Small scale combustion of pelletized low quality wood – impact of the additives on ash characteristics and emission behaviour

Thomas Zeng

Side Workshop “REDUCING WASTE WOOD ASH RELATED OPERATIONAL PROBLEMS IN USING ADDITIVES”
WORLD SUSTAINABLE ENERGY DAYS in WELS, Austria on 28th of February 2019
Objective

- To determine the influence of recycled gypsum and halloysite on reducing ash related operational problems in combustion of wood waste fuels.

  ✓ Impact of the used additives on gaseous and particulate matter emission behaviour

  ✓ Impact of the used additives on bottom ash slagging and emission behaviour
Raw materials

- Residues from wood chip board production, i.e. A II used wood (WCB)
  - Particle size: about 60% < 3.15 mm
  - Bulk density: 337 kg/m³
- Wood logging residues (WLR)
  - Wood chip quality: less than class B (ISO 17225-4)
  - M10
- Gypsum, G (CaSO₄·2H₂O)
  - Origin: Gips Recycling Nederland BV
  - Bulk density: 700 kg/m³
- Hallosite, H (Al₂(Si₂O₇).2H₂O)
  - Origin: PTH INTERMARK, Poland
  - Bulk density: 1080 kg/m³
Raw materials – additive amounts

• Calculation of Gypsum addition

\[ S_{\text{add}} = (F_{\text{stoich}} \times ((K + Na)/2 + Zn + Pb) - 0.64 \times S_{\text{fuel}}) / 0.64 \]

• Calculation of Halloysite addition

\[ \text{Alk}_{\text{cap}} = \text{Al}_{\text{add}} - (K_{\text{add}} + Na_{\text{add}} + 2(Ca_{\text{add}} + Mg_{\text{add}})) \]
\[ \text{Amount}_{\text{add}} = (K_{\text{fuel}} + Na_{\text{fuel}}) / \text{Alk}_{\text{cap}} \]

• WLR (\(F_{\text{stoich}}=1.5\))
  ✓ Gypsum: 13.4 kg Add / t dry fuel
  ✓ Halloysite: 31.7 kg Add / t dry fuel

• WCB (\(F_{\text{stoich}}=1.5\))
  ✓ Gypsum: 4.3 kg Add / t dry fuel
  ✓ Halloysite: 10.6 kg Add / t dry fuel
Pelleting tests

Netzsch hammer mill
type CONDUX-Hammermühle
(CHM 230/200-N3):
- 4 kW
- 3000 U/min

Conditioning
type Chargenmischer
(AT-ENGINEERING, Slowakia):
- capacity 0.3 m³

Salmatec pelleting plant
type Maxima 360-40 mini:
- 30 kW
- 3-Koller-System
- integrated monitoring of temperature and energy consumption

Pellet cooling device
own design (DBFZ):
- heating 18 kW
- ventilation 3 kW
- capacity ca. 1 m³
### Pelleting tests

#### Extraneous material

#### Wearing of hammer

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Production related amount of fines [wt%]</th>
<th>Pellet mass flow [kg/h]</th>
<th>Specific energy consumption [kWh/kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>WLR</td>
<td>25.9</td>
<td>70.5</td>
<td>0.30</td>
</tr>
<tr>
<td>WLR+G</td>
<td>15.8</td>
<td>79.4</td>
<td>0.27</td>
</tr>
<tr>
<td>WLR+H</td>
<td>11.7</td>
<td>127.5</td>
<td>0.19</td>
</tr>
<tr>
<td>WCB</td>
<td>16.4</td>
<td>104.7</td>
<td>0.20</td>
</tr>
<tr>
<td>WCB+G</td>
<td>11.3</td>
<td>90.9</td>
<td>0.22</td>
</tr>
<tr>
<td>WCB+H</td>
<td>15.1</td>
<td>87.9</td>
<td>0.17</td>
</tr>
</tbody>
</table>
Combustion tests

