The uneven ash melting behavior of pulverized blended Chinese coals

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Visiting scholar of the University of Newcastle, AU  

Related Papers  

Determination of The Mineral Distribution In Pulverized Coal Using Densitometry And Laser Particle Sizing (2005)  

The influence of included minerals on the intrinsic reactivity of chars prepared at 900 °C in a drop tube furnace and a muffle furnace (2009)
1. Introduction
2. Experimental
3. Results and discussion
4. Conclusions
5. Acknowledgement
1 Introduction
Coal reserves in China
Severe ash fouling and slagging problems both inside the furnace and in the convective pass were found when the Zhundong coal is fired in utility boilers.
To mitigate the ash deposition of the Zhundong coal, coal blending is currently practiced in utility boilers.
The problem with AFT mainly results from that it is related to the bulk chemistry and fusion temperature of the ash.
Mineral matter is not evenly distributed in coal


A more clear look of included minerals in a char with SEM observation

Hong Zhang  Fuel 88 (2009) 2303–2310
Figure 7  SEM pictures of pulverized Jincheng coal ashes and its density fractions under 1300 °C

ZHANG Peng-qi  J Chinese fuel chemistry 46(2017)1-7
The ash deposition rate is determined by a sum of the four independent rates, the inertial impaction, thermophoresis, condensation and chemical reaction.

M.U. Garba  Fuel 113 (2013) 863–872
Gengda Li    Fuel 143 (2015) 430–437
The present work as reported in this paper was aimed to study:

a) The uneven ash fusion characteristics of blended coals
b) The size distribution of the density fractions’ ash of coal blends.

so as to predict ash deposition behavior of coal blend in boilers more accurately.
2 Experimental
Table 1 Proximate analysis and ultimate analysis of Zhundong and Jincheng coals

<table>
<thead>
<tr>
<th>Sample</th>
<th>Proximate analysis (wt, %)</th>
<th>Ultimate analysis (wt, %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M_{ad}</td>
<td>A_{ad}</td>
</tr>
<tr>
<td>ZD</td>
<td>9.05</td>
<td>14.15</td>
</tr>
<tr>
<td>JC</td>
<td>3.66</td>
<td>16.91</td>
</tr>
</tbody>
</table>

Table 2 Ash fusion temperatures of Zhundong and Jincheng coals

<table>
<thead>
<tr>
<th>Sample</th>
<th>DT(°C)</th>
<th>ST(°C)</th>
<th>HT(°C)</th>
<th>FT(°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZD</td>
<td>1140</td>
<td>1160</td>
<td>1170</td>
<td>1180</td>
</tr>
<tr>
<td>JC</td>
<td>1530</td>
<td>1550</td>
<td>1560</td>
<td>1580</td>
</tr>
</tbody>
</table>

Table 3 The chemical composition of Zhundong and Jincheng coal ashes

<table>
<thead>
<tr>
<th>Sample</th>
<th>SiO\textsubscript{2}</th>
<th>Al\textsubscript{2}O\textsubscript{3}</th>
<th>Fe\textsubscript{2}O\textsubscript{3}</th>
<th>CaO</th>
<th>MgO</th>
<th>SO\textsubscript{3}</th>
<th>TiO\textsubscript{2}</th>
<th>K\textsubscript{2}O</th>
<th>Na\textsubscript{2}O</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZD</td>
<td>52.19</td>
<td>12.54</td>
<td>7.08</td>
<td>11.21</td>
<td>3.62</td>
<td>5.88</td>
<td>0.66</td>
<td>1.46</td>
<td>4.07</td>
</tr>
<tr>
<td>JC</td>
<td>47.78</td>
<td>33.97</td>
<td>8.04</td>
<td>3.44</td>
<td>0.50</td>
<td>2.03</td>
<td>1.19</td>
<td>0.97</td>
<td>0.38</td>
</tr>
</tbody>
</table>
Blending and grinding procedure

ZD:JC
100:0
70:30
50:50
30:70
0:100

<3 mm
Grinding together
<0.15 mm

Blending and grinding procedure
Density separation: 1.4-2.0 kg/cm³

Proximate analysis

Optical microscopic observation

XRF and XRD analysis

AFT

SEM

FactSage calculation

Particle size analysis

Analyses
3 Results and discussion
3.1 Effect of blending ratio on the density composition of the Coal blends
Fig. 1 The density compositions and their ash contents of pulverized ZD and JC coals
Fig. 2 The density compositions of the three blended coals and their calculated weight-averaged results.
Fig. 3 The change of proximate composition and their calculated weight-averaged results with density in the 50:50 blended coal
Fig. 4 Optical microscopic observation of the density fractions of the 50:50 coal blend
Conclusion 1:
Grinding process has influence on the density composition of coal blends. The easy grinding component will be more thoroughly separated.
3.2 Effect of coal blending on the Chemical Composition and Mineral Composition of Blended Coals and their density fractions
Table 3 The chemical composition of their density fractions of ZD and JC

