Analysis on the Efficiency of the Air Classification of Fly Ash

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Abstract

The efficiency of the air classification of fly ash was investigated. Due to the wide variations in the size consist of fly ash, it is commonly practiced to use more than techniques to measure the entire size range. Especially for fly ash, the sieving techniques are used to obtain information not only on the size distribution but also on the carbon distribution throughout the size. However, there is a substantial amount in the sub-sieve size range, and consequently, sub-sieve analyzer is used to obtain the information on the size distribution in the finer end. Since the size definitions differ depending on the measurement methods, it is necessary to convert one type of data to the other. Using a recently developed technique for inter-conversion of sizes, the separation efficiency of a commercial classifier was analyzed using the Tromp curve. The results showed that the cut size was about 55μm and the bypass was 17%. Sharpness Index was calculated to be 0.25, which indicated an inefficient separation. This could be reasoned from the heterogeneous nature of the fly ash particles, which limited sharp separation of the particles in the range of 30–100μm.

1. Introduction

Air classification is the most commonly used method for removing the unburned carbon from fly ash in commercial scale. This method is based on the fact that the carbon is concentrated in the larger size fractions of the fly ash in the form of highly porous coke. In fact, it is often sufficient to separate out the +40μm to produce a clean fly ash with less than 3% LOI with a theoretical yield over 70%. Ideally, mechanical sieving would be the best for this purpose because the separation is based solely on size. However, the fineness of the fly ash makes it difficult to use mechanical sieving in a large industrial scale. On the other hand, air classification can be used effectively for separation of fine particles down to 10 μm with a large throughput. But this separation is generally based on the settling rate of a particle in air, which is determined by not only its size, but also the specific gravity and shape of the particle. The most common method of analyzing the separation efficiency of air classifiers is by using a performance curve, or
Tromp curve (also refer to as partition or selectivity curve). This method is based on a graphical analysis which simply relates the weight percentage of each particle size in the feed which reports to the underflow to particle size. Therefore, the calculations needed for obtaining a Tromp curve are straightforward once the size distributions of the feed, overflow and underflow are known. In this paper, the detailed analysis on the separation efficiencies of air classifier was conducted with the size distributions inter-converted using their method.

2. Background

When particles put into another size measuring device, the size distribution will be reported differently due to the definition of the size. The particle size measurement methods give the same only if the particles are perfect spheres. As the particles diverge from the spherical shape, the correlation of particle size analyses conducted by different methods requires correction for shape. Various techniques have been developed for different instrument combinations to solve the mismatch. To solve the mismatch, the method employed in this paper uses a similar approach, but it does not require functional forms for the size distribution. The technique assume that particles of a √2 sieve size fraction of geometric mean size xi will distribute into instrument size X with a function that does not vary with relative size. Figure 1 shows the typical size distribution obtained when a narrow sieve size fraction is analyzed by laser diffractometry on a cumulative basis. This distribution of the size has value of 1 to 0 and has an S shape, which can be conveniently represented by a log-logistic function

\[
F(X) = \frac{1}{1 + \left( \frac{X}{\mu x_i} \right)^2}
\]

or a lognormal distribution:

\[
F(X) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\ln\left(\frac{X}{\mu x_i}\right)} \exp\left(-\frac{u^2}{2}\right)du
\]

where F(X) is the cumulative mass fraction less than size X and \( \mu, \lambda \) and \( \sigma \) are dimensionless constants. For the log-logistic function

\[
d_{i,j} = \frac{1}{1 + \left( \frac{X_i}{\mu x_j} \right)^{\lambda}} - \frac{1}{1 + \left( \frac{X_i + 1}{\mu x_j} \right)^{-\lambda}}
\]

that is, \( d_{i,j} \) is the fraction of material in screen size interval j which appears in sub-sieve size interval i. This problem can be avoided by a least squared error minimization method. The method used for the conversion was a back-calculation of the set of \( i,j \) values directly by a search for the optimum set of \( p \) values minimizing the least squares objective function subject to constraints and . Various

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nonlinear optimization methods such as the Wolfe reduced gradient method (Bazaraa et al., 1993) can be used for this purpose.

\[ \text{min. SSQ} = \sum [\varphi_{i}^{(\text{calc})} - \varphi_{i}^{(\text{exp})}]^2 \]  

(4)

3. Experimental

Fly ash samples were taken from an air classifier currently used in commercial scale. The size analysis of powders included both sieve and laser diffractometer analysis (Cilas, Model 1064). The subject sample was dispersed in water and was then washed through a 500 mesh (25μm) sieve with a gentle spray of water. The fine material was recovered by filtration. The fractions were also analyzed by the Cilas size analyzer to determine how a \( \sqrt{2} \) range sieve sample distributed into the Cilas sizes. This information was used to obtain a conversion factor between the two sizing techniques. Loss on ignition tests were conducted on each size fraction and the whole sample in accordance with ASTM C311.

4. Result and Discussion

Figure 4 shows the Tromp curve values. It can be seen that the Tromp values do not approach zero as the particle becomes fine, but exhibits a by-pass. The by-pass occurs with most classifiers, to a greater or less extent. It represents the proportion of the feed stream which bypasses to the coarse stream without classification. If this proportion is designated a, only the remaining proportion of the feed, 1-a, is subject to the classification. The classification number, ci, is then related with si values as follows:

\[ c_i = \frac{s_i - a}{1 - a} \]  

(5)

Many functional forms have been used for the function ci. But the log-logistic function is used in this paper for its simplicity. The log-logistic function with an asymptotic value is:

\[ s(X_i) = a + \frac{1 - a}{1 + \left( \frac{X_i}{X_{50}} \right)^b} \]  

(6)

The solid line in Figure 4 is the fitted line obtained with a commercial curve fitting program. The values of a, x50, and b were 0.17, 55, 1.59, respectively, indicating that the cut size is about 55μm and the bypass is 17%. The Sharpness Index is calculated to be 0.28, which is low when compared with the efficiency usually obtained in single ore classifications. On the other hand, the bypass value is not large.
Table 2 Calculations for the Tromp curve

<table>
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<tr>
<th>Size</th>
<th>Size distribution, w%</th>
<th>Feeding</th>
<th>Final</th>
<th>Coarse</th>
<th>( u - t</th>
<th>( u - g</th>
<th>( P_1 )</th>
<th>( s_1</th>
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<td>1.72</td>
<td>4.75</td>
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</table>

\( u = 50.00 \)
\( g = 3.65 \)
\( \text{Sieve Efficiency} = 50.00/\text{50.32} = 0.99 \)

\( P_1 \), the calculated distribution of the size classified by the 50.00 mesh; \( s_1 \), the calculated distribution of the size classified by the 3.65 mesh; \( u - t \), the difference between the size at the feeding and the size at the final; \( u - g \), the difference between the size at the feeding and the size at the coarse; \( P_1 \), the percentage of the size classified by the 50.00 mesh; \( s_1 \), the percentage of the size classified by the 3.65 mesh; \( u - t \), the difference between the size at the feeding and the size at the final; \( u - g \), the difference between the size at the feeding and the size at the coarse; \( P_1 \), the percentage of the size classified by the 50.00 mesh; \( s_1 \), the percentage of the size classified by the 3.65 mesh; \( u - t \), the difference between the size at the feeding and the size at the final; \( u - g \), the difference between the size at the feeding and the size at the coarse; \( P_1 \), the percentage of the size classified by the 50.00 mesh; \( s_1 \), the percentage of the size classified by the 3.65 mesh;