1 of 1

DEVELOPMENT OF A GAS-PROMOTED OIL AGGLOMERATION PROCESS

Technical Progress Report

December 1, 1993 - February 28, 1994

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PURPOSE

The overall purpose of this research project is to carry out the preliminary laboratory-scale development of a gas-promoted, oil agglomeration process for cleaning coal using model mixing systems.

INTRODUCTION

It was reported previously (ref. 1) that a model mixing system had been designed and constructed for conducting oil agglomeration tests in such a way that agitator speed and torque can be measured as well as agglomeration performance. The design of the system is similar to that of standard industrial mixing systems used for mixing solid particles, liquid, and gas. Figure 1 is a cross section view of the system. The tank has an inside diameter of 15.24 cm (6.0 in.), height of 15.24 cm (6.0 in.), and volume of 2860 ml. The tank has 4 vertical baffles which extend inward a distance of 1.27 cm (0.50 in.). The contents of the tank are agitated by a six-blade, Rushton-type impeller which is driven by a 1/18 HP, variable speed motor that can be operated over a speed range of 200 to 2500 rpm. The motor control unit provides an indication of both agitator speed and torque.

Equipment is also provided for monitoring the progress of agglomeration during a batch test. This equipment includes a photometric dispersion analyzer for measuring the turbidity of

Figure 1. The 2.86 L mixing system designed for conducting oil agglomeration tests.

the particle suspension. In order to measure the turbidity a small stream of material is withdrawn from the mixing tank and conducted through an optical cell associated with the photometric dispersion analyzer. The material is then returned to the mixing tank. A peristaltic pump located between the optical cell and the mixing tank is used for circulating the material.

During the past quarter a series of shakedown tests was carried out to calibrate the equipment and to determine some of its operating characteristics. The accuracy of the agitator speed and torque measuring instrument was checked. Also the gas dispersing effectiveness of the mixing system was investigated. In addition, the effects of agitator speed and solids concentration on agitator torque and power requirements were studied.

WORK PERFORMED

The agitator speed indicator was checked by operating the drive motor at various speeds and comparing the indicated speeds with the values measured with an electronic tachometer. The latter was a model B-891 made by Power Instruments, Inc. The two sets of readings are presented in Table 1 for comparison. It can be seen that the indicated speed was slightly lower than the speed measured with the tachometer over the whole range of speed. However, the difference in readings was small, being only 3-5% in the low and middle speed range and 1-2% in the high speed range. Therefore, the accuracy of the agitator speed indicator was deemed adequate.

Table 1. Comparison of measured and indicated agitator speeds.

Indicated Speed, rpm	500	1000	1250	1500	2010
Measured Speed, rpm	518	1050	1300	1530	2030
Difference, %	3.5	4.8	3.8	2.0	1.0

The agitator torque indicator was checked by a calorimetric technique which involved determining the stirring time required to produce a 10.0°C rise in the temperature of a calorimeter and its contents at a known agitator speed. The calorimeter consisted of a 700 ml Dewar vacuum flask fitted with a cork stopper, an electrical resistance heater, and a mercury thermometer with 0.1°C divisions. The agitator from the agglomeration system was set up to stir the contents of the calorimeter. Initially 400 ml water was placed in the calorimeter, a known voltage was applied across the resistance heater, and the time required to produce a temperature rise of 10.0°C was determined. Since the resistance of the heater was known, the power input could be determined as well as the total energy input required to produce a 10.0°C temperature rise. A series of five trials produced the results shown in Table 2. For this series of trials, the average total energy input required to produce a 10.0°C temperature rise was 354.8 w-min.

A second series of trials was carried out using only the energy output of the agitator to raise the temperature of the calorimeter. For each trial the stirring time required to raise the

Table 2. The electrical power input required to raise the temperature of the calorimeter 10.0°C

Voltage, volts	Current, amp.	Resistance, ohm	Power, watt	Time, min.	Tot. input, ^a w-min.
2.34	2.13	1.10	4.98	71.2	354
2.52	2.29	1.10	5.77	60.5	349
2.69	2.45	1.10	6.58	54.1	356
3.09	2.81	1.10	8.68	40.8	354
3.30	3.00	1.10	9.90	36.5	361

^aTotal energy input required to produce 10.0°C temperature rise.

temperature of the calorimeter 10.0°C was measured. The indicated agitator speed and torque were noted. The average power delivered by the agitator was determined by means of the following relation:

$$\text{Power input in watts} = \frac{354.8 \text{ w-min}}{\text{stirring time in min.}}$$

The agitator torque was then calculated by using the expression,

$$\text{Torque in g-cm} = \frac{97510 (\text{Power in watts})}{\text{Agitator speed in rpm}}$$

The torque determined by this method is compared with the indicated torque in Table 3 for the various trials conducted at different agitator speeds. The torque determined calorimetrically was consistently lower by 9-12% than the indicated torque.

