MODELING THE EFFECTS OF EXCLUDED MINERALS ON THE COMBUSTION-DERIVED ASH PARTICLE SIZE DISTRIBUTION

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Introduction

Ash deposition is a significant concern associated with pulverized coal combustion. One factor believed to affect the extent of deposition is the size distribution of the ash particles formed during combustion. Ash particle composition is also believed to be an important factor because the variation in individual particle compositions will lead directly to a variation in molten ash particle viscosity and therefore will affect ash deposition. Predictive models that can provide an accurate representation of ash particle size and composition distributions are therefore a necessary tool in evaluating the deposition potential of individual coals.

Ash particles formed during combustion derive from the inorganic minerals in the coal, minerals that can be present either as excluded minerals (discrete minerals separate from the coal) or included (associated with the organic portion of the coal) [1,2,6]. While models have been developed to predict ash particle size and composition distributions during combustion, there has been no significant effort to address the potential importance of excluded minerals. In this paper, the use of an ash particle formation model to systematically address the effect of excluded minerals on ash particle formation is presented.

Simulation

The model used to predict ash formation is derived from earlier models that are based upon the concept of mineral redistribution and coal particle reaction.[5] Necessary input data include mineral size and composition data from computer controlled scanning electron microscopy (CCSEM) and coal ultimate and proximate analyses.

In this study, the amount of excluded mineral matter was varied systematically from 1% to 90% on a number basis. Identical size distributions and composition distributions were assumed for both the excluded and included minerals in all cases. An ash content of 7.4 weight percent was assumed, and the coal properties were taken to be those of a Kentucky bituminous coal.

The effect of coal particle swelling (cenosphere formation) was considered by examining a non-swelling coal and two swelling coals (swelling index of 1.1 and 2.0) as shown in Table 1. Ash particle formation calculations were conducted under conditions of full mineral coalescence. The assumed particle size distribution and composition of the coal mineral matter are also shown in Table 1.

Table 1. Coal characteristics and combustion conditions

Stoichiometric Ratio:	1.2
Coal:	Bituminous
T gas:	1538°C
Swelling Index:	1, 1.1, 2
Proximate (wt%, as received)	
Fixed Carbon	56.5
Volatile Matter	33.8
Ash	7.4
Moisture	33.8
Mineral Composition (%vol)	
Quartz	12.6
Kaolinite	26.2
Illite	15.3
Miscellaneous Silicates	30.0
Pyrite	3.4
Others	14.5
Mineral Size Distribution (%vol)	
2 µm	
4 µm	18.4
8 µm	28.2
16 µm	18.4
30 µm	18.1
60 µm	6.8
80 µm	5.7
	3.9

Results and Discussion

As the amount of excluded mineral matter in the coal increased (for fixed swelling index), the fraction of ash particles present in the smallest size range (2 and 4 µm) also increased as shown in Figure 1. This is indicative of the decrease in coalescence expected at lower fractions of included minerals. Increased fragmentation of excluded minerals may also be contributing, although the amount of reactive minerals present in this particular coal (i.e. pyrite) is relatively small. This behavior was observed for all three swelling indexes (Figures 2 and 3). This was again attributed primarily to a decrease in mineral coalescence, with fragmentation possibly contributing as a secondary effect. This is consistent with the calculations of Yan et al.[6], who found that fragmentation was more important for the excluded minerals. In general, fragmentation is viewed as being more important for reactive excluded minerals such as pyrite and calcite but not significant for clays.[3]

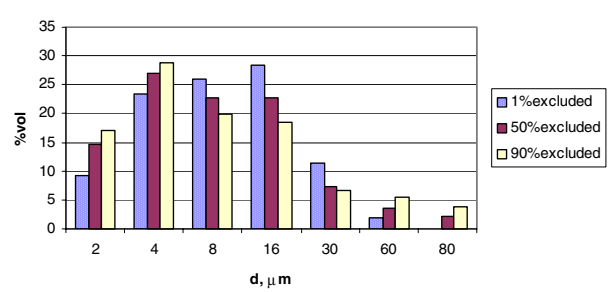

Figure 1. Ash size distribution for a coal with SI = 1.1, at different excluded % (number basis).

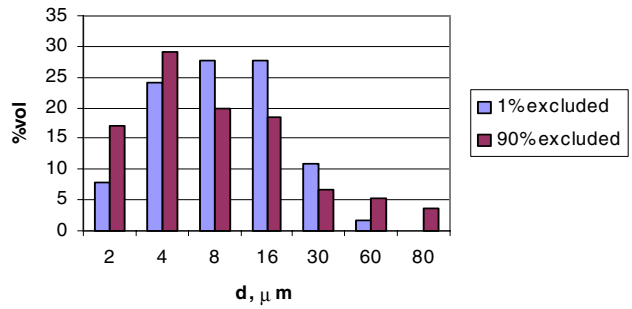

Figure 2. Ash size distribution for a non-swelling coal (SI = 1.0), at different % excluded (number basis).

