Alf-Cemind Workshop / Athen
16th May 2007

Technology Options for the Cement Industry with the Use of Alternative Fuels

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Head of Pyro Process Engineering
KHD Humboldt Wedag GmbH
1. Secondary Fuels – Challenge and Opportunity
   - Properties and Fuel Characteristics
   - Influences on Process and Equipment

2. Technical Solutions
   - Burner Technology
   - Calciner Technology
   - Kiln exit-gas extraction (Bypass Systems)

3. Case Study:
   Plant Comparison considering Primary and Secondary Fuels
Secondary Fuels – Challenge and Opportunity

- Animal-meal
- Municipal Waste
- Rice husks
- Sewage-sludge
- RDF
- Rubber chips
- Wood chips
- Tires
Influences of Secondary Fuel Utilisation on Pyro Process

Challenges:

Global Goals:

- Saving of natural resources
- Reduction of CO$_2$ emissions (Emission trading)
- Thermal recycling

Individual Goals:

- Earning of disposal fees
- Reduction of fuel costs “negative fuel costs”
- Stronger market position
Influences of Secondary Fuel Utilisation on Pyro Process

However:

- Establishment of an additional fuel management
- Silos and storage facilities, dosing and transport equipment

Process influenced by:

- Higher specific waste gas volume and pressure drop
- Increase of specific heat demand
- Increase of chlorine and sulphur input within the system
- .....
### Typical Secondary Fuels

<table>
<thead>
<tr>
<th></th>
<th>Petcoke</th>
<th>Tyres</th>
<th>Fluff RDF</th>
<th>Sewage sludge</th>
<th>Animal meal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moisture [%]</strong></td>
<td>0,11</td>
<td>1,00</td>
<td><strong>17,80</strong></td>
<td>6,60</td>
<td>3,40</td>
</tr>
<tr>
<td><strong>Volatiles [%]</strong></td>
<td>10,90</td>
<td>61,00</td>
<td><strong>65,00</strong></td>
<td>45,30</td>
<td>68,70</td>
</tr>
<tr>
<td><strong>Hardgrove [°H]</strong></td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cal. Value H_u [kJ/kg]</strong></td>
<td>34830</td>
<td>29480</td>
<td><strong>14650</strong></td>
<td>9849</td>
<td>19990</td>
</tr>
<tr>
<td><strong>Ash [% w.f.]</strong></td>
<td>1,28</td>
<td>7,50</td>
<td><strong>17,69</strong></td>
<td>46,20</td>
<td>20,50</td>
</tr>
<tr>
<td><strong>Carbon [% w.f.]</strong></td>
<td>86,36</td>
<td>81,00</td>
<td><strong>53,08</strong></td>
<td>26,60</td>
<td>43,80</td>
</tr>
<tr>
<td><strong>Hydrogen [% w.f.]</strong></td>
<td>3,49</td>
<td>6,70</td>
<td><strong>7,26</strong></td>
<td>4,93</td>
<td>5,30</td>
</tr>
<tr>
<td><strong>Oxigen [% w.f.]</strong></td>
<td>1,85</td>
<td>3,00</td>
<td><strong>19,50</strong></td>
<td>16,00</td>
<td>16,90</td>
</tr>
<tr>
<td><strong>Nitrogen [% w.f.]</strong></td>
<td>1,61</td>
<td>0,30</td>
<td><strong>0,47</strong></td>
<td>5,73</td>
<td>8,90</td>
</tr>
<tr>
<td><strong>Chloride [% w.f.]</strong></td>
<td>0,01</td>
<td>0,10</td>
<td><strong>1,20</strong></td>
<td>0,05</td>
<td>0,60</td>
</tr>
<tr>
<td><strong>Sulphur [% w.f.]</strong></td>
<td>5,40</td>
<td>1,70</td>
<td><strong>0,80</strong></td>
<td>0,46</td>
<td>0,50</td>
</tr>
<tr>
<td><strong>P_2O_5 [% w.f.]</strong></td>
<td>&lt; 0,01</td>
<td>&lt; 0,01</td>
<td>&lt; <strong>1,0</strong></td>
<td>&lt; 5,0</td>
<td>&lt; 0,1</td>
</tr>
<tr>
<td><strong>Hg [ppm]</strong></td>
<td>&lt; 0,01</td>
<td>&lt; 0,01</td>
<td>&lt; <strong>1,0</strong></td>
<td>&lt; 5,0</td>
<td>&lt; 0,1</td>
</tr>
<tr>
<td><strong>Cd + Tl [ppm]</strong></td>
<td>&lt; 10,0</td>
<td>&lt; 20,0</td>
<td>&lt; <strong>20,0</strong></td>
<td>&lt; 10,0</td>
<td>&lt; 10,0</td>
</tr>
<tr>
<td><strong>Σ(Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V) [ppm]</strong></td>
<td>&lt; 3000</td>
<td>&lt; 2000</td>
<td>&lt; <strong>2000</strong></td>
<td>&lt; 5000</td>
<td>&lt; 1000</td>
</tr>
</tbody>
</table>
### Characteristics of some solid fuels

