Cenosphere Separation from Fly Ash Using Pneumatic Transport, Triboelectric Processing

Tapiwa Z. Gurupira, Charles L. Jones and John M. Stencel
Center for Applied Energy Research, University of Kentucky
2540 Research Park Drive, Lexington, KY 40511-8410

Abstract

It is well known that cenospheres are one of many valuable components within coal combustion ash. Traditionally, only particles having densities < 1 gm/cm^3 have been called 'cenospheric'. This terminology is probably because cenospheres float on water, allowing harvesting from wet ash impoundments. In combustion fly ashes, the relative amount of cenospheres is typically around 1%. However, cenospheres are really gas bubble-containing particles independent of their bulk density. Hence, their density may be greater than 1 gm/cm^3 and their concentration in combustion ash much greater than 1%.

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 separator. Processing at feed rates up to 20 kg/hr, the low LOI products of separation were subjected to float-sink analysis plus centrifugation. The float-sink media included distilled water by itself, and mixtures of water with lithium metatungstate; the mixtures had densities between 1.0 gm/cm^3-to-2.0 gm/cm^3. The recovered particles were examined by scanning electron and optical microscopy to provide additional information on their physical properties. Product characteristics and recoveries are discussed relative to processing operations and opportunities.

Introduction

Cenospheres are formed from coal combustion ash when it is in a molten state. Flowing with the combustion gas stream, the temperature of the molten particles is rapidly quenched, thereby 'freezing in' a 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 typically less than 1 gm/cm^3. These particles float on water within wet ash impoundments and their harvesting can be accomplished by pond skimming. The word cenosphere is 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 <1%.

Fly ash produced during the combustion of Kentucky No. 9 coal may have up to a 9% its particles with densities less than 2 gm/cm^3; in San Miguel coal fly ash, the concentration may be as high as 87%. These values suggest that significant opportunities exist for harvesting cenospheres of density < 2 gm/cm^3 from ash in its dry form if selective extraction could be accomplished efficiently.

Experimental

Two combustion fly ashes were examined for cenosphere extraction using pneumatic transport, triboelectric separation technology on a laboratory scale. The ashes were obtained from utilities burning eastern US bituminous coals. They were subjected to mechanical sieving after which the larger size fraction was processed using a triboelectric separator

They were processed in their as-sampled or parent state and after they were heated in an oven at 750°C for 16 hours ("carbon burnout ashes"). There were no significant differences in the mass recoveries of cenospheres from the triboelectric separation experiments for ashes pre-treated at 750°C versus for the parent ashes. This result suggested that the 750°C treatment did not alter the size or density distribution of the ashes.

Float-sink with centrifugation analyses using distilled water and lithium metatungstate solutions were used to quantify the recovery of cenospheres of various densities. Solutions of density of 1.5 gm/cm^3 and 2.0 gm/cm^3 were made and then poured into 75 ml sealable, graduated cylinders into each of which up to 1.5 gm of sample was added. The cylinders were then placed in a centrifuge, rotated at 2000 rpm for periods up to ten minutes. After centrifugation, the particles floating on the surface were suctioned off, drained into and through a 2 μm filter, dried at 60°C and then weighed.

The triboelectric separated products before and after the float-sink analyses were examined by optical and scanning electron microscopy. They were also subjected to size distribution analysis using a laser granulometer.

Results

The LOI of a feed ash was 6.26% and it had cenosphere concentrations ~ 0.6% - for densities < 1 gm/cm^3; and 17.6% - for densities between 1 gm/cm^3-to-2 gm/cm^3. The initial triboelectric testing was done in a way to give three products which were labeled: cenospheres; ash-like; and, carbon-rich. The yields and LOI contents in these three products were: 7% wt.%/2.9% LOI; 78% wt.%/12.65% LOI; and 15% wt./27.5% LOI, respectively. In the cenosphere product, the concentrations of particles: having densities < 1 gm/cm^3 was 6%; having densities < 1.5 gm/cm^3 was 27%; and having densities < 2 gm/cm^3 was 44%. Hence, there was a ten-fold increase in the cenosphere content at density < 1 gm/cm^3 and about a three-fold increase at density < 2.0 gm/cm^3. This speciation suggests a significant bias of the triboelectric separator to produce cenopheres of density < 1 gm/cm^3.

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 its operation.