NO$_x$ emission from combustion pre-dried brown coal and its chars
Presentation Overview

• Background

• Experimental
  o Combustion of lignite with different moisture content in oxy atmosphere
  o Lignite pyrolysis and char characterization
  o Char combustion process

• Conclusions
Background

Reduction of carbon dioxide from utility plant fired with lignite is important due to electricity production in Poland based on lignite coal is ~35%* as:

Oxy Combustion Technology

thus subject of Polish Research and Development Strategic Program: “Advanced Technologies for Energy Generation” project no. 2 “Oxy-combustion technology for PC and FBC boilers with CO₂ capture”

* Cire, Agencja Rynku Energii, Dane za rok 2012 udział paliwa w wytwarzaniu energii elektrycznej w elektrowniach zawodowych
Experimental- Aim of research

- Comparison of the oxy-combustion process of lignite with various initial moisture content, and its char
- The effect of initial lignite moisture content on NO\textsubscript{x} emission
- Comparison of gaseous N-species elements from pyrolysis in N\textsubscript{2} and CO\textsubscript{2} atmosphere
- Characterization of char produced in CO\textsubscript{2} and N\textsubscript{2} atmosphere at 1000°C in drop tube
- The NO\textsubscript{x} emission from chars combustion
The research were performed in an isothermal flow reactor.

Reactor details:
- length = 2.5 m,
- diameter = 135 mm
- wall temperature 1250 °C
- fuel flow=0.1÷1.4 kg/h
- primary flow=1500 l/h
- secondary flow=2500 l/h
Combustion process, pyrolysis and char combustion scheme to compare the nitrogen emission during the combustion in the AIR and OXY atmosphere.

**NO\textsubscript{x} research schedule**

- **Fuel (lignite)**
  - Combustion
    - In OXY
    - In AIR
      - NO\textsubscript{x} measurement
      - NO\textsubscript{x} measurement
  - Pyrolysis
    - Gas
      - HCN, NH\textsubscript{3}, NO
      - Fuel N measurement
      - NO\textsubscript{x} measurement
      - Char
      - Char
    - In CO\textsubscript{2}
    - In N\textsubscript{2}
      - Fuel N measurement
      - NO\textsubscript{x} measurement
      - Gas
      - Analysis of solid pyrolysis products
      - Combustion
        - In OXY
        - In AIR
        - NO\textsubscript{x} measurement
        - Ash
        - NO\textsubscript{x} measurement
        - Ash
        - NO\textsubscript{x} measurement
        - Ash
        - NO\textsubscript{x} measurement
        - Ash
Fuel characterization

Proximate and ultimate analysis of lignite K8.

<table>
<thead>
<tr>
<th>C&lt;sup&gt;d&lt;/sup&gt;</th>
<th>H&lt;sup&gt;d&lt;/sup&gt;</th>
<th>N&lt;sup&gt;d&lt;/sup&gt;</th>
<th>S&lt;sup&gt;d&lt;/sup&gt;</th>
<th>ASH&lt;sup&gt;d&lt;/sup&gt;</th>
<th>VM&lt;sup&gt;d&lt;/sup&gt;</th>
<th>HHV&lt;sup&gt;d&lt;/sup&gt;</th>
<th>LHV&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>MJ/kg</td>
<td>MJ/kg</td>
</tr>
<tr>
<td>56,47</td>
<td>5,34</td>
<td>0,72</td>
<td>0,87</td>
<td>18,04</td>
<td>76,30</td>
<td>22,60</td>
<td>21,39</td>
</tr>
</tbody>
</table>

Walls reactor temperature: 1200°C

NO<sub>x</sub> emission was studied for OXY and AIR combustion of pulverized lignite coal (d<0,2mm) from polish mine. Initial lignite moisture content: 7%, 15%, 24%, 33%
In the range of examined moisture content in the fuel, the minimal emission was obtained from the predried lignite of moisture content $M=7\%$.

Increasing initial moisture content in lignite has a negative effect on NO$_x$ emission.

The emission from lignite oxy-combustion is always lower than the emission from air combustion.

The emission from lignite oxy-combustion is always lower than the emission from air combustion.
Lignite pyrolysis

Pyrolysis was conducted for lignite coal with different moisture content (7%; 14%), pyrolysis in two different gases (CO₂, N₂).

The detailed analysis of the N-fuel species transformed to the gaseous form during pyrolysis were carried out in CO₂ and N₂ atmosphere for lignite with M=1,5% moisture content.

Pyrolysis temperature: 1000°C
residence time: 1-2 s
Initial moisture content of raw lignite has small effect on total mass loss. More significant is atmosphere of pyrolysis.

- N-loss in $\text{CO}_2$ is higher for dryer lignite: aprox. by 5.67%.
- N-losses in $\text{N}_2$ is higher for dryer lignite: aprox. by 5.37%.
- N-loss in $\text{CO}_2$ to $\text{N}_2$ atmosphere are: 10% and 9.7% higher respectively for 7% and 14% moisture content of lignite.
Mass loss during pyrolysis

Total mass loss for CO$_2$ atmosphere is higher than N$_2$ atmosphere. Especially it is visible for C element.
Char characterization

The specific surface of the char\(\text{CO}_2\) is greater than from char\(\text{N}_2\).
The difference is visible for char produced from M=14% lignite, and M=1.5%
Char characterization

and is stronger for dry lignite.

AND: the moisture has more significant effect on the specific surface than the atmosphere.

\[ M = 1.5\% \]
CO, H₂, and CH₄ concentration from pyrolysis in CO₂ and N₂

Lower moisture content increase the CO formation in CO₂ atmosphere.
Pyrolysis results

The atmosphere effect on N-fuel species in gaseous form

For the same moisture (M=1,5%): N-fuel is mainly emitted as a HCN compound in examined N₂ and CO₂ atmospheres.