<table>
<thead>
<tr>
<th></th>
<th>coal</th>
<th>petcoke</th>
<th>anthracite</th>
<th>tyre chips</th>
<th>fluff-RDF</th>
<th>animal meal</th>
<th>sewage sludge</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heat value</strong></td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟥</td>
</tr>
<tr>
<td><strong>Preparation</strong></td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
</tr>
<tr>
<td><strong>Handling</strong></td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
</tr>
<tr>
<td><strong>Chlorine Input</strong></td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🦜</td>
</tr>
<tr>
<td><strong>Sulfur Input</strong></td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🦜</td>
</tr>
<tr>
<td><strong>NOx reduction potential</strong></td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
</tr>
<tr>
<td><strong>Fuel costs</strong></td>
<td>🟥</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
<td>🟢</td>
</tr>
</tbody>
</table>

- 🟢: positive
- 🟢: indifferent
- 🟥: negative
Feeding Points for Secondary Fuels

**Kiln system without pre-calciner**

Low pre-calcination rate of hot meal (app. 40%)

Fuel used for sintering and calcination in the kiln

Possible to use fuels with “delayed heat release” in the kiln burner to shift energy to the calcination zone.
**Kiln system with pre-calciner and combustion chamber**

- **Calcining zone**
- **Transition and Sintering zone**
- **Combustion Chamber**

High pre-calcination rate of hot meal (> 90%)

Fuel energy in the calciner (up to 60 %) is used for pre-calcination

Fuel energy in the kiln is used for sintering

Shifting secondary fuels with „low quality“ properties to the combustion chamber.

=> Increased Flexibility
### Technical Solutions - Burning Technology

#### Examples for typical secondary fuels

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Heat Value [MJ/kg]</th>
<th>PYROSTREAM Kiln burner</th>
<th>PYROCLON R LN Calciner</th>
<th>PYROCLON R LN Combustion Chamber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Oil</td>
<td>~ 33</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Animal Meal</td>
<td>~ 17</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Petrolcoke</td>
<td>~ 33</td>
<td>Max. 5%</td>
<td>Max. 5%</td>
<td>Max. 10%</td>
</tr>
<tr>
<td>Anthrazite</td>
<td></td>
<td>R 90µm</td>
<td>R 90µm</td>
<td>R 90µm</td>
</tr>
<tr>
<td>Hard Plastics</td>
<td>~ 27</td>
<td>0 – 4 mm</td>
<td>0 – 5 mm</td>
<td>0 – 50 mm</td>
</tr>
<tr>
<td>Tyre Chips/Rubber residues</td>
<td>~ 32</td>
<td>-</td>
<td>Max. 40 x 40 mm</td>
<td>Max. 70 x 70 mm</td>
</tr>
<tr>
<td>Fluff-RDF</td>
<td>~ 18</td>
<td>0 – 10 mm</td>
<td>0 – 30 mm</td>
<td>0 – 100 mm</td>
</tr>
<tr>
<td>Biomass/Sewage Sludge</td>
<td>~ 15</td>
<td>0 – 4 mm</td>
<td>0 – 5 mm</td>
<td>0 – 50 mm</td>
</tr>
</tbody>
</table>
Technical Solutions - Burner Technology

