DEVELOPMENT OF A GAS-PROMOTED OIL AGGLOMERATION PROCESS

Quarterly Technical Progress Report

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ABSTRACT

The series of agglomeration tests designed to study the agglomeration characteristics of Pittsburgh No. 8 coal with i-octane was continued using a larger agitated tank. This series is designed to determine the effects of various parameters on the size and structure of the agglomerates formed, the rate of agglomeration, coal recovery, and ash rejection. The results reported here show that once spherical agglomerates are formed they continue to grow at almost a constant rate which is proportional to the concentration of i-octane. The constant growth rate is interrupted when spherical agglomerates combine to form large clusters. This only seems to occur with a large concentration of i-octane (e.g., 30 v/w%) and limited agitator power. The present results also show that coal recovery and ash rejection are highly dependent on agglomerate size when the mean agglomerate diameter is less than the size of the openings in the screen used for recovering the agglomerates.

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EXECUTIVE SUMMARY

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. Specific objectives include determining the nature of the gas promotion mechanism, the effects of hydrodynamic factors and key parameters on process performance, and a suitable basis for size scale-up of the mixing system.

The experimental results reported here were obtained by agglomerating Pittsburgh No. 8 coal with i-octane in an enclosed agitated tank having a diameter of 11.4 cm. Agglomeration was promoted by introducing a small amount of air at the start of each batch run. The progress of agglomeration was monitored by observing changes in agitator torque while agitator speed was held constant. The final product was recovered by screening. By analyzing the agglomerated product it was possible to determine the size and ash content of the product. By varying the treatment time it became possible to observe the growth rate of spherical agglomerates. Therefore, a series of agglomeration tests was conducted to study the effects of i-octane concentration and agitator speed on the growth rate. The results were also used to relate coal recovery and ash rejection to treatment time and/or mean agglomerate size.

It was found that the growth rate of spherical agglomerates was almost constant during a batch test once small agglomerates were formed. However, when a large concentration of i-octane (e.g., 30 v/w%) was used in conjunction with a lower agitator speed (e.g., 1450 rpm), the constant growth rate was interrupted by the formation of large clusters of agglomerates. For constant growth rate conditions, the growth rate was proportional to i-octane concentration. At the highest i-octane concentration (i.e., 30 v/w%), the growth rate

increased modestly when the agitator speed was increased, but this effect was not observed at a lower concentration.

The recovery of agglomerates by screening depended on the size of the agglomerates relative to the size of the screen openings. Consequently, the recovery decreased when the average size of the agglomerates was less than the size of the openings. The decline in recovery also resulted in less ash rejection and a larger product ash content.

INTRODUCTION

A series of tests have been underway in which small amounts of air have been used to promote the agglomeration of Pittsburgh No. 8 coal with i-octane. The results of preliminary tests in this series were reported previously (ref. 1). These tests were carried out with a 7.62 cm diameter agitated tank and with a 3.65 cm diameter impeller. The results indicated that the rate of agglomeration was improved by an increase in either oil concentration or agitator speed. The results also showed that increases in oil concentration, agitator speed and/or treatment time tended to improve coal recovery and ash rejection.

Further agglomeration tests in the series have been conducted and the results are reported below. These tests were carried out with a 11.4 cm diameter agitated tank and with a 5.08 cm diameter impeller. While the diameter of the tank was only 1.5 times greater than the diameter of the tank used previously, the volume of the tank was 3.38 times greater. The two tanks are geometrically similar. The additional tests were conducted to determine the effects of agitation time and various system parameters on coal recovery and grade so the overall purpose was similar to that of the previous tests in the series.

