2001 International Ash Utilization Symposium, Center for Applied Energy Research, University of Kentucky, Paper #44.

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New Products from Coal Combustion Ash: Selective Extraction of Particles with Density < 2

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KEYWORDS: construction products, beneficiation

ABSTRACT

Spherical and hollow fly ash particles having density < 1g/cm^3 are known as cenospheres. Their concentration in coal combustion ash is typically << 1%; as a consequence, their value is relatively high (~$0.70/kg). However, cenospheres are really particles containing gas bubbles independent of their density. Hence, cenosphere densities can vary between 0.6 g/cm^3 to near or greater than 2.0 g/cm^3. They can constitute up to 80% of some fly ashes, but there is no economic way of selectively extracting them.

We report on the selective extraction of cenospheres, defined as particles having bulk densities < 2 gm/cm^3, from combustion fly ashes by the use of a specially-designed, pneumatic transport, triboelectric separation system. Processing at feed rates up to 20 kg/hr, the concentration of low density products were measured by float-sink analysis plus centrifugation. The float-sink media included distilled water and lithium metatungstate, the densities of which were varied between 1.0 gm/cm^3-to-2.0 gm/cm^3. Pneumatic transport, triboelectric separation tests to optimize product selectivity are described. The products were analyzed by optical and scanning electron microscopy, He pycnometry and laser granulometry. Depending on the ash, an overall product density of near 1.6 gm/cm^3 could be obtained. They would be useful for creating lighter-weight ceramics and building materials, and for specialized coatings.

Introduction

Although dependent on the size of the coal injected into the combustor, the type of combustor and coal-firing technology, the mineral matter content of the coal and other operation and coal parameters, typical fly ash particle diameters are between 0-300 ìm (1) These particles contain a myriad of constituents which, if efficiently and economically extracted, may increase significantly the commercial applications of combustion ash. Cenospheres have high intrinsic values and many known applications (2-3).

Cenospheres are formed from the ash when it is in a molten state. In this state, a spherical shape is formed because it minimizes surface tension. Flowing with the combustion gas stream, their temperature is rapidly quenched, thereby 'freezing in' the spherical shape. Any gas bubbles within the molten particles are also trapped inside the spheres. These bubbles cause the production of cenospheres; bubbles may occur in multiple forms within the 'frozen' particles, or as single, concentric forms that are nearly as great as the diameter of the particles.

The thickness of cenosphere walls may be very small - eg < 10% of the particle diameter - and, if so, the resultant bulk densities are less than 1 gm/cm^3. These particles float on water within wet ash impoundments and their harvesting can be accomplished by pond skimming. Traditionally, the word cenosphere has been identified with these <1 gm/cm^3 particles. However, the real meaning of cenosphere entails particles that have gas bubbles incorporated within their structure. In general, it is known that the relative amount of <1 gm/cm^3 cenospheres in combustion fly ashes is around 1%.

However, there is actually considerably higher concentrations of cenospheres in combustion ash. It has been determined (1) that, for fly ash produced during the combustion of Kentucky No. 9 coal, the concentration of cenospheres having bulk densities less than 2 gm/cm^3 is about 9%; for fly ash from San Miguel coal, the concentration of cenospheres with densities less than 2 gm/cm^3 was almost 87%. Of course, these values depend on parameters other than just the type of coal combusted. These data suggest significant opportunities for technology application if selective extraction of cenospheres could be accomplished efficiently.

Experimental

When fly ash particles - or any physical mixture having diameters between about 0-300 ìm - are transported through specially designed transport piping, they attain a high surface charge (~10^{-4} coulombs/kg). The polarity of this charge is dependent on the work function of the particles; for the case of fly ash, the carbon attains a positive charge whereas the ash attains a negative charge. The charge polarity on cenospheres will be the same as on the ash constituents, leading therefore to effective carbon or LOI reduction in the recovered value-added products.

The feed rate capacity of the continuous feed, laboratory-scale, triboelectric separation system used in this study is between 1-40 kg/hr. A screw feeder dropped the combustion ash into a transport line leading to the top of a parallel plate electric field zone. Three products, including a high-LOI fraction, a medium LOI fraction and a low LOI fraction, were collected at the bottom of the electric field using cyclones. For each test, the mass balance between the amount of ash fed to the separator and the amount of ash collected in the cyclones was near 92-95%.

Two combustion fly ashes were tested. They were obtained from utilities burning eastern US bituminous coals. Their loss on ignition (LOI) was measured by calculating the mass loss of pre-weighed samples as a consequence of heating at 750^oC for over two hours.