The PYRO-JET Burner

A typical multi-channel burner for various fuels. To achieve highest substitution rates, the burner can fire different combustibles in mixed rates: Sewage sludge, animal meal, coal, used oil, solvents and contaminated water.
Technical Solutions - Burner Technology

PYROJET®-Burner in a German cement plant

- Slots for secondary fuel atomization
- Secondary fuel channel
- Main swirl air slots
- Inner coal dust nozzle
Technical Solutions - Burner Technology

► PYROSTREAM®-Burner for improved adjustment of flame shape and intensity
Technical Solutions - Burner Technology

Fuel mix, thermal input, for two KHD burners

► PYRO-JET Burner (Swiss)
  ▶ 25% Coal
  ▶ 19% Oil
  ▶ 13% Solvents
  ▶ 34% Plastics (<10 mm)
  ▶ 9% Sewage Sludge

► PYROSTREAM Burner (France)
  ▶ 36% Coal
  ▶ 35% Animal Meal
  ▶ 23% Fluff (<25 mm)
  ▶ 6% Solvents
Technical Solutions - Calciner Technology

PYROCLON® LowNOx Calciner:

- primary fuels like lignite, coal, oil, gas
- alternative fuels like liquids or animal meal

Fuels: suspended in air and easy to ignite  lumpy and difficult to ignite
Technical Solutions - Calciner Technology

Extended PYROCLON® LowNOx Calciner:
- fine anthracite & petcoke (< 5% R 90µm)
- Fluff - RDF / sewage sludge / shredded tyres

Fuels: suspended in air and easy to ignite  lumpy and difficult to ignite
Technical Solutions - Calciner Technology

**PYROCLON® LowNOx Calciner with ignition module:**
✓ coarse anthracite & petcoke (5-8% R90µm)

Fuels: suspended in air and easy to ignite  lumpy and difficult to ignite
Technical Solutions - Calciner Technology

regular  extended  Ignition module  Combustion chamber

Fuels: suspended in air and easy to ignite  lumpy and difficult to ignite
Technical Solutions - Calciner Technology

**PYROCLON®-R LowNOx**

- Staged combustion
- Low cost NOx - reduction without additives (SNCR process)
- High efficiency and flexibility
- > 30 references
- BAT „Best Available Technique“
  Emission level: < 500 mg NO₂/Nm³
PYROCLON® LowNOx Calciner
Holnam, Devil’s Slide Plant

Feeding level for diaper & tyre chips
(max. 40% / 50 x 50 mm²)

PYROTOP® compact swirl chamber
PYROCLON®-R Calciner with Combustion Chamber

- Meal from second last cyclone
- Swirl air
- Combustion air
- Swirl air
- Bypass air
- Tertiary air
- Secondary fuel
- Gas
- Burner - swirl air
- Coal / petcoke
Advantages

- High flexibility and efficiency.
- Lower demand on fuel quality and preparation
  - saving of treatment costs
- Ignition and start of combustion in pure air at high temperatures (T \sim 1200°C).
- Raw meal feeding to the swirl air leads to meal fogging at the wall and thereby protecting it against overheating.
- Winning of additional retention time. Final burnout in pre-calciner.
Norcem A.S. / Dalen
Modification of PYROCLON - Calciner with Combustion Chamber
Modernisation Steps of Kiln Line 6

- **1966:** “Basis” 1600 t/d
  - PH: 3556/4
  - Kiln: 4.4 x 68 m
  - Cooler: 54 m²