RESULTS AND DISCUSSION

The agglomeration tests were conducted with coal from the Pittsburgh No. 8 Seam in Belmont County, Ohio. This coal contained 5.0% sulfur and 28% ash on a dry basis. The preparation of this material and the equipment and procedure used for conducting agglomeration tests were described previously (ref. 2). All of the tests reported below were carried out with a 11.4 cm diameter agitated tank using a 5.08 cm diameter impeller. A solids concentration of 30 w/v% was utilized in each test, and pure i-octane was the

agglomerant employed in each test. The particle suspension was first degassed and then dosed with i-octane. After the suspension was conditioned for 5 min. with the agitator running at the desired test speed, a known volume of air was introduced which started the process of agglomeration. As the test continued, agitator speed was held constant while agitator torque was allowed to vary. The torque was measured and recorded continuously because it had been shown previously that changes in the torque provided an indication of the progress of agglomeration (ref. 2). The mixing tank was cooled with an ice batch to maintain the temperature of the suspension close to room temperature. At the end of a run a sample of the suspension was collected for examination with a microscope. The range of agglomerate size was noted as well as the general shape of the agglomerates. The remaining suspension was then diluted with an equal volume of water and separated with a 250 μm screen. The agglomerated product and the tailings were recovered separately and then dried and weighed. The ash content of the product and tailings was determined subsequently.

For some runs the average agglomerate diameter was determined by means of automated image analysis (AIA). Measurements were carried out with a Nikon optical microscope which was connected to a computer.

The conditions employed and the results obtained in the present series of agglomeration tests or runs are presented in Table 1. The following conditions were varied among these tests: oil concentration, air concentration, agitator speed, and total time of agitation after air was introduced.. For each of the tests a record was obtained of the variation in agitator torque with time as well as an indication of coal recovery and ash rejection. Typical results are shown in Figure 1 for three runs conducted at different agitator speeds but otherwise

Table 1. Experimental conditions and results of oil agglomeration runs with 11.4 cm diameter agitated tank and with 5.08 cm diameter impeller.

Run No.	Oil, v/w%	Air, v/w%	Speed, rpm	Time, ^a min.	Size, ^b mm	Ash, ^b w/w%	Ash Rej., ^c %	Coal Rec., ^d %
49	30	10	1600	45	0.20-0.30	10.36	68.87	97.36
50	30	9	1600	50	0.20-0.25	10.52	70.22	95.53
51	30	9	1600	90	0.40-0.60	8.64	74.27	96.51
52	30	9	1600	15	0.15-0.20	8.95	69.43	94.34
53	30	9	1600	30	0.18-0.22	13.22	64.21	95.39
54	30	15	1600	30	0.20-0.22	8.90	73.96	95.52
55	30	9	1750	90	0.40-0.60	8.79	74.50	96.90
56	30	9	1750	30	0.15-0.20	8.21	74.89	95.06
57	30	9	1750	50	0.25-0.32	8.45	74.04	97.14
58	30	9	1750	15	0.12-0.15	11.04	65.94	93.36
59	30	9	1450	30	0.10-0.15	13.01	61.30	90.93
60	30	9	1450	15	0.08-0.10	18.97	45.97	87.49
61	30	9	1450	90	1.20-4.00	8.33	77.05	96.72
62	30	9	1450	50	0.15-0.25	10.84	68.87	95.25
63	30	4.5	1450	90	0.25-0.40	9.78	72.77	96.44
64	20	9	1600	90	0.09-0.12	14.98	62.32	83.18
65	20	9	1600	60	0.07-0.10	15.35	64.11	75.36
66	20	9	1750	90	0.08-0.12	14.59	60.37	87.47
67	20	9	1750	60	0.07-0.10	15.51	60.65	80.92
68	20	9	1750	30	0.05-0.07	19.59	58.17	65.63
69	20	9	1450	90	0.07-0.12	16.45	58.90	83.34
70	20	9	1450	60	0.06-0.10	17.51	59.70	74.97
71	20	9	1450	30	0.05-0.06	22.68	38.57	81.77

^aTreatment time following introduction of air.

^bSize range and ash content of agglomerates.

^cAsh rejected to tailings.

^dCoal recovery on a dry, ash-free basis.

Figure 1. Results of three runs conducted with 30 v/w% oil, 9 v/w% air, and different agitator speeds in 11.4 cm diameter tank.

