Co-Combustion of Wood Pellet with sub-bituminous coal in a 340MWe CFB Boiler

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Needs for Co-combustion of Biomass

- Necessity for
  - One of measures for reduction of CO₂ → Co-firing biomass with coal

- Necessity for
  - Increasing penalty surcharge due to non-compliance of RPS target in Korea

<table>
<thead>
<tr>
<th>Year</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penalty to KEPCO’s 5 Power Generation Companies</td>
<td>22.7 Million US$</td>
<td>44.4 Million US$</td>
</tr>
</tbody>
</table>

- Expecting further increase of penalty because of increased duty rate of RPS

<table>
<thead>
<tr>
<th>Year</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>...</th>
<th>2024~</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duty rate</td>
<td>2.0</td>
<td>2.5</td>
<td>3.0</td>
<td>3.0</td>
<td>3.5</td>
<td>4.0</td>
<td>...</td>
<td>10.0</td>
</tr>
</tbody>
</table>

- Therefore, in the field of non-sunlight sector
  - Co-firing biomass(Wood pellet) is a realistic method to reduce CO₂,
  - In most cases, co-firing levels on a continuous basis were generally below 5%
    → Test for co-firing over 10% of biomass was carried out in Yeosu CFB boiler
Yeosu CFB Boiler

- **Type**
  - CFB, Subcritical
  - Natural Circulation
  - Balanced Draft System

- **BMCR Condition**
  - Main Steam Flow: 1025 T/H
  - Main/Reheat Steam P @ T: 171.5/32.31 kg/cm², 541/541 ℃

- **Fuel**
  - Sub-bituminous coal (160T/H)
  - Fuel feeder: Volumetric, Front(6), Rear(4)

- **Emission Control Designed**
  - SO₂ (O₂: 6%): 50ppm
  - NOₓ(O₂: 6%): 50ppm

- **Rectangular Furnace Design**
  - More than 2:1 Aspect Ratio
    - to Allow for Good Fuel Mixing
  - Size: 42m(H) x 34m(W) x 8m(L)

- **Cyclone (4)**
  - Steam cooled compact type
## Fuel Characteristics

<table>
<thead>
<tr>
<th>Proximate</th>
<th>Unit</th>
<th>Wood pellet</th>
<th>Sub-bituminous coal</th>
<th>a/b</th>
</tr>
</thead>
<tbody>
<tr>
<td>VM</td>
<td>%</td>
<td>73.47</td>
<td>73.22</td>
<td>74.33</td>
</tr>
<tr>
<td>Moisture</td>
<td>%</td>
<td>7.56</td>
<td>8.29</td>
<td>7.93</td>
</tr>
<tr>
<td>FC</td>
<td>%</td>
<td>17.13</td>
<td>16.59</td>
<td>16.54</td>
</tr>
<tr>
<td>Ash</td>
<td>%</td>
<td>1.84</td>
<td>1.90</td>
<td>1.20</td>
</tr>
<tr>
<td>Na₂O</td>
<td>%</td>
<td>4.28</td>
<td>3.19</td>
<td>0.40</td>
</tr>
<tr>
<td>K₂O</td>
<td>%</td>
<td>13.75</td>
<td>9.03</td>
<td>15.84</td>
</tr>
<tr>
<td>Total S</td>
<td>%</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>IDT</td>
<td>°C</td>
<td>1314</td>
<td>1477</td>
<td>1137</td>
</tr>
<tr>
<td>Total Cl</td>
<td>%</td>
<td>0.025</td>
<td>0.021</td>
<td>-</td>
</tr>
<tr>
<td>Calorific Value</td>
<td>kcal</td>
<td>4371</td>
<td>4342</td>
<td>4496</td>
</tr>
</tbody>
</table>

### Wood pellet 10% co-firing with coal

<table>
<thead>
<tr>
<th></th>
<th>10% co-firing with coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>S/Cl</td>
<td>1.9</td>
</tr>
<tr>
<td>Cl/K</td>
<td>0.14</td>
</tr>
</tbody>
</table>

- S/Cl > 4 (No corrosion), S/Cl < 2 (Corrosion) (Born, 2005)
- Cl/K < 1, reduce corrosion, (Miettinen, 2003)
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**Kinetic Analysis by TGA**

- Max. reactivity temp. of wood pellet is lower than that of sub-bituminous coal

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**Wood Pellet**

- 1st (35-200°C) Moisture drying
- 2nd (200-370°C) Main components devolatilization; hemi-cellulose, cellulose, lignin
- 3rd (370-470 °C) Volatile & Carbon combustion

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**Sub-bituminous coal**

- 1st (35-200°C) Moisture drying,
- 2nd, 3rd (200-550°C) Volatile & Carbon combustion
Wood Pellet Feeding System

- R&D facility → for <10% cofiring biomass
- Commercial facility → for > 10% cofiring biomass
- Wood pellet fed before putting on coal
- Wood pellet transportation by conveyor.
Fuel Feeding Unbalance (1st stage test_1)

- Co-firing

Coal pocket

Final coal feeder amount decreases in spite of low calorific value ??
Fuel Feeding Unbalance (1\textsuperscript{st} stage test_2)

- Reduction after co-firing
+ Increase after co-firing

![Graph showing O2 concentration changes over time with co-firing notations.](image)
Unlike 1st stage test, fuel feeding rate increased with the increase of co-firing ratio.

- Re-calibration & bias control for each feeder
Lower parts of the furnace: T ↓, Exit of the furnace & cyclones: T ↑,
- Combustion moved into the higher part of the furnace due to volatiles
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Emissions

**Dust**
- Slope = 0.03

**NOx**
- Slope = -0.87

**SOx**
- Slope = -47.4

**Ash content**
- Slope = 0.15

**S content**
- Slope = -0.04
Hazardous Materials

Korean regulation limit = 0.1 ng-TEQ/Sm³

<table>
<thead>
<tr>
<th>Item</th>
<th>Fly ash (10% co-firing)</th>
<th>Bottom ash (10% co-firing)</th>
<th>Permissible Conc. level in Korea</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st</td>
<td>2nd</td>
<td>1st</td>
</tr>
<tr>
<td>Pb</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>As</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Hg</td>
<td>0.0006</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>CN(-)</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Cr(4+)</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Cd</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>

Dioxin emission (ng-TEQ/Sm³)

Wood pellet or RDF co-firing ratio

- 5 % RDF, 200MW CFB boiler [Lee et al., Donghae, Korea]
- This study
- 20 - 30 % RDF, 27MW CFB boiler [Wan et al., China]
Co-combustion of wood pellet with sub-bituminous coal from 0% to 15% in a 340MWe CFB boiler was performed successfully.

Temperature at the lower bed decreased with the increase of co-firing ratio due to shift of volatile combustion and reduction of char oxidation.

As the furnace height increased, the slope of temperature variation increased.

Heat absorption of heat exchangers located in the back pass increased whereas those of evaporator and superheater in the furnace decreased.

Dioxin emission was comparable with other CFB boilers co-firing RDF and biomass with coal.
Thank you for your attention!