CCSEM Investigation of Ash Formation during Oxyfuel Combustion

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Outline

1. Background
2. Experimental setup and analysis method
3. Results and discussion
4. Conclusion
Background

Oxy-fuel combustion technology

Ash related problems, as slagging, fouling and corrosion, are still a matter of concern, and are recognized as a major source of uncertainty in the technology.
Many researchers found that the chemical compositions of fly ash and ash deposits were not significantly different between air condition and oxyfuel condition, but higher deposition rate and deposition propensity in oxyfuel condition.

- gas flow rate
- combustion temperature
- chemical changes of the flue gas

Mineral???
Composition and size distribution

CCSEM (computer-controlled scanning electron microscopy) is a useful technology on the basic of the mineral particles that can characterize the minerals of ash particles in term of size, shape, abundance and associations.

The present work was addressed toward the ash characteristic of a Chinese coal by using computer-controlled scanning electron microscopy (CCSEM),
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2 Experimental setup and analysis method

High temperature drop tube furnace (DTF)

<table>
<thead>
<tr>
<th>Summary of Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle feed rate</td>
</tr>
<tr>
<td>Particle residence time</td>
</tr>
<tr>
<td>Particle heating rate</td>
</tr>
<tr>
<td>Gas supply primary burner</td>
</tr>
<tr>
<td>Gas supply secondary burner</td>
</tr>
<tr>
<td>Operating pressure</td>
</tr>
<tr>
<td>Reaction tube inner diameter</td>
</tr>
<tr>
<td>Reaction tube length</td>
</tr>
<tr>
<td>Max. electrical heating temperature</td>
</tr>
<tr>
<td>Probes for (fractionated)</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
2 Experimental setup and analysis method

➢ Coal Selection

<table>
<thead>
<tr>
<th>Proximate analysis (%)</th>
<th>Ultimate analysis (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M_{\text{ad}} )</td>
<td>( V_{\text{ad}} )</td>
</tr>
<tr>
<td>ZD coal</td>
<td>5.04</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>( \text{SiO}_2 )</th>
<th>( \text{Al}_2\text{O}_3 )</th>
<th>( \text{Fe}_2\text{O}_3 )</th>
<th>( \text{TiO}_2 )</th>
<th>( \text{CaO} )</th>
<th>( \text{MgO} )</th>
<th>( \text{K}_2\text{O} )</th>
<th>( \text{Na}_2\text{O} )</th>
<th>( \text{SO}_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>44.75</td>
<td>19.33</td>
<td>5.47</td>
<td>1.52</td>
<td>11.24</td>
<td>3.44</td>
<td>1.52</td>
<td>4.79</td>
<td>7.55</td>
</tr>
</tbody>
</table>

Particle Size: 38~74μm

➢ Experiment condition

<table>
<thead>
<tr>
<th>Feed Rate</th>
<th>Temperature (°C)</th>
<th>Burnout Ratio</th>
<th>O(_2)/N(_2)</th>
<th>O(_2)/CO(_2)</th>
<th>O(_2)/CO(_2)</th>
<th>O(_2)/CO(_2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10g/h</td>
<td>1450</td>
<td>20%</td>
<td>20%</td>
<td>30%</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>90.47</td>
<td>91.92</td>
<td>90.19</td>
<td>92.87</td>
<td></td>
</tr>
</tbody>
</table>

Sampling time was about 4 hours in DTF, and all samples were ashed at 550°C to remove organic carbon.
## Analysis method

<table>
<thead>
<tr>
<th>Type of test</th>
<th>Pretreatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLA</td>
<td>Curing, Grinding, Polishing, Carbon Coating;</td>
</tr>
</tbody>
</table>

Catch the image (BSE)

Deduct the background

Identify the mineral (Zyglicke and Steadman, 1990)
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Results and discussion

Size distribution of raw coal and bulk ash particles

Correction method

\[ g(A) = \int_{0}^{\infty} p(A|D)f(D)dD \]

King (1982)

\[ P(A|D) = 1 - \left[ 1 - \frac{4A}{\pi D^2} \right]^{1/2} \]

\[ P(A|D) = 0.0 (A = 0) \]

\[ P(A|D) = 1.0 (A > A_{\text{max}}) \]
Results and discussion

Composition of raw coal

XRF and CCSEM results only have a little error. 86% of ash is excluded mineral and the rest is included mineral.
Results and discussion

Composition of bulk ashes

Compared with ash composition of raw coal, there are just a little different among the samples from these conditions.
Mineral composition in the bulk ashes

High $O_2$ concentration enhances the co-melting of mineral; High $CO_2$ concentration inhibits the decomposition of carbonate mineral.
Results and discussion

- Distribution of ash-deposition-related elements

- More Na form the co-melting mineral with Fe, Ca, K.

- $O_2 \uparrow \ T_{\text{particle}} \uparrow$

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Results and discussion

Distribution of ash-deposition-related elements

- More Fe from the co-melting mineral;
- $O_2 \uparrow \rightarrow T_{\text{particle}} \uparrow$
  - More Fe from co-melting mineral and unclassified mineral;
Results and discussion

Distribution of ash-deposition-related elements

More calcite was decomposing and forming the co-melting mineral;

O₂ ↑  T_{particle} ↑

Coal combustion国家重点实验室
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In this study, the effect of gas phase conditions on the physical and chemical changes of ashes were investigated by CCSEM. The following results are obtained:

- Oxyfuel combustion produced less fine particles (<10μm) and more coarse particles (>10μm) than air combustion at the same O₂ concentration, and there are more fine particles (<10μm) and less coarse particles (>10μm) in oxyfuel combustion with the increasing of O₂ concentration.

- High O₂ concentration enhances the co-melting of mineral, and high CO₂ concentration not only affects the transformations of coal minerals, but also shortens the decomposition process and extends the oxidation process slightly.

- The increasing of particle temperature can not only enhance the vaporization of refractory oxide, but also enhance interaction of the finely dispersed combined with inherent mineral particles.
Thank you for your attention!

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