To investigate the effects of agitator speed and solids concentration on mixer torque and power, a quantity of Upper Freeport coal was first crushed and then ground in a series of small batches in a 1.1 L ball mill. For each batch 145 g coal, 100 ml water, and 145 stainless steel

Table 3. Comparison of indicated agitator torque and the torque required to produce a calorimeter temperature rise of 10.0°C at the indicated agitator speed

Indicated		Stirring time, min	Power ^b input, watts	Torque ^c (ΔT based) g-cm	Difference in Torque, %
Speed rpm	Torque g-cm				
1550	350	70.75	5.01	316	10.8
1750	420	52.50	6.76	377	11.4
2000	520	36.27	9.78	477	9.0
2260	550	31.20	11.37	491	12.0

^bPower input = 354.8/stirring time

^cTorque = 97510 (power input)/N

balls having a diameter of 1.27 cm were placed in the mill, and the coal was ground for 10 min.

This process produced a relatively coarse product having the following size distribution:

<u>Mesh size,</u>	<u>Weight, %</u>
+40	58.7
-40/+100	30.3
-100/+200	4.6
-200	6.4

The mixing unit was filled initially with pure water, and the indicated agitator torque was determined at various agitator speeds. Then sufficient ground coal was added to the mixing unit to provide a solids concentration of 5 w/v%, and the torque was measured again at various speeds. The operation was repeated with increasing concentrations of coal until the final set of measurements was made with a solids concentration of 50 w/v%. The indicated agitator speed and torque were used to calculate the agitator power for each combination of speed and solids concentration. The results obtained for solids concentrations of 0, 15, and 30 w/v% over a speed range of 1000 to 2000 rpm are shown in Figure 2. It is apparent that agitator power was affected greatly by agitator speed while being affected only slightly by solids concentration. In fact the power was found to be directly proportional to $N^{3.1}$ where N is agitator speed. This result agrees with the findings of earlier investigators who have observed that agitator power is proportional to N^3 for turbulent mixing (ref. 2). The finding that agitator power was only 6-9% greater for a solids concentration of 30 v/w% than for pure water was unexpected, but may have been due to the relatively coarse size of the coal particles. This finding is cause for further study, and the measurements will be repeated with much smaller particles.

Figure 2. Correlation between agitator power and agitator speed.

To determine the gas dispersing effectiveness of the mixing system, several tests were conducted in which the mixing unit was first filled with water. The agitator speed was set, and the indicated agitator torque was noted. Next a measured amount of water was withdrawn from the mixing unit with a syringe which caused a corresponding volume of air to be drawn into the unit. The degree of gas dispersion was observed, and the indicated agitator torque was recorded. Additional increments of air were introduced until altogether 200 ml had been introduced. This operation was repeated for various agitator speeds.

The effect of introducing air into the mixing unit on indicated agitator torque is shown by Figure 3. It can be seen that the introduction of small amounts of air caused the torque to decrease slightly at any given stirring speed. The effect of air on torque was more apparent at

Figure 3. Effect of small amounts of air on agitator torque.

higher speeds. At 2000 rpm the rate of change of torque with respect to the volume of air introduced was very noticeable until 100 ml had been introduced. Beyond this point the rate of change was very slight. Visually it was observed that only small amounts of air were dispersed in the water, particularly with an agitator speed of 1500 rpm. At this speed most of the air was trapped in a layer above the surface of the liquid. At higher speeds more air was displaced and less was trapped above the liquid. If gas dispersion proves to be a limiting factor, it will be necessary to increase the level of agitation either by increasing the stirring speed or impeller diameter.

PLANS FOR NEXT QUARTER

Since the agreement between the indicated agitator torque and the torque determined calorimetrically was not as close as needed for accurate work, further torque measurements will be conducted, possibly by using a different technique. Also further consideration will be given to the effect of solids concentration on torque and power requirements. Tests will be conducted using a much finer particle size distribution. Additional consideration will also be given to the power required to achieve a higher level of gas dispersion. This will require installing a larger agitator drive motor. In addition, consideration will be given to the agitator power required for dispersing oil and for producing compact agglomerates.

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