POC-Scale Testing of a Triboelectrostatic Separator for Fine Coal Cleaning

by

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Abstract

Triboelectrostatic separation (TES) processes are capable of removing ash and sulfur from coal to very low levels but at relatively low Btu recoveries. Furthermore, they suffer from low throughput. On the other hand, TES processes are dry processes that do not incur high costs of dewatering at down stream. The objective of the present investigation is, therefore, to further develop the TES process developed at FETC and test it at a proof-of-concept scale. In this communication, the results obtained to date using a prototype bench-scale unit will be presented. Also shown will be the basic information on triboelectrification, which is essential for designing an efficient TES unit.

Introduction

The Federal Energy Technology Center (FETC) developed a triboelectrostatic separation (TES) process, which is capable of removing mineral matter from coal without using water. A distinct advantage of this process is that it is a dry process, so that it does not entail costly steps of dewatering, which is the major impediment for commercial deployment of many advanced fine coal cleaning processes. It is the objective of this project to further develop the process and test it at proof-of-concept (POC) scale.

During the past year, bench-scale test work has been conducted to identify the process variables that are critical for designing an efficient POC-scale TES unit capable of processing 200-250 kg/hr of feeds. In this communication, some of the bench-scale test results obtained to date are presented, along with the information concerning the mechanism of triboelectrification.

Experimental

Apparatus

On-line Charge Monitor In order to study the charging mechanisms, an on-line tribocharge monitoring system has been developed in this project. It consists of a copper in-line mixer placed in a Faraday cage. The in-line mixer charger is connected to an electrometer (Keithly Model-642) by means of a coaxial cable to monitor the tribocharge being generated in the in-line mixer charger on-line.

Bench-scale Triboelectrostatic Separator An entrained flow triboelectrostatic separator (TES) has been developed in this project. It consists of a tribocharger and a set of two rotating drum electrodes. Coal particles exiting the tribocharger enter the non-uniform potential field created between the two electrodes. The positively and negatively charged particles are separated by splitting the flow between the two electrodes by means of a splitter. Three different tribochargers, i.e., in-line mixer, Plexiglas tubing, and a turbocharger, were tested in the present work.

Samples

Charge measurements were conducted on coal (a clean Pittsburgh No.8 coal assaying 6.27%ash and 1.68%sulfur), quartz (SiO_2), and pyrite. These samples were pulverized and dry-screened to obtain different size fractions, i.e., -40+65, -65+100, -100+200 mesh. A clean Pittsburgh seam coal was used as the feed for bench-scale TES tests. Two different size fractions, i.e., -140+200 and -200 mesh, were used for the tests.

Results and Discussion

Figure 1a shows the results of the charge measurements conducted as a function of air velocity at a feed rate of 0.2 kg/min. It shows that coal particles are positively charged, while mineral matter (represented by quartz) is negatively charged. It also shows that the charge density (given in units of C/kg) increases with increasing air velocity, which may be attributed to the increase in the velocity with which a particle impinges on the copper walls and the blades of the in-line mixer charger. This finding suggests that wall charging plays an important role in the overall charging mechanism. The results presented in Figure 1a show the following: i) The charge density increases with decreasing particle size, and the difference in charge densities of quartz and pyrite increases with decreasing particle size; ii) The difference increases with increasing air velocity; iii) Pyrite is more negatively charged than quartz.

Figure 1b shows the results of the charge measurements conducted by changing the feed rate. The measurements were conducted with coal, quartz and pyrite samples at 1.9 m/sec of air velocity. As shown, charge density decreases with increasing feed rate regardless of particle size. At a given air velocity, an increase in feed rate should decrease the velocity of the particles impinging on the copper wall and colliding with each other, resulting in a low charge density. It should be possible to overcome this problem by increasing the air velocity when feed rate is increased.

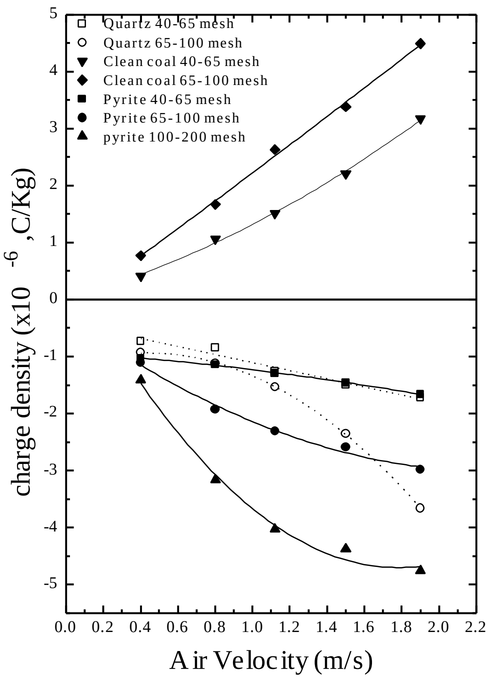

Figure 1a: The effect of air velocity on charge density. The results were obtained on Pittsburgh #8 coal, quartz and pyrite at a feed rate of 0.2 kg/min, air pressure of 40 psi, and temperature at 28-30^{o}C.