Float-sink with centrifugation analyses using distilled water and lithium metatungstate solutions were used to quantify the recovery of cenospheres of various densities that could be obtained from the parent ashes and were obtained as a consequence of triboelectric separation of the parent ashes. The density of lithium metatungstate is 3 gm/cm^3. Mixing it with distilled water provided solutions of density 1.5 gm/cm^3 and 2.0 gm/cm^3. These solutions were poured into 75 ml sealable, graduated cylinders into which up to 1.5 gm of sample was added. From these analyses, mass recoveries of cenospheres were measured.

The triboelectric separated products before and after the float-sink analyses were examined by optical and scanning electron microscopy. They were subjected to size distribution analysis using a laser Coulter particle size analyzer. Particle densities were measured using a He pycnometer.

Results

The operational parameters of the triboelectric separator were varied to examine their effect on the selective recovery of products. The recovery curve for the low LOI product is given in Figure 1. For a parent ash having a 6.5% LOI, nearly 80% recovery at a 3% LOI product could be attained for this ash even at a 5kV voltage.

Particle densities of the low LOI products, obtained using different separator voltages, are presented in Figure 2. The feed ash density was 2.46 g/cm^3. As the voltage was increased, the density of the low LOI product decreased by 17%, attaining a minimum value near 2.1 g/cm^3 at a voltage of 15 kV. From the float-sink analyses, nearly 40% of this product had a density less than 2 g/cm^3. Assuming an average of 1.5 g/cm^3 for the low-density fraction, and a 2.5 g/cm^3 density for the remaining 60% of the sample, one can calculate a theoretical product density of 2.1 g/cm^3, a value in agreement with the data presented in Figure 2 at a voltage of 15 kV.

Figure 3 summarizes data on particle diameters and densities, along with the LOI and weight percent recovery of products. These data are part of an initial effort to understand the potential of pneumatic transport, triboelectric separation for selectively extracting value-added components from combustion fly ash. Further experimentation is underway to refine this operation.

Conclusions

The application of pneumatic transport, triboelectric separation technology for the selective extraction of value-added components within coal combustion fly was investigated. Preliminary data suggest that process parameters can be adjusted that enable the selective extraction of products. Further experimentation is needed on a variety of ashes which have a range of cenosphere concentrations.

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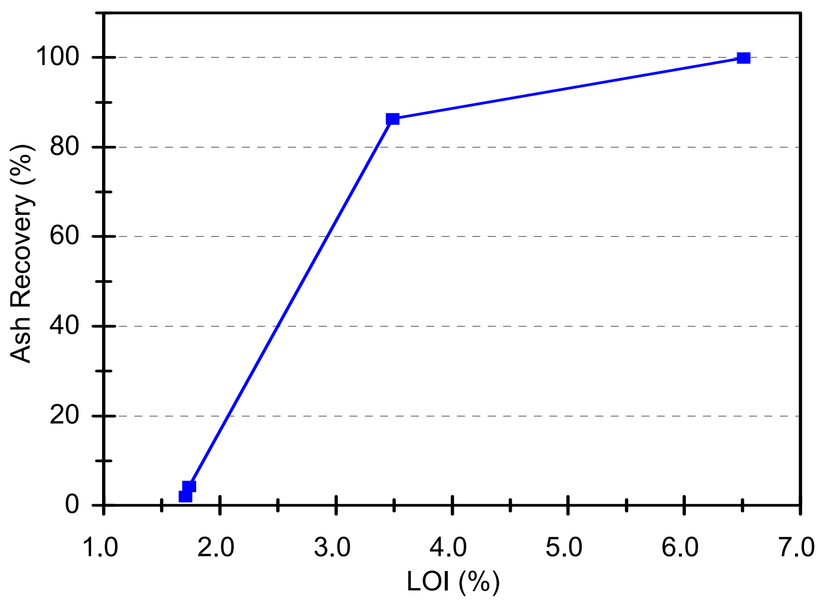

Figure 1. Ash recovery for low LOI products from one of the ashes tested.

