NUMERICAL SIMULATION RESEARCH ON 600MW BOILER WITH DIFFERENT SINGLE BURNER HEAT POWER

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Introduction

Boiler has larger capacity and higher condition

**World**
- To avoid complex air and coal powder pipe system
- Boiler volume and single burner heat power $\uparrow$
- Operation badly and scorification seriously
- Single burner heat power $\downarrow$

**China**
- Babcock, adopts smaller burner (16.28~19.77MW), Good working condition
- FW, adopts larger burner (48.8~58.8MW) for 510/550MW, 58.15~81.4MW) for 620/700MW.

**Research gap**
- Boiler capacity $\uparrow$, (600MW, 1000MW)
- Coal property, different from coal abroad
## Geometrical model

<table>
<thead>
<tr>
<th>Geometrical model attributes</th>
<th>Measure</th>
<th>Unit</th>
<th>How to select it</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furnace structure size</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Furnace width</td>
<td>( a )</td>
<td>19419.2 mm</td>
<td>Some 600MW power plant of Huaneng corp. information form internet</td>
<td></td>
</tr>
<tr>
<td>Furnace depth</td>
<td>( b )</td>
<td>15456.2 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Furnace height</td>
<td>( h )</td>
<td>67000 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>combustion chamber hopper dip angle</td>
<td>( \gamma )</td>
<td>55°</td>
<td>*</td>
<td>50° ~55°</td>
</tr>
<tr>
<td>Chamber hopper Throat width</td>
<td>( E )</td>
<td>1243.2 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Covering flame angle length</td>
<td>( D )</td>
<td>5152.1 mm</td>
<td>About 1/3 of furnace depth</td>
<td></td>
</tr>
<tr>
<td>Covering flame angle Inclined angle</td>
<td>( \beta )</td>
<td>25°</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Covering flame angle on</td>
<td>( a )</td>
<td>45°</td>
<td>*</td>
<td>&lt;coal burner design and operation&gt;, 30~50&lt;principle of boiler and calculate&gt;, Larger value should be adopted by more ash fuel</td>
</tr>
<tr>
<td>Horizontal flue depth</td>
<td></td>
<td>5686.4 mm</td>
<td>Refer to 600MW boiler of Huaneng</td>
<td></td>
</tr>
<tr>
<td>Burner primary air spout interlamellar spacing</td>
<td>( H_1 )</td>
<td>4957.1 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spout level distance between the same layer burner</td>
<td>( H_2 )</td>
<td>3657.6 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance from the top spout to platen superheater bottom</td>
<td>( H_3 )</td>
<td>27322.3 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance from the bottom spout to chamber hopper inflexion point</td>
<td>( H_4 )</td>
<td>2397.7 mm</td>
<td>Some 600MW power plant of Huaneng corp. information form internet</td>
<td>2.4~3.6m, larger value for slagging coal</td>
</tr>
<tr>
<td>The distance between outboard burner and flank</td>
<td>( d )</td>
<td>4223.2 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance between the center OFA and top burner</td>
<td>( H_s )</td>
<td>7004.6 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance between the outboard OFA and top burner</td>
<td>( H_a )</td>
<td>4272.3 mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ 3H_2 + 2d = a \]
Modeling and method

physical model---mathematical model

Gas phase
(continues) model

\[
\frac{\partial}{\partial x_i} \left( \rho U_i \phi \right) = \frac{\partial}{\partial x_i} \left( \Gamma \phi \frac{\partial \phi}{\partial x_i} \right) + S_\phi
\]

\[
\frac{dU_{pi}}{dt} = F_D (U_i - U_{pi}) + \frac{g_i (\rho_p - \rho)}{\rho_p} + F_i
\]

\[
P_i = \frac{18 \mu}{\rho_p d_p^2} C_D \text{Re}
\]

\[
\text{Re} = \frac{\rho d_p |U_{pi} - U_i|}{\mu}
\]

\[
C_D = a_1 + \frac{a_2}{\text{Re}} + \frac{a_3}{\text{Re}^2}
\]

Pulverized coal
phase (discrete particle) model

\[
\frac{dV}{dt} = (\alpha_1 k_1 + \alpha_2 k_2) m_p
\]

\[
k_n = k_{0n} \exp(- \frac{E_n}{RT_p}), n = 1, 2
\]

\[
\frac{dm_p}{dt} = -\pi d_p^2 P_{\alpha x} \frac{k_c k_d}{k_c + k_d}
\]

\[
k_d = C_1 \left[ \frac{(T_p + T_g)}{2} \right]^{0.75}
\]

\[
k_c = C_2 e^{-\left( \frac{E}{RT_p} \right)}
\]