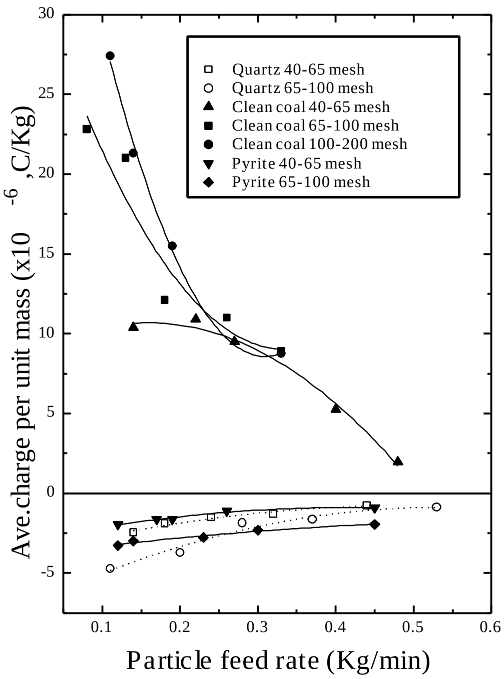

Figure 1b: The effect of feed rate on charge density. The results were obtained on Pittsburgh #8 coal, quartz and pyrite samples with air velocity of 1.9 m/s, air pressure of 40 psi and temperature at 28-30^{o}C.

Figure 2 shows the results of the parametric study of the charging mechanisms using the composite Box-and-Behnken experimental design technique. A 4x27 test matrix was developed, which is designed to investigate the effects of four major operating parameters, i.e, i) air velocity, ii) feed rate, iii) particle size, and iv) feed composition (ash content in the feed), at three levels, i.e., high (+1), normal (0), and low (-1). It is shown that the charge density increases under the following conditions: i) increasing air velocity, ii) decreasing feed rate, and iii) decreasing particle size. These results are consistent with those presented in Figures in 1a.and 1b. The statistical analysis did not identify the optimum conditions within the bounds of the variables studied in the present work.

A Pittsburgh No. 8 coal sample (-200 mesh) assaying 5.9% ash, 1.6% total sulfur was subjected to a series bench-scale TES tests by varying the potential difference between the two electrodes. In general, the TES process is capable of producing very clean products but at low yields. Therefore, the reject streams were subjected to two more stages of TES process to minimize the Btu loss. The results are given in Figures 3a and 3b in the form of grade vs. recovery curves. The curves shift considerably depending on the potential difference between the electrodes. It appears that the electrode potential of 20 kV is not strong enough to pull the charged particles toward the electrodes. The best results have