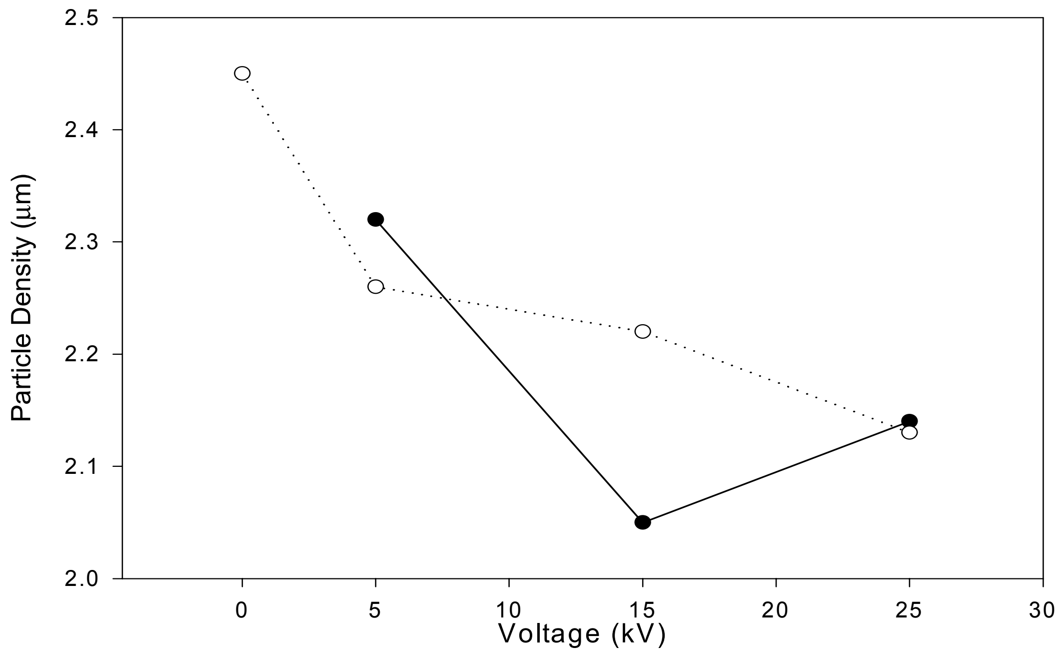

Figure 2. Particle density versus voltage for triboelectric beneficiation of combustion ash.

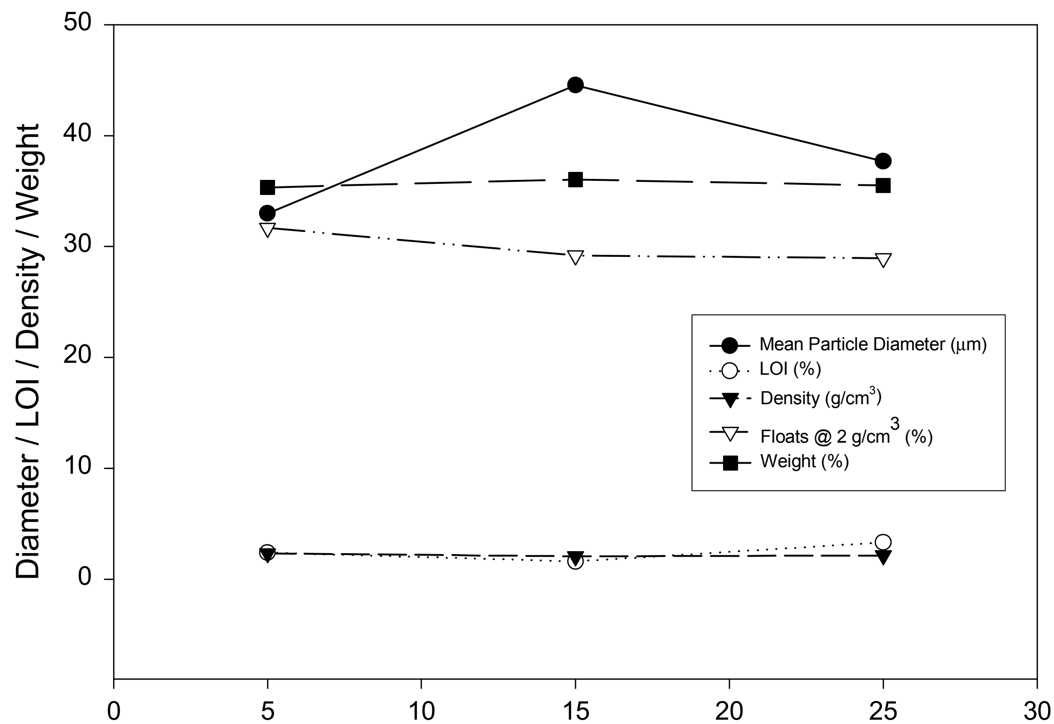

Figure 3. Particle diameter, LOI, density and weight percent of products.