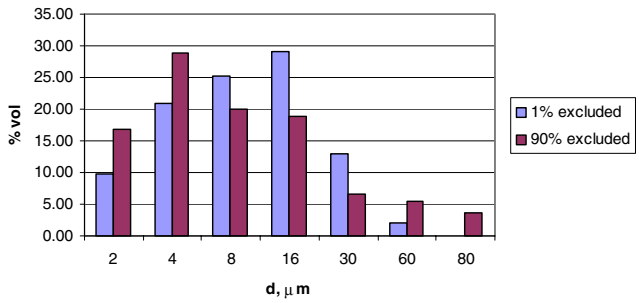

Figure 3. Ash particle size distribution for a swelling coal (SI = 2.0), at different % excluded (number basis).

As expected, changes in the fraction of excluded mineral matter also affected the composition distribution of the resulting ash. The aluminosilicate category (SiAl) represents aluminosilicate derived ash particles that have no third element (for example, K or Ca) present at concentrations greater than 6%. As coalescence increases, the amount of such ash particles is therefore expected to increase. Examining the data in Figure 4, there is a clear decrease in aluminosilicates (SiAl) as the fraction of excluded mineral matter increases. The higher concentrations of excluded minerals thus allows for increased retention of silicates (Si) and other associations like potassium aluminosilicates (SiAlK) and iron aluminosilicates (SiAlFe).

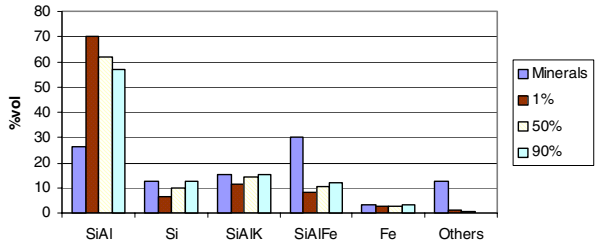

Figure 4. Ash composition for a swelling coal (SI = 1.1), at different % excluded (number basis).

Notes:

- "Miscellaneous silicate" minerals were included as SiAlFe.
- "Others" include miscellaneous carbonates, phosphates and sulfates; siderite and calcite.

Comparing the concentrations of specific ash particle types with the parent minerals (i.e., comparing illite with the SiAlK in the ash), it is clear that at higher concentrations of excluded mineral matter, the amount in the ash remains relatively constant. At an excluded mineral matter concentration of 50% the change becomes insignificant. Significant interaction between iron and aluminosilicates was observed, but this was only slightly influenced by the amount of excluded minerals.

When comparing the three swelling indexes analyzed, at a higher swelling index, the amount of small particles (2μm) increased. The explanation for this is that the more highly swelled chars are allowed to fragment more readily.

This study varies the amount of excluded minerals, considering the same mineral distribution for both excluded and included minerals. Some authors, however, have reported that the size distribution of the included minerals is finer than that of the excluded minerals[6]. Other authors have concluded the opposite[4]. The former study was made with an Australian high-rank coal (Newlands). The latter study was based on analysis of eighteen coals from the UK, US, South America, South Africa and Australia. Australian and South African coals showed more mineral-organic association than British and North American coals. In all of the coals from this latter study, excluded minerals were between 3 and 19 wt% of the total mineral matter, with median sizes of about 4-7 μm and top sizes of 40-70 μm. (finer size distribution than included particles). A study including the effects of these different size distributions is underway.

Conclusions

The effect of the amount of excluded mineral particles on the coal-derived ash particle size was examined. As the amount of excluded mineral matter increased, an increase in the amount of the smallest ash particles was observed. This was attributed to a decrease in the extent of coalescence of the smallest minerals. As excluded mineral matter amounts increased, larger concentrations of silicates, and potassium and iron aluminosilicates were observed as a result of their lack of transformation ("dilution") into aluminosilicate particles.

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References

(1) Benson, S. Jones, M. Harb, J. In *Fundamentals of coal combustion: for clean and efficient use*. Elsevier, **1993**. pp. 299-373
(2) Rusell, N. Mendez, L. Wigley, F. Williamson, J. *Fuel*. **2002**, 81,p. 657-663.
(3) Sarofim, A. Helble, J. In *The Impact of Ash Deposition on Coal Fired Plants*. J. Williamson, and F. Wigley. **1994**, ,pp. 583-597.
(4) Wigley, F. Williamson, J. Gibb, W. *Fuel*. **1997**, 76, p 1283-1288.
(5) Wilemski, G. Srinivasachar, S. *Proc of Eng Foundation Conference*. June **1993**. p 151-164.
(6) Yan, L. Gupta, R. Wall, T. *Fuel*. **2002**, 81,p. 337-344.