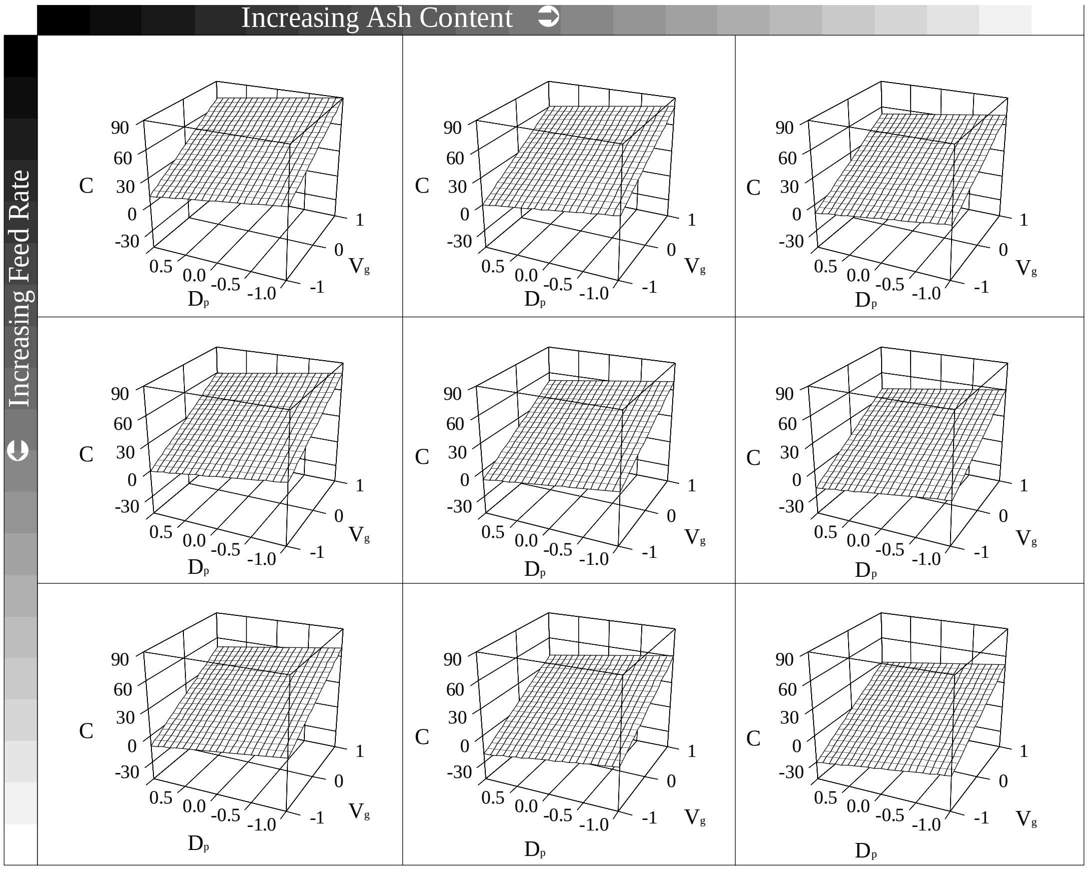

Figure 2 Test results of the parametric study of the charging mechanisms using the composite Box-and-Behnken experimental design technique.

been obtained at 40 kV. The results obtained at 70 kV are inferior to those obtained at 40 kV, for which two possible reasons may be considered. First, some of the mineral matter may acquire charges by induction in a high potential field. Although the inductive charging can occur only with conductors (e.g., pyrite) there may be sufficient moisture on the surfaces of the ash-forming minerals in coal that will make them behave as conductors. Second, in a high electric field, highly charged particles may move so quickly toward the oppositely charged electrodes that some of the unwanted particles report to wrong product streams, causing a decrease in separation efficiency.

One important objective of the project is to maximize the throughput of the TES unit. Therefore, a series of bench-scale tests were conducted on the Pittsburgh coal (-150+200 mesh) assaying 6.4% ash and 1.68% total sulfur by varying feed rates. At a given feed rate, the refuse product was subjected to two stages of scavenging, while the clean coal product was subjected to two stages of cleaning. The results are given in the form of grade vs. recovery curves in Figures 4a and -b. The results are normalized with respect to feed ash and sulfur contents, so that the shift in grade vs. recovery curves due to the changes in feed rate can be seen more clearly. As shown, the curves shift to the left (i.e., separation efficiency improves) with initial increase in feed rate; however, further increase in throughput beyond 28.2 kg/hr results in a decrease in separation efficiency.

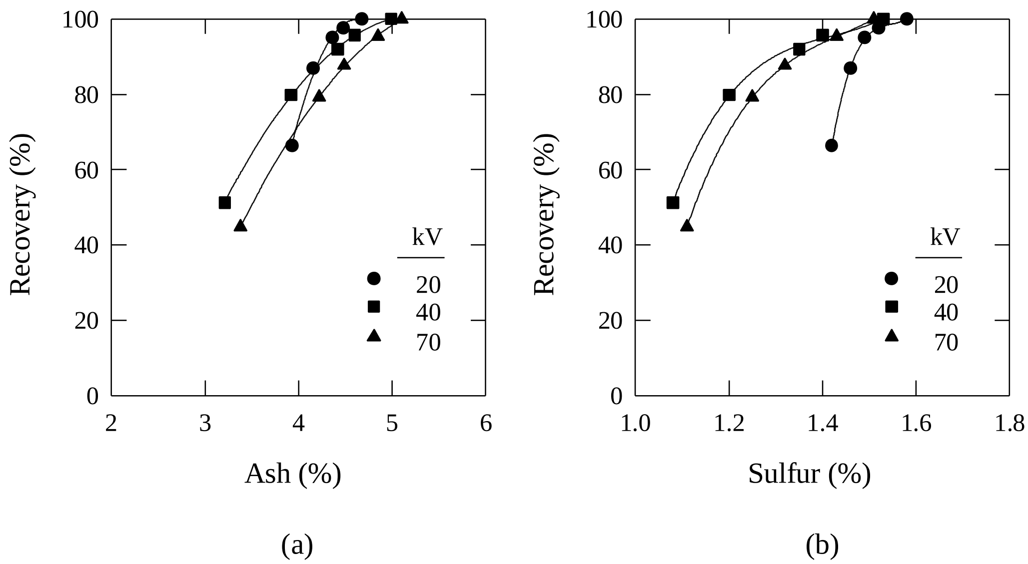

Figure 3 The effect of electrode potential on the separation efficiency of the bench-scale TES unit. Tests were conducted at a feed rate of 4kg/hr.

