Use of Biomass and Biogenic Carbonisates in EAF Steelmaking

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  ➔ Biochar/syngas production
  ➔ Lab scale trials
  ➔ Results of first industrial scale trials

■ RFCS “GREENEAF II” (Demonstration Project; 24 months)
  ➔ Biochar/Biomass acquisition
  ➔ Results of first industrial scale biomass campaigns
“GREENEAF I”
“Sustainable EAF steel production”
RFSR-CT-2009-00004
Start: 1\textsuperscript{st} of July 2009  End: 30\textsuperscript{th} of June 2012

Main Target:

“Investigation of the partial or total substitution of coal and natural gas with charcoal and syngas produced from pyrolysis of biomass.”
Project partners “GREENEAF I”

Sources: project partners
Chemical and physical characterization of biochar produced by the project partners

Definition of the pyrolysis process parameters for the optimization of organic charcoal production based on the specific requirements for use in the EAF (processing and agglomeration included)

Calculations on the potential of impact by using biochar on the energy and mass balances as well as all important process parameters

Implementation of melting experiments using biochar as charge and injection carbon in the pilot arc furnace. On the basis of these melting trials, the impact on the energy and material balances, process stability and off-gas emissions will be investigated

Perform and interpret off-gas-measurement campaigns using biochar in the electric arc furnaces of the industrial project partners (DEW)
Syngas/biochar production (TC)

The demonstrative pyrolysis plant can be fed with about 200 kg/h of fuel and the necessary heat energy for pyrolysis reactions is supplied by a gas burner of the maximum power of 500 KW.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>81.1%</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.29%</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>4.79 g/Kg</td>
</tr>
<tr>
<td>Volatile matter</td>
<td>7.7%</td>
</tr>
<tr>
<td>Moisture</td>
<td>5.6%</td>
</tr>
<tr>
<td>Ash content</td>
<td>9.1%</td>
</tr>
</tbody>
</table>
Slag foaming trials

- Al₂O₃-crucible
- konische Form
- Volumen: 325 ml
- Source: GTS-Ceramics
- Ca. 550 °C
- Heated by NG/oxygen burners
- Ca. 1600 °C

Sample compositions (calculated on basis of C+FeO-reduction):

- 100 g slag + 14,9 g DEW injection-coal
- 100 g slag + 16,95 g FENO injection-coal
- 100 g slag + 17,2 g biochar from TC (grapeseeds)
- 100 g slag + 21,54 g biochar from wood residues gasification

Source: GTS-Ceramics
Results of slag foaming trials

Injection coal

Foamy slag height: 50 mm
Volume increase: 250 %

Injection coal DEW

Foamy slag height: 76 mm
Volume increase: 378 %
Results of slag foaming trials

Grape seed biochar

Foamy slag height: 98 mm
Volume increase: 491 %

Biochar from wood gasification

Foamy slag height: 82 mm
Volume increase: 421 %

→ Biochar is in general suitable for slag foaming
Technical data:
- Transformer rated power: 850 kVA
- Secondary voltage: 250-850 V in 10 steps
- Arc current: max. 2 kA
- Active power: max. 600 kW

Water cooled furnace consists of:
- Fixed top reactor
- Moveable crucible, max. capacity 40 l or
- 200 kg steel melt

Other equipments:
- Cooling water circulations
- Off-gas exhausting system
- Process control and automation with PLC

Features:
- Operation mode: AC or DC
- Airtight operation with defined gas atmosphere (Ar, N₂, CO/CO₂, compressed air) injected through side channels and through electrode borehole possible
- Bottom purging for melt homogenisation
- Sampling probe for chemical analysis and temperature of melt
Results of pilot tests

- No adverse effects on the energy balance as well as the composition of crude steel detectable by using biochar instead of anthracite
- Pneumatic conveying and injection of biochar fines possible to produce a foamy slag
- Problems occurred regarding the handling and the reaction behavior of the dusty material
Results of industrial injection trials
Results of industrial charge carbon trials
Results of industrial charge carbon trials

- The Measurements at the electric arc furnace at DEW in Siegen have been performed successfully. Off-gas data of both reference and biochar charges could have been recorded, evaluated and compared to each other.