<table>
<thead>
<tr>
<th>Sample</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>SO₃</th>
<th>TiO₂</th>
<th>K₂O</th>
<th>Na₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZD16</td>
<td>30.40</td>
<td>12.54</td>
<td>6.77</td>
<td>28.03</td>
<td>8.51</td>
<td>8.32</td>
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<td>0.35</td>
<td>1.14</td>
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<tr>
<td>ZD1617</td>
<td>63.15</td>
<td>13.28</td>
<td>6.82</td>
<td>4.93</td>
<td>1.85</td>
<td>2.91</td>
<td>0.66</td>
<td>1.91</td>
<td>3.07</td>
</tr>
<tr>
<td>ZD17</td>
<td>64.79</td>
<td>12.93</td>
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<td>1.60</td>
<td>2.82</td>
<td>0.67</td>
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<td>3.55</td>
</tr>
<tr>
<td>JC16</td>
<td>48.94</td>
<td>37.53</td>
<td>4.58</td>
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<td>0.65</td>
<td>0.64</td>
<td>1.34</td>
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<td>JC1617</td>
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</tr>
<tr>
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<td>25.78</td>
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<td>3.51</td>
<td>1.03</td>
<td>0.82</td>
<td>0.44</td>
</tr>
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</table>
Table 4 The chemical composition and their calculated weight-averaged results of their density fractions of coal blend B5050

<table>
<thead>
<tr>
<th>Sample</th>
<th>SiO$_2$</th>
<th>Al$_2$O$_3$</th>
<th>Fe$_2$O$_3$</th>
<th>CaO</th>
<th>MgO</th>
<th>SO$_3$</th>
<th>TiO$_2$</th>
<th>K$_2$O</th>
<th>Na$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td>B16</td>
<td>42.98</td>
<td>27.50</td>
<td>5.61</td>
<td>10.66</td>
<td>3.10</td>
<td>3.19</td>
<td>1.02</td>
<td>1.01</td>
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<tr>
<td>B1617</td>
<td>55.38</td>
<td>24.12</td>
<td>7.77</td>
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<td>2.19</td>
<td>0.92</td>
<td>1.37</td>
<td>1.72</td>
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<tr>
<td>B1718</td>
<td>57.81</td>
<td>20.84</td>
<td>7.41</td>
<td>4.08</td>
<td>1.08</td>
<td>2.72</td>
<td>0.84</td>
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<td>1.79</td>
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<tr>
<td>B18</td>
<td>58.37</td>
<td>20.06</td>
<td>8.21</td>
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<td>0.99</td>
<td>3.19</td>
<td>0.83</td>
<td>1.53</td>
<td>1.88</td>
</tr>
</tbody>
</table>
Figure 5 XRD Analysis of the density fractions of blended Coal
Q-Quartz; H-Hamite; A- Anhydrite; M- Muscovite
N- Feldspar; C- Calcite K- Kaolinite
Table 4 The chemical composition and their calculated weight-averaged results of their density fractions of coal blend B5050

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<td>5.61</td>
<td>10.66</td>
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<td>2.94</td>
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<tr>
<td>B16&lt;sub&gt;cal&lt;/sub&gt;</td>
<td>38.56</td>
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<td>17.14</td>
<td>5.05</td>
<td>4.94</td>
<td>0.81</td>
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<td>0.83</td>
</tr>
<tr>
<td>B1617</td>
<td>55.38</td>
<td>24.12</td>
<td>7.77</td>
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<tr>
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<td>57.63</td>
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<td>1.08</td>
<td>2.72</td>
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<td>1.79</td>
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<tr>
<td>B1718&lt;sub&gt;cal&lt;/sub&gt;</td>
<td>59.04</td>
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<tr>
<td>B18</td>
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<td>1.97</td>
<td>0.92</td>
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Conclusion 2:

The difference in chemical composition among different density fractions in the coal blend is greatly narrowed as compared with its parent coals.
3.3 The Ash Melting Behaviors of Blended Coal and its density fractions
Fig. 6 The influence of blending ratio on the AFTs of coal blends
Figure 7: The AFTs of the density fractions of blended coal B5050
Fig. 8 The SEM graphs of density fractions of coal blend B5050 under 1300°C

<1.6

1.6-1.7

1.7-1.8
Fig. 9 The liquid contents in the melt of the four density fractions of B5050 between 900°C and 1500°C
Conclusion 3:
An uneven ash melting behavior among different density fractions was observed for the blended coal.
3.4 The Size distributions of ash particles in different density fractions
The size distribution of coal ash of different density fractions in ZD and JC coal
The size distribution of coal ash of different density fractions in coal blend B5050
Conclusion 4:
Minerals in different state within raw coal evolve into ash in different size distribution. For the coal blend, ash from the two highest density fractions was much coarser than the other density fractions.
3.4 Discussions
Pulverized blended coals are composed of particles with different density. Which density fraction determines the melting behaviour of the whole coal in boilers?
The ash deposition rate is determined by a sum of the four independent rates, the inertial impaction, thermophoresis, condensation and chemical reaction.
The two highest density fractions have low AFT and larger particle size of ash. They’ll determine the whole slagging performance of the coal blend.
Conclusion 5:

The ash melting behavior of coal blend should be determined by the two highest density fractions, as they have low AFT and large ash particles.
4 Conclusions
Grinding process has influence on the density composition of coal blends. The difference in chemical composition among different density fractions in the coal blend is greatly narrowed as compared with its parent coals. An uneven ash melting behavior among different density fractions was observed for the blended coal. For the coal blend, ash from the two highest density fractions was much coarser than the other density fractions. The ash melting behavior of coal blend should be determined by the two highest density fractions, as they have low AFT and large ash particles.
5 ACKNOWLEDGEMENTS

The authors thank to the united financial support from National Nature Science Foundation of China (NSFC) and Shanxi Low Carbon Coal Foundation with project number U1510106.
Thank you for your attention!

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