3}

Table 22. The stress, strain and Poisson ratio of a compressed cake made from a 150 x 200 mesh size Black Creek coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	3556.80	10.12	2.85×10^{-3}
31.83	8161.92	30.36	3.72×10^{-3}
47.75	13235.04	80.96	6.12×10^{-3}
63.66	17933.76	177.10	9.88×10^{-3}
79.58	23802.48	313.72	13.18×10^{-3}
95.49	28416.96	485.76	17.09×10^{-3}
111.41	31889.52	829.84	26.02×10^{-3}

Table 23. The stress, strain and Poisson ratio of a compressed cake made from a 200 x 270 mesh size Black Creek coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	1310.40		
31.83	2995.20		
47.75	5353.92	20.24	3.78×10^{-3}
63.66	8115.12	40.48	4.99×10^{-3}
79.58	11671.92	75.90	6.50×10^{-3}
95.49	15369.12	126.50	8.23×10^{-3}
111.41	19478.16	197.34	10.13×10^{-3}
127.32	24017.76	323.84	13.48×10^{-3}

Table 24. The stress, strain and Poisson ratio of a compressed cake made from a minus 60 mesh size Black Creek coal.

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
6.37	1581.84		
12.73	3818.88	10.12	2.65×10^{-3}
19.10	6177.60	25.30	4.10×10^{-3}
25.47	8255.52	40.48	4.90×10^{-3}
31.83	10670.40	60.72	5.69×10^{-3}
38.20	13431.60	101.20	7.53×10^{-3}
44.56	16604.64	151.80	9.14×10^{-3}
50.93	18794.88	212.52	11.31×10^{-3}
57.30	20854.08	263.12	12.62×10^{-3}
63.66	23166.00	333.96	14.42×10^{-3}
70.03	24785.28	495.88	20.01×10^{-3}
76.39	26685.36	607.20	22.75×10^{-3}

Table 25. The particle size distributions resulting from the compression of 50 x 60 mesh coal at 12,700 psi and the maximum stress, strain and Poisson ratio exhibited by the respective dry cakes.

Size (mesh)	Cumulative Weight Percent Passing			
	Black Creek	Illinois #6	Pittsburgh #8	Pocahontas #3
50	100.0	100.0	100.0	100.0
60	65.1	69.88	83.52	96.97
100	35.74	35.36	45.72	67.31
150	25.46	23.19	32.13	50.46
200	17.57	14.34	20.32	31.93
270	13.21	9.35	11.52	11.21
Max σ (psi)	31.83	31.83	47.75	171.89
Max ϵ_v	22464	17082	4006.08	21556.08
Poisson Ratio	14.19X10 ⁻³	13.33X10 ⁻³	3.79X10 ⁻³	16.43X10 ⁻³

Table 26. The particle size distributions resulting from the compression of 60 x 100 mesh coal at 12,700 psi and the maximum stress, strain and Poisson ratio exhibited by the respective dry cakes.

Size (mesh)	Cumulative Weight Percent Passing			
	Black Creek	Illinois #6	Pittsburgh #8	Pocahontas #3
60	100.0	100.0	100.0	100.0
100	54.62	60.87	63.04	77.65
150	33.91	35.78	40.26	58.13
200	21.81	22.08	22.44	26.30
270	14.93	15.42	11.43	6.70
Max σ (psi)	50.93	76.39	101.86	318.31
Max ϵ_v	27087.84	41052.96	21808.80	27144.0
Poisson Ratio	24.66X10 ⁻³	16.76X10 ⁻³	17.40X10 ⁻³	19.01X10 ⁻³

Table 27. The particle size distributions resulting from the compression of 150 x 200 mesh coal at 12,700 psi and the maximum stress, strain and Poisson ratio exhibited by the respective dry cakes.

Size	Cumulative Weight Percent Passing			
(mesh)	Black Creek	Illinois #6	Pittsburgh #8	Pocahontas #3
150	100.0	100.0	100.0	100.0
200	60.58	45.60	39.56	55.23
270	26.69	25.25	17.48	18.44
Max σ (psi)	111.41	143.24	82.76	318.31
Max ϵ_v	31889.52	34856.64	9294.48	29016
Poisson Ratio	26.02X10 ⁻³	25.55X10 ⁻³	-----	12.91X10 ⁻³

Table 28. The particle size distributions resulting from the compression of minus 60 mesh coal at 12,700 psi and the maximum stress, strain and Poisson ratio exhibited by the respective dry cakes.

Size	Cumulative Weight Percent Passing			
(mesh)	Black Creek	Illinois #6	Pittsburgh #8	Pocahontas #3
60	100.0	100.0	100.0	100.0
100	74.93	72.19	77.70	80.46
150	54.85	51.69	54.99	62.39
200	37.01	33.38	21.67	28.26
270	22.72	18.86	9.90	8.34
Max σ (psi)	76.39	101.86	165.52	238.73
Max ϵ_v	26685.36	28360.80	45826.56	24654.24
Poisson Ratio	22.75X10 ⁻³	31.22X10 ⁻³	2.54X10 ⁻³	18.06X10 ⁻³

Table 29. The particle size distributions resulting from the compression of 200 x 270 mesh coal at 12,700 psi and the maximum stress, strain and Poisson ratio exhibited by the respective dry cakes.

Size	Cumulative Weight Percent Passing			
(μm)	Black Creek	Illinois #6	Pittsburgh #8	Pocahontas #3
192	100.0	100.0	100.0	100.0
128	99.9	99.9	100.0	100.0
96	99.7	99.6	100.0	100.0
64	88.7	83.3	92.5	96.8
48	81.4	73.3	84.4	93.4
32	58.4	46.5	62.2	77.4
24	45.6	34.0	47.8	64.7
16	31.8	23.1	33.3	47.6
12	22.3	16.1	23.4	35.4
8	14.7	11.1	16.4	24.3
6	10.5	8.1	11.8	17.5
4	6.9	5.7	8.3	11.5
3	4.7	4.0	5.9	7.9
2	3.0	2.7	4.2	5.2
1.5	1.7	1.5	2.6	3.3
1	1.4	1.2	2.1	2.7
Max σ (psi)	127.32	152.79	190.99	477.47
Max ϵ_v	24017.76	34070.4	20872.8	28491.84
Poisson Ratio	13.48×10^{-3}	18.12×10^{-3}	17.7×10^{-3}	15.27×10^{-3}

**Table 30 Comparison of Predicted Optimized Responses
with Experimental Results for Illinois #6 Coal**

Test Conditions				Energy Consumption (KWH/Ton)		Product Size (D50, μ)	
Media	RPM (X1)	% Solids (X2)	Feed Size in Mesh (X3)	Predicted	Expl.	Predicted	Expl.
Sand	3280 (+2)	44 (1.4)	50X60 (+2)			5.81	5.3
Sand	2204 (-0.24)	40 (+1)	270X325 (-2)	206.75	170.21		
Steel	1975 (-0.81)	37 (-0.7)	50X60 (+2)			3.83	3.9
Steel	1734 (-1.41)	38 (+0.8)	200X325 (-2)	131.77	314.12		

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