Figure 2. Results of three runs conducted with 20 v/w% oil, 9 v/w% air, and different agitator speeds in 11.4 cm diameter tank.

similar conditions including an oil concentration of 30 v/w% and air concentration of 9 v/w%. These runs were extended for 90 min. and varied with both impeller speed and treatment time. The results of another set of runs conducted under similar conditions except for an oil concentration of 20 v/w% are indicated in Figure 2. Although the variation in agitator torque with impeller speed and treatment time was similar to that observed with the larger oil concentration, it is apparent that the changes in torque amplitude were less with the lower oil concentration. Also at the lowest impeller speed (1450 rpm) the series of fluctuations in torque which appeared after 70 min. of treatment with the higher oil concentration did not appear with the lower oil concentration. These fluctuations seemed to correspond with the formation of large clusters of agglomerates.

The results of the preceding runs together with those of runs conducted for shorter time intervals showed how agglomerate size varied with treatment time for a given oil concentration and impeller speed. With an oil concentration of 30 v/w%, evidence of spherical agglomeration appeared within 5 to 15 min. after air was introduced, whereas with an oil concentration of 20 v/w% such evidence did not appear until somewhat later. Extending the treatment beyond the first appearance of spherical agglomerates produced larger agglomerates. The growth in agglomerate size is indicated in Figures 3 and 4 for runs made with impeller speeds of 1750 and 1450 rpm, respectively. It can be seen that the growth was much more rapid with 30 v/w% oil than with 20 v/w% oil regardless of impeller speed. Furthermore, for an oil concentration of 30 v/w% the growth was more rapid with an impeller speed of 1750 rpm than with a speed of 1450 rpm until a time was reached when

Figure 3. Variation in agglomerate size with treatment time for runs made with an agitator speed of 1750 rpm.

Figure 4. Variation in agglomerate size with treatment time for runs made with an agitator speed of 1450 rpm.

large clusters were produced at the lower speed. Such clusters did not appear at the higher speed. The effect of agitator speed on growth rate was insignificant when an oil concentration of 20 v/w% was employed.

The growth in the size of the agglomerates which took place as the treatment time was extended seemed to improve both the recovery and quality of the agglomerates. The improvement is indicated in Figures 5 and 6 which show that coal recovery and ash rejection increased with increasing treatment time while the ash content of the agglomerates decreased. It is believed that this improvement occurred primarily because as agglomerate size increased fewer agglomerates passed through the 250 μm separation screen which was used for recovering the agglomerates. However, the decline in ash content of the agglomerates with treatment time indicates that the quality of the agglomerates increased as well as their size.

A more direct indication of the effect of agglomerate size on coal recovery and ash rejection was obtained by plotting these parameters against the mean agglomerate diameter for runs 62 to 69 (see Figure 7). It was possible to make such a plot because the mean agglomerate diameter had been determined for each of these runs by automatic image analysis. The results indicate that coal recovery increased sharply with increasing agglomerate diameter until a value of diameter somewhat less than 190 μm was produced. An increase in diameter beyond this value had little effect. Again the results suggest that the recovery of smaller agglomerates declined because they were not retained by the separation screen.

Figure 5. Effect of treatment time on coal recovery, ash rejection, and product ash content for two sets of runs conducted at different agitator speeds but with 30 v/w% oil and 9 v/w% air.

Figure 6. Effect of treatment time on coal recovery, ash rejection, and product ash content for two sets of runs conducted at different agitator speeds but with 20 v/w% oil and 9 v/w% air.

Figure 7. Effect of mean agglomerate diameter determined by AIA on coal recovery, ash rejection, and product ash content for runs 62 to 69.

CONCLUSIONS

The results of the agglomeration tests made with a 11.4 cm diameter mixing tank which are presented here were generally similar to the results obtained with a 7.62 cm diameter tank which were reported previously. However, the present results provide a clearer picture of agglomerate growth and its effect on cleaning efficiency. It was found that once spherical agglomerates are produced they continue to grow steadily in size, and the rate of growth is proportional to the oil concentration. The constant growth rate is interrupted when spherical agglomerates combine to form clusters. This only happened with an oil concentration of 30 v/w% and an agitator speed of 1450 rpm.

An increase in agitator speed from 1450 rpm to 1750 rpm produced a modest increase in growth rate when an oil concentration of 30 v/w% was employed, but such an increase had

no effect on the growth rate when an oil concentration of 20 v/w% was used. It was also found that coal recovery and ash rejection were highly dependent on agglomerate size when the mean agglomerate diameter was less than the size of the openings in the screen used for separating and recovering the agglomerates.

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