Combustion
model

Reaction of Volatile matter

two mutually competing single step reactions are used

Reaction of char particles

The heterogeneous char oxidation rate is calculated by a kinetics/diffusion model developed by Field et al.
Modeling and method

NOx formation model

accurate velocity, temperature, mixture species profiles

post processing program

De Soete’s model

3(char-N):7(volatile-N)

9(HCN from Volatile-N):1(NH3 from volatile-N)

Thermal NOx

Fuel NOx

solving the corresponding transport equations with HCN and NH3
Simulation Results

1. Flow and temperature field characteristic
2. Inflammation performance
3. The burn-out characteristic
4. NO$_x$ Emission
5. Boiler Absorbed heat
6. The velocity and temperature distribution of furnace outlet
7. Hot corrosion of water wall tendency analyzing
Simulation Results

1. Flow and temperature field characteristic

24 burners

Four vertical sections velocity vector of furnace
Simulation Results

1. Flow and temperature field characteristic

Partial enlarged details of velocity vector in main combustion zone
## 2. Inflammation performance

Temperature distribution at burner axis of different burner single power conditions.
3. The burn-out characteristic
4. NO$_x$ Emission
5. Boiler Absorbed heat

Heat absorption capacity of furnace/10^6 W

Furnace volume heat release rate q,v kW/m^3
6. The velocity and temperature distribution of furnace outlet

Furnace outlet velocity distribution
6. The velocity and temperature distribution of furnace outlet

Furnace outlet temperature distribution

- 18 burners
- 24 burners
- 30 burners
- 36 burners
- 40 burners
- 48 burners
Simulation Results

7. Hot corrosion of water wall tendency analyzing

Variable distribution in Furnace with 18 burners

Variable distribution in Furnace with 24 burners
7. Hot corrosion of water wall tendency analyzing

Variable distribution in Furnace with 30 burners

Variable distribution in Furnace with 36 burners
Simulation Results

7. Hot corrosion of water wall tendency analyzing

Variable distribution in Furnace with 40 burners

Variable distribution in Furnace with 48 burners
## Summary and Conclusion

### 600MW-boiler combustion simulation results

<table>
<thead>
<tr>
<th>Single heat power (MW)</th>
<th>Burner numbers</th>
<th>Ignition distance</th>
<th>Burn-out characteristic</th>
<th>NOx-emission</th>
<th>Heat absorption capacity of furnace*10^8 W</th>
<th>Most heat deviation of water wall</th>
<th>Furnace outlet velocity and temperature distribution</th>
<th>Hot corrosion of water wall tendency</th>
</tr>
</thead>
<tbody>
<tr>
<td>80.32</td>
<td>18</td>
<td>Longer</td>
<td>Better</td>
<td>Lower</td>
<td>9.147</td>
<td>Larger</td>
<td>Easy</td>
<td>Easy</td>
</tr>
<tr>
<td>60.24</td>
<td>24</td>
<td>Shorter</td>
<td>common</td>
<td>Higher</td>
<td>9.229</td>
<td>Larger</td>
<td>Not easy</td>
<td>Hard</td>
</tr>
<tr>
<td>48.19</td>
<td>30</td>
<td>Too long</td>
<td>better</td>
<td>A little high</td>
<td>9.195</td>
<td>Larger</td>
<td>Little effect, within 1m/s, 10℃</td>
<td>Not easy</td>
</tr>
<tr>
<td>40.16</td>
<td>36</td>
<td>proper</td>
<td>better</td>
<td>lower</td>
<td>8.742</td>
<td>Lower</td>
<td>Not easy</td>
<td>Not easy</td>
</tr>
<tr>
<td>36.14</td>
<td>40</td>
<td>shorter</td>
<td>worse</td>
<td>Highest</td>
<td>8.046</td>
<td>Lower</td>
<td>Not easy</td>
<td>Not easy</td>
</tr>
<tr>
<td>30.12</td>
<td>48</td>
<td>shorter</td>
<td>best</td>
<td>Lower</td>
<td>9.227</td>
<td>Lower</td>
<td>Not easy</td>
<td>Not easy</td>
</tr>
<tr>
<td><strong>Optimum number</strong></td>
<td><strong>48</strong></td>
<td><strong>48</strong></td>
<td><strong>18/36/48</strong></td>
<td><strong>No effect</strong></td>
<td><strong>36</strong></td>
<td><strong>30</strong></td>
<td><strong>Not easy</strong></td>
<td><strong>Not easy</strong></td>
</tr>
</tbody>
</table>
Thank You!