Carbon Containing Waste

Plasma Processing

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ADVANTAGES OF PLASMA METHODS FOR WASTE PROCESSING

• Complete decomposition of the waste with the formation of basic compounds that considerably simplifies the cleaning of contaminants;
• Possible co-processing of different types of waste without pre-sorting;
• A significant decrease in the volume of flue gases, and, consequently, the load on the gas cleaning system;
• Smaller carryover of dispersed particles;
• High performance with small dimensions of equipment;
• Ability to create a desired gaseous atmosphere;
• Ability to produce the final product in a stable form;
• Possibility of operative adjustment the process by changing the flow rate of oxidant (air) and power of plasma torches.
From waste to electricity through integrated plasma gasification

TYPICAL COMPOSITION OF CARBONACEOUS WASTE

Chemical Composition of Carbonaceous Waste, Wt. %

<table>
<thead>
<tr>
<th>C</th>
<th>H</th>
<th>O</th>
<th>N</th>
<th>S</th>
<th>Cl</th>
<th>H₂O</th>
<th>Fe₂O₃</th>
<th>SiO₂</th>
<th>CaCO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>34.15</td>
<td>5.85</td>
<td>6.29</td>
<td>8.16</td>
<td>0.94</td>
<td>5.3</td>
<td>32.31</td>
<td>3.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>
For computation of the solid carbonaceous waste gasification thermodynamic code TERRA was used. The calculations were performed over a range of temperatures from 300 to 3000 K and pressure 0.1 MPa.

**Initial Composition of the System for Computation**

- 10 kg of SCW + 4 kg of air
- 10 kg of SCW + 1 kg of steam
10 kg of SCW + 4 kg of air

T = 1600 K:
CO – 31.7%
H₂ – 50.7%
N₂ – 15.0%

Concentration of the gas components dependence on the temperature of the solid carbonaceous waste plasma processing.
THERMODYNAMIC COMPUTATION

10 kg of SCW + 1 kg of steam

T = 1600 K:
- CO – 33.6%
- H₂ – 60.9%
- N₂ – 3.4%

Concentration of the gas components dependence on the temperature of the solid carbonaceous waste plasma processing
THERMODYNAMIC COMPUTATION

10 kg of SCW + 4 kg of air

Concentration of the condensed phase components dependence on temperature of the solid carbonaceous waste plasma processing
THERMODYNAMIC COMPUTATION

10 kg of SCW + 1 kg of steam

Concentration of the condensed phase components dependence on temperature of the solid carbonaceous waste plasma processing
THERMODYNAMIC COMPUTATION

T = 1600 K:

$Q_{sp1} = 1.92 \text{ kW h/kg}$

$Q_{sp2} = 2.44 \text{ kW h/kg}$

Specific power consumption dependence on temperature of the Solid Carbonaceous Waste processing

1 - 10 kg of SCW + 4 kg of air; 2 - 10 kg of SCW + 1 kg of steam
## THERMODYNAMIC COMPUTATION

<table>
<thead>
<tr>
<th>10 kg of SCW + 4 kg of air</th>
<th>10 kg of SCW + 1 kg of steam</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T</strong> = 1600 K, <strong>X_C</strong> = 100 %</td>
<td></td>
</tr>
<tr>
<td><strong>Q_{sp}</strong> – 1.92 kW h/kg</td>
<td><strong>Q_{sp}</strong> – 2.44 kW h/kg</td>
</tr>
<tr>
<td><strong>CO</strong> – 31.7%</td>
<td><strong>CO</strong> – 33.6%</td>
</tr>
<tr>
<td><strong>H_2</strong> – 50.7%</td>
<td><strong>H_2</strong> – 60.9%</td>
</tr>
<tr>
<td><strong>N_2</strong> – 15.0%</td>
<td><strong>N_2</strong> – 3.4%</td>
</tr>
<tr>
<td><strong>HHV</strong> - 3410 kcal/kg</td>
<td><strong>HHV</strong> - 4640 kcal/kg</td>
</tr>
</tbody>
</table>
Functional Scheme of the Experimental Installation for Plasma Gasification of Solid Carbonaceous Waste