**BUT**: Higher quantity of NO and NO₂ is observed in CO₂ than N₂
Moisture effect on N-fuel species in gaseous form

CO₂ atmosphere leads to higher conversion from N-fuel to N-gaseous species

**AND:** An important aspect on N-species has an initial moisture of lignite (in N₂ atmosphere)
Char combustion

Last part of the study was char combustion.Chars from N\textsubscript{2} and CO\textsubscript{2} pyrolysis process were combusted in Oxy and Air atmosphere.

NO\textsubscript{x} emission from chars combustion was studied for O\textsubscript{2}/CO\textsubscript{2} 25/75 and AIR atmosphere.

Walls reactor temperature: 1200°C

<table>
<thead>
<tr>
<th>Char</th>
<th>C\textsubscript{d} %</th>
<th>H\textsubscript{d} %</th>
<th>N\textsubscript{d} %</th>
<th>S\textsubscript{d} %</th>
<th>O\textsubscript{d} %</th>
<th>Ash\textsubscript{d} %</th>
<th>Q\textsubscript{d}\textsuperscript{s} MJ/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Char K8CO\textsubscript{2} (M\textsubscript{raw}=1,5%)</td>
<td>53,21</td>
<td>0,41</td>
<td>0,50</td>
<td>0,09</td>
<td>0,47</td>
<td>45,30</td>
<td>18,52</td>
</tr>
<tr>
<td>Char K8N\textsubscript{2} (M\textsubscript{raw}=1,5%)</td>
<td>66,24</td>
<td>1,13</td>
<td>0,61</td>
<td>0,09</td>
<td>6,17</td>
<td>25,76</td>
<td>22,90</td>
</tr>
</tbody>
</table>

Analysis of solid pyrolysis products

Combustion

In OXY

NO\textsubscript{x} measurement

Ash

CharCO\textsubscript{2}

CharN\textsubscript{2}

Combustion

In AIR

NO\textsubscript{x} measurement

Ash

In OXY

NO\textsubscript{x} measurement

Ash

In AIR

NO\textsubscript{x} measurement

Ash
Char combustion

Temperature distribution of char combustion.

T1

T2

T3

T4

T5
Char combustion

$\text{NO}_x$ emission from combustion in OXY 25 and AIR brown coal (K8, M=7%) and its charK8CO$_2$ in ppm

$\text{NO}_x$ emission from combustion in OXY 25 and AIR brown coal (K9, M=7%) and its charK9N$_2$ in ppm
Char combustion

NO\textsubscript{x} emission from combustion in OXY 25 and AIR brown coal (K8, M=7\%) and its char K8 CO\textsubscript{2}

NO\textsubscript{x} emission from combustion in OXY 25 and AIR brown coal (K9, M=7\%) and its char K9 N\textsubscript{2}

The emission of char combustion is higher than raw coal.
**Conclusion**

### COMBUSTION OF LIGNITE

- The NO\(_x\) emission (mg/MJ) from oxy-combustion of lignite at oxy ratio \(O_2/CO_2 = 15/85 – 30/70\) is lower than from air conventional combustion for all investigated lignite moisture content.

- However, the lignite moisture content influences on NO\(_x\) emission level i.e. NO\(_x\) increases with moisture content increases in the rate depending on excess oxygen.

- The minimal NO\(_x\) emission was obtained for the predried lignite with 7% moisture.

### PYROLYSIS:

- The gas environment is significant parameter affecting on mass release, and initial lignite moisture content only slightly affect on mass release.

- But both parameters: gas environment and initial lignite moisture content influence on pyrolitic gas composition. *Especially on CO & H\(_2\) content*
Conclusion

PYROLITIC GAS:

• TFN concentration in gas obtained in pyrolysis of lignite (M=1.5%) in CO$_2$ environment is higher than from pyrolysis in N$_2$; HCN is dominant compound in both atmospheres – and higher quantity of NO and NO$_2$ is observed in CO$_2$ than N$_2$.
• The higher moisture content of lignite ~14% causes that all TFN despite NO are significantly higher in pyrolitic gas.
• NO\textsubscript{x} emission from charCO2 combustion in Oxy25 and air atmosphere is similar level, and NO\textsubscript{x} emission for char N\textsubscript{2} is lower from Oxy25 combustion than from air combustion.

It can exhibit that the effect of internal surface and the size of chars pores distribution is important for generation/reduction of NO\textsubscript{x}.

(charsCO2 characterizes larger internal surfaces compare with charN2)
Acknowledgements

This scientific work was supported by the National Centre for Research and Development, within the confines of Research and Development Strategic Program “Advanced Technologies for Energy Generation” project no. 2 “Oxy-combustion technology for PC and FBC boilers with CO2 capture”. Agreement no. SP/E/2/66420/10. The support is gratefully acknowledged.


Research team: Marcin Baranowski, Jakub Dlugosz, Michał Czerep, Krystian Krochmalny, Jerzy Michalski, Michal Ostrycharczyk, Olga Siedlecka, Jacek Zgóra
Thank you for attention.

Dr hab. Halina Pawlak-Kruczek Prof. nadzw. PWr
e-mail: halina.kruczek@pwr.wroc.pl
or hkruczek@pwr.wroc.pl

Department of Mechanical and Power Engineering
Wroclaw University of Technology
27 Wybrzeze Wyspianskiego
50-370 Wroclaw, Poland
tel./fax: +48 71 320 39 42

Website:
http://fluid.itcmp.pwr.wroc.pl/~hkruczek/index_eng.html

3rd Oxyfuel Combustion Conference OCC3
9th - 13th September 2013, Ponferrada Spain