- CO increase in the second bucket observed while char utilization (20% in the off-gas respect 16%) is not a dramatic value which can be controlled optimizing the operating practice and with a longer industrial testing.
Biochar briquettes have been produced in pilot scale.
Results of Biochar-briquette-utilization
“GREENEAF II”

“Biochar for a sustainable EAF steel production”

RFSR-CT-2014-00003

Start: 1st of July 2014   End: 30th of June 2016

Main Target:

“Validation of char/biomass utilization to replace coal in EAF-steelmaking process”
Project partners “GREENEAF II”
Role of the IOB in “GREENEAF II”

- Analysis, characterization and comparison with fossil coals regarding the reactivity of the acquired biochar (for charging as well as for foaming)
- Specific foaming tests at laboratory scale
- Testing of additives (pulverized coal, oxides) to activate the reducing reaction of FeO and C forming CO in lab scale to reduce the number of industrial tests.
- Support of the industrial trials at GMH by elaboration of data from the experimentation
- Full LCA study about the utilization of biochar in the EAF based on the collected and analyzed data from project partners
Biochar acquisition

- After an intensive market analysis no supplier was able to deliver an adequate amount of biochar (>350 tons) for industrial EAF campaign.

- Palm kernel shells were available and have been chosen for industrial campaigns.

Analysis in [M-%]:

- $C_{\text{total}}$: 44.8
- $C_{\text{fix}}$: 34.4
- Moisture (105°C): 11.9
- Ash (815°C): 1.83
- Volatiles: 63.4
- Heating value (as received): 16.8 MJ/kg

Palm kernel shells (dried)
GMH conducted two trial campaigns testing the use of palm kern shells as a substitute for charge carbon

<table>
<thead>
<tr>
<th>Campaign</th>
<th>Period</th>
<th>Material</th>
<th>Nr. of heats</th>
</tr>
</thead>
<tbody>
<tr>
<td>PKS campaign</td>
<td>09.10.-01.11.2014</td>
<td>PKS, moist (as is)</td>
<td>404 heats</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~ 1.8 t/heat</td>
<td>700 t PKS</td>
</tr>
<tr>
<td>Reference campaign</td>
<td>01.11.-20.11.2014</td>
<td>Anthracite</td>
<td>287 heats</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~ 1.1 t/heat</td>
<td></td>
</tr>
<tr>
<td>PKS campaign</td>
<td>20.11.-09.12.2014</td>
<td>PKS, dry</td>
<td>305 heats</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~ 2 t/heat</td>
<td>700 t PKS</td>
</tr>
<tr>
<td>Reference campaign</td>
<td>09.12.-13.12.2014</td>
<td>Anthracite</td>
<td>87 heats</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~ 1.2 t/heat</td>
<td></td>
</tr>
</tbody>
</table>
Industrial tests and analysis of results

- Preliminary evaluation results, divided in different evaluation groups because of different working conditions

<table>
<thead>
<tr>
<th>Evaluation groups</th>
<th>Nr of heats</th>
<th>Mean electric energy input [kWh/t]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PKS, moist 2nd bucket</td>
<td>59</td>
<td>452</td>
</tr>
<tr>
<td>PKS, moist</td>
<td>253</td>
<td>459</td>
</tr>
<tr>
<td>PKS, moist (failure Br3)</td>
<td>72</td>
<td>476</td>
</tr>
<tr>
<td>Anthracite</td>
<td>371</td>
<td>451</td>
</tr>
<tr>
<td>PKS, dry</td>
<td>305</td>
<td>454</td>
</tr>
</tbody>
</table>
Industrial tests and analysis of results
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\[ PCR = \frac{CO_2 + H_2O}{CO + H_2 + H_2O + CO_2} \]
Köhle model\textsuperscript{1} as a benchmark to evaluate the combined influence of all parameters

\[ h_{th} = 375 + 400 \cdot \left[ \frac{m_{\text{met}}}{m_{\text{tap}}} - 1 \right] + 1000 \cdot \frac{m_{\text{SB}}}{m_{\text{tap}}} + 0.3 \cdot [T_{\text{tap}} - 1600] + t_{t2t} \]

\[ -8 \cdot v_{\text{NG}} - 4.3 \cdot v_{\text{L}} - 2.8 \cdot v_{\text{PC}} - 50 \cdot \frac{m_{\text{sh}}}{m_{\text{tap}}} \]

\textsuperscript{1} Köhle, S.: Recent improvements in modelling energy consumption of electric arc furnaces, Proc. 7\textsuperscript{th} Europ. Electric Steelmaking Conf., 26-29 May 2002, Venice, Italy
Industrial tests and analysis of results
Thank you for your attention!

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