1 – SCW gasification zone; 2 – pipe for supplying of briquetted SCW; 3 – reactor; 4 – arc plasma torch; 5 – plasma flame; 6 – flue gas cooling unit; 7 – gas purification unit with a bag filter; 8 – gas sampling system for analysis; 9 – exhaust system; 10 – slag formation zone
Plasma torch is the main element of the installation

Schematic of a long-service-life plasma torch of 70 kW
Plasma torch is the main element of the installation

Long-service-life plasma torch of 70 kW in operation: temperature of the plasma flame is 5000 K
Reactor with Plasma Torch
SCW Gasification

Paper / Cardboard: 21%
Food waste: 21%
Textile: 2%
Rubber, leather and...: 2%
Wood: 5%
Plastic: 13%
Metals: 3%
Glass: 2%
Calcium carbonate: 2%

SCW briquette

Hot solid products of SCW plasma gasification
SCW Gasification

Plasma reactor in action (T=1400°C)

Synthesis gas flame (T=1500°C)
CO+H₂=71.1%
PARAMETERS OF THE PLASMA INSTALLATION

- Burning device - DC plasma torch, output power of 35 to 70 kW.
- Plasma forming gas – air, flow 3.3 g/s (12 kg/h).
- Geometric dimensions of the reactor:
  - height – 0.45 m, side – 0.45 m, lining – 65 mm.
- Amount of processed material - SCW: 30.0 kg / h
- Modes of operation: warming up - 5 minutes, gasification of SCW - 3 min, melting of inorganic matter - 7 min. The total work cycle (including cooling and loading of new portion) - 30 min.
## GAS COMPOSITION AFTER PLASMA PROCESSING OF SCW

<table>
<thead>
<tr>
<th>Gas</th>
<th>Percentage, Vol. %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experiment</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>26.5</td>
</tr>
<tr>
<td>Hydrogen (H₂)</td>
<td>44.6</td>
</tr>
<tr>
<td>Nitrogen (N₂)</td>
<td>28.9</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
### COMPOSITION OF SLAG AFTER PLASMA PROCESSING OF SCW

<table>
<thead>
<tr>
<th>Slag components</th>
<th>Percentage, Wt. %</th>
<th>Experiment</th>
<th>Computation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron carbide ($\text{Fe}_3\text{C}$)</td>
<td>60.2</td>
<td>25.2</td>
<td></td>
</tr>
<tr>
<td>Calcium silicate ($\text{CaSiO}_3$)</td>
<td>21</td>
<td>44.7</td>
<td></td>
</tr>
<tr>
<td>Silica ($\text{SiO}_2$)</td>
<td>13</td>
<td>16.3</td>
<td></td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>3</td>
<td>13.8</td>
<td></td>
</tr>
<tr>
<td>Carbon (C)</td>
<td>2.8</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total:</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>$\chi_C$</td>
<td>91.8</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Specific power consumption $Q_{sp}$ (kW h/kg)</td>
<td>2.25</td>
<td>1.92</td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

According to thermodynamic calculations, the highest yield of synthesis gas during plasma gasification of carbonaceous waste in air and steam environments is obtained at a temperature of 1600K. At this temperature, the specific power consumption for air gasification of SCW is 1.92 kWh/kg, while for steam gasification, it is 2.44 kWh/kg.

At air-plasma gasification of SCW, high-calorie synthesis gas at a concentration of 82.4% (CO - 31.7%, H₂ - 50.7%) can be obtained, whereas at steam-plasma gasification, it is 94.5% (CO - 33.6%, H₂ - 60.9%). The specific heat of combustion of the synthesis gas produced by air gasification is 3410 kcal/kg, whereas for steam, it is 4640 kcal/kg.

Harmful impurities were not detected in either the gaseous or the condensed products. High-calorific synthesis gas is obtained from organic mass of SCW, and from mineral mass - neutral slag consisting essentially of iron carbide, calcium silicate, silica, and iron.

Comparison of experimental results and calculations showed good agreement.