- Analysis of biomass fuels (major and minor components, physical-mechanical properties, proximate analysis)
- Small-scale heating appliance with moving step grate (nominal heat capacity 30 kW)
- Measurement of gaseous emissions CO, NO\textsubscript{x}, SO\textsubscript{2}, HCl (Ansyco / FTIR Gasmet CR)
- Measurement of total particulate matter emissions, TPM (VDI 2066-1)
- Sampling and analysis of bottom ash and total particulate matter for analysis (ICP, XRD)
Additive and fuel pellet analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>WLR</th>
<th>WLR+G</th>
<th>WLR+H</th>
<th>WCB</th>
<th>WCB+G</th>
<th>WCB+H</th>
<th>Clean wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk density</td>
<td>kg/m³</td>
<td>661</td>
<td>671</td>
<td>648</td>
<td>569</td>
<td>614</td>
<td>600</td>
<td>633</td>
</tr>
<tr>
<td>Mechanical durability</td>
<td>wt%</td>
<td>95.69</td>
<td>94.2</td>
<td>93.9</td>
<td>94.3</td>
<td>96.1</td>
<td>95.2</td>
<td>99.0</td>
</tr>
<tr>
<td>Ash content</td>
<td>wt% dry</td>
<td>3.10</td>
<td>4.53</td>
<td>6.15</td>
<td>1.49</td>
<td>1.79</td>
<td>2.26</td>
<td>0.33</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>wt% dry</td>
<td>0.50</td>
<td>0.47</td>
<td>0.45</td>
<td>4.33</td>
<td>4.37</td>
<td>4.15</td>
<td>0.21</td>
</tr>
<tr>
<td>Chlorine</td>
<td>wt% dry</td>
<td>0.012</td>
<td>0.011</td>
<td>0.012</td>
<td>0.026</td>
<td>0.026</td>
<td>0.028</td>
<td>0.01</td>
</tr>
<tr>
<td>Sulfur</td>
<td>wt% dry</td>
<td>0.045</td>
<td>0.200</td>
<td>0.048</td>
<td>0.027</td>
<td>0.093</td>
<td>0.028</td>
<td>0.004</td>
</tr>
<tr>
<td>Potassium</td>
<td>mg/kg dry</td>
<td>2310</td>
<td>2330</td>
<td>2400</td>
<td>453</td>
<td>390</td>
<td>295</td>
<td>497</td>
</tr>
<tr>
<td>(Si+P+K)/(Ca+Mg)</td>
<td>mol/mol</td>
<td>1.82</td>
<td>1.53</td>
<td>3.43</td>
<td>0.64</td>
<td>0.45</td>
<td>1.18</td>
<td>0.8</td>
</tr>
<tr>
<td>Si/K</td>
<td>mol/mol</td>
<td>3.13</td>
<td>4.01</td>
<td>7.25</td>
<td>2.88</td>
<td>309</td>
<td>10.10</td>
<td>0.38</td>
</tr>
<tr>
<td>2S/Cl</td>
<td>mol/mol</td>
<td>8.29</td>
<td>40.21</td>
<td>8.85</td>
<td>2.30</td>
<td>7.91</td>
<td>2.21</td>
<td>0.80</td>
</tr>
<tr>
<td>K/Cl</td>
<td>mol/mol</td>
<td>17.46</td>
<td>19.21</td>
<td>18.14</td>
<td>1.58</td>
<td>1.36</td>
<td>0.96</td>
<td>4.1</td>
</tr>
</tbody>
</table>
Emissions

[Bar chart showing emissions of CO, NOx, SO2, HCl, and TPM for different samples labeled WLR, WLR+G, WLR+H, WCB, WCB+G, WCB+H, and Clean wood. Each bar represents the emissions in mg/m³, STP, d.b., 13 vol.-% O₂.]

REFAWOOD
Emissions

SO$_2$ emission [mg/m$^3$, d.b., 13 vol.% O$_2$] vs. S content in the fuel [wt.% d.b.]

linear fit: R$^2=0.99$
Analysis of total particulate matter

[Bar chart showing the analysis of total particulate matter with different categories and elements represented by specific colors.

Elements: Rest, Zn, Si, P, Na, Mg, K, Fe, Ca, Al, Pb, S.


Values are presented in wt.% d.b. C free basis.]
Bottom ash analysis
Conclusions

Halloysite

- Although the addition of H provides advantages for pelleting and reduction of particulate matter in the flue gas, the increase of ash content and the risk of bottom ash slagging seem to provide serious challenges for waste wood combustion in small scale boilers.

Gypsum

- Although high SO\(_2\) emissions were observed, the reduction potential of Cl containing particles is promising.
- Good prediction of Gypsum amounts is required to minimise potential SO\(_2\) emissions.
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Ansprechpartner
Prof. Dr. mont. Michael Nelles
Daniel Mayer
Prof. Dr.-Ing. Daniela Thrän
Dr.-Ing. Jan Liebetrau
Dr.-Ing. Volker Lenz
Dr.-Ing. Franziska Müller-Langer
Dr.rer.nat. Ingo Hartmann

DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH
Torgauer Straße 116
D-04347 Leipzig
Tel.: +49 (0)341 2434-112
E-Mail: info@dbfz.de
www.dbfz.de

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