The changes in separation efficiency with feed rate are more clearly shown in Figure 5. At very low feed rates, the particles may not be sufficiently charged because there may not be enough particles to collide with each other and create charges by means of the inter-particle charging mechanism. The separation efficiency remains more or less constant at feed rates between approximately 10 and 30 kg/hr.

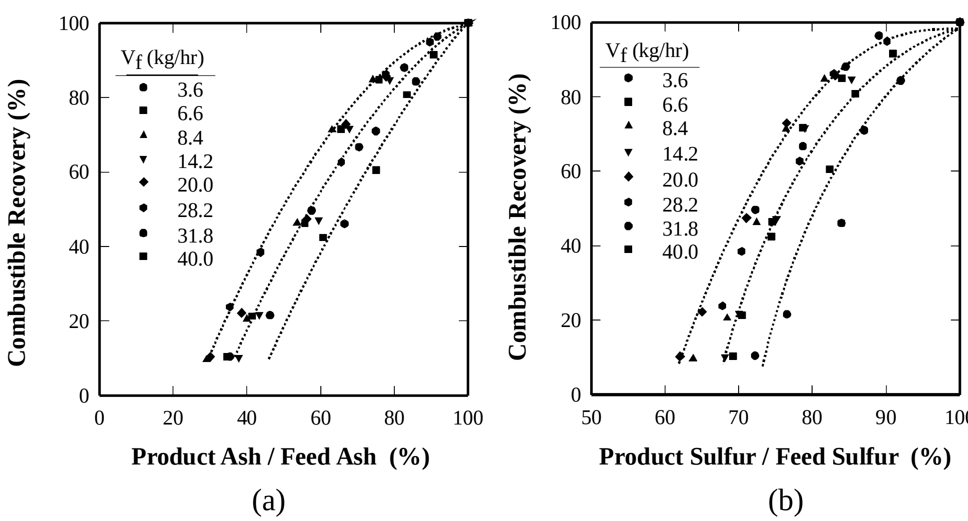

Figure 4 The effect of feed rate on separation efficiency of the bench-scale TES unit. Tests were conducted on a clean Pittsburgh No. 8 coal sample and the results were normalized with respect to the feed grade.

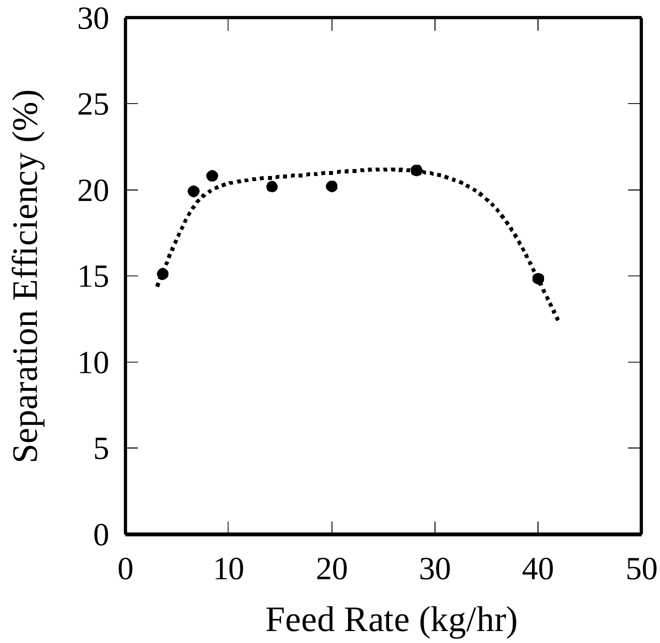

Figure 5 Effect of feed rate on the separation efficiency. Tests were conducted on a clean Pittsburgh No. 8 coal sample (-140+200 mesh).

As the feed rate is increased above 30 kg/hr, the separation efficiency deteriorates significantly, possibly due to the lack of both inter-particle and wall charging mechanisms. It is possible to further increase the throughput by increasing the energy dissipation, which is defined as the energy input per unit time and unit mass of a feed.

Summary

1. An on-line triboelectrostatic charge monitor has been developed, and used to measure the charges of coal, quartz, and pyrite. The results show that coal is positively charged, while quartz and pyrite are negatively charged.

2. The difference between the charge densities of coal and mineral matter can be maximized by decreasing particle size, increasing particle (or compressed air velocity), and decreasing feed rate.

3. The use of turbocharger greatly increased the efficiency of triboelectrification and, hence, the throughput of the bench-scale TES unit.

4. A clean Pittsburgh coal sample was tested on the bench-scale TES unit by changing the feed rate. The results showed that the maximum throughput is approximately 30 kg/hr. Beyond this limit, the separation efficiency decreases considerably.