- **1988:** “Prod. Increase” 3500 t/d
  - PH + Calc.: PR-LowNOx 5356 / 5635/4
  - Cooler: 70 m²

- **2002:** “Secondary Fuels” 3500 t/d
  - PR calciner with combustion chamber
  - max. increase of secondary fuels
PYROCLON® Calciner with Combustion Chamber:
Norcem Plant / Norway

- Successfully in operation since December 2004
- 90% of the calciner fuel is substituted by secondary fuels
- CO at stack, dry at 11%: < 0.1 %

Calciner (combustion chamber): 60 th-% of total fuel

- Coal / Pet coke / Animal Meal mix: 6 th-%
- Solid hazardous waste: 16 th-%
- Fluff RDF: 38 th-%

Main burner: 40 th-% of total fuel

- Coal / Pet coke mix: 34 th-%
- Liquid hazardous waste: 4 th-%
- Animal meal: 2 th-%

Typically:
16 to 18 t/h of solid haz. waste and heterogenous RDF fed to the combustion chamber
Holcim
Campulung / Romania
New Kiln Line 4000 t/d

Top Air Duct

Combustion Chamber

Static Orifice
Technical Solutions - Bypass Systems

KHD Bypass System

- Efficient mixing of gas streams
- Rapid cooling of the bypass gases
- Homogenous mixing gas temperature
- Patented water injection system
Technical Solutions - Bypass Systems

Influence of sulphur and chlorides on preheater operation
Typical Arrangement for Bypass Extraction

- Bypass gas to dedusting
- Mixing chamber
- Cooling air
- Kiln inlet chamber
- Tertiary air duct
Case study:
Conventional Plant for Primary Fuels

Plant A

Production 3500 t/d
Coal 27,8 MJ/kg

Specific heat consumption 2956 kJ/kg cli
Specific waste gas amount at fan inlet 1,4 Nm³/kg
Pressure drop at fan inlet - 47 mbar
Case study:
Plant for Primary and Secondary Fuels

**Plant B**

Production: 3500 t/d

Primary-Secondary Fuel Mix: 16,8 MJ/kg

(≈ 40% coal, ≈ 60% altern. fuel mix)

Specific heat consumption: 3274 kJ/kg cli

Specific waste gas amount at fan inlet: 1,6 Nm³/kg

Pressure drop at fan inlet: - 68 mbar
# Case Study:

## Comparison

<table>
<thead>
<tr>
<th></th>
<th>Plant A</th>
<th>Plant B</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Fuel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant without combustion chamber, bypass and extended calciner</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Specific heat demand</strong></td>
<td>2956 kJ/kg cli.</td>
<td>3274 kJ/kg cli.</td>
<td>+ 10 %</td>
</tr>
<tr>
<td><strong>Specific exhaust gas amount</strong></td>
<td>1.4 Nm³/kg cli.</td>
<td>1.6 Nm³/kg cli.</td>
<td>+ 14 %</td>
</tr>
<tr>
<td><strong>Pressure drop at fan inlet</strong></td>
<td>- 47 mbar</td>
<td>- 68 mbar</td>
<td>+ 45 %</td>
</tr>
</tbody>
</table>
Case study:
10% more in specific heat demand shared to …

Plant with combustion chamber, extended calciner and bypass

- Exhaust Gas: 40%
- Bypass: 39%
- Radiation: Kiln: 12%
- Radiation: Preheater, Calciner: 8%
- Dust: 1%
Challenge of Using Secondary Fuels

Development of costs absolut

Costs

Profit

Time

Target

- x%

Costs / t clinker

Profit

Development of costs absolut

Costs

Profit

Time

Target

- x%
KHD Humboldt

“150 Years Leadership in Technology”

and Cement Plant Engineering

- Innovative, reliable technology
- High availability and flexibility
- Low specific energy demand
- Low emission levels
- Customised solutions