Fractionation of Flash Pyrolysis Condensates by Staged Condensation

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Fractionation of Flash Pyrolysis Condensates by Staged Condensation

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Stefan Conrad, Jan Westermeyer; Thermochemical Processes and Hydrocarbons

Chania, Crete, 01.10.2015
AGENDA

1. Ablative Flash Pyrolysis

2. Staged pyrolysis vapour condensation
   - Two staged condensation
   - Three staged condensation
   - Creation of Value

3. Summary
AGENDA

1. Ablative Flash Pyrolysis

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3. Summary
Ablative Flash Pyrolysis – Principle

F

vapor

T ~550°C
t < 1s
O₂ = 0

char
(15-40%)
gas
(10-20%)

T pyrolysis condensate
(40-70%)

secondary reactions

condensation

CO₂

CH₄

C₂H₆

H₂O

CO
Ablative Flash Pyrolysis – Products

- Wheat/barley straw
- Pyrolysis char
- Condensate (aqueous)
- Condensate (organic)
Ablative Flash Pyrolysis – Laboratory Plant

Input:
< 10 kg/h

Heating:
electrical

Cooling:
indirect

Aerosol sep.:
ESP
### Ablative Flash Pyrolysis – Quality of Condensates

<table>
<thead>
<tr>
<th></th>
<th>aqueous</th>
<th>organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>mass ratio</td>
<td>67.5 %</td>
<td>32.5 %</td>
</tr>
<tr>
<td>total Water</td>
<td>61.7 %</td>
<td>25.3 %</td>
</tr>
<tr>
<td>nonaromatic Acids</td>
<td>7.4 %</td>
<td>5.9 %</td>
</tr>
<tr>
<td>nonaromatic Alcohols</td>
<td>1.5 %</td>
<td>0.3 %</td>
</tr>
<tr>
<td>nonaromatic Aldehydes</td>
<td>0.0 %</td>
<td>1.1 %</td>
</tr>
<tr>
<td>nonaromatic Ketones</td>
<td>5.9 %</td>
<td>7.1 %</td>
</tr>
<tr>
<td>Phenols</td>
<td>1.2 %</td>
<td>12.0 %</td>
</tr>
<tr>
<td>Sugars</td>
<td>1.6 %</td>
<td>1.5 %</td>
</tr>
<tr>
<td>Heterocyclic Sub.</td>
<td>1.4 %</td>
<td>2.9 %</td>
</tr>
<tr>
<td>not GC-detectable Sub.</td>
<td>19.1 %</td>
<td>42.4 %</td>
</tr>
<tr>
<td>lower Heating value</td>
<td>7.9 MJ/kg</td>
<td>22.3 MJ/kg</td>
</tr>
</tbody>
</table>

wheat / barley straw, 549 °C
AGENDA

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3. Summary
Staged condensation – Approach
Staged Condensation – Two stages experiment
Staged Condensation – Two stages experiment

- Condensation 1: 300 °C, 45% (Water: 10%, Nonaromatic Acids: 7%, Nonaromatic Aldehydes: 3%, Nonaromatic Ketones: 8%, Phenols: 12%, Sugars: 4%, not detected substances: 52%), Heating Value (LHV): 23 MJ/kg
- Condensation 2: 89 °C, 55% (Water: 75%, Nonaromatic Acids: 8%, nonaromatic Aldehydes: 0%, nonaromatic Ketones: 6%, Phenols: 0%, Sugars: 0%, not detected substances: 8%), Heating Value (LHV): 5 MJ/kg

Total condensate (two-phase) weighted average values: 12 °C, 8% (Water: 46%)

- Condensate of wheat/barley straw: 539 °C, 50 bar pressure

Note: 2 based on the fraction, 1 based on the raw material.
Staged Condensation – Three stages experiment
Staged Condensation – Three stages experiment

![Graph showing temperatures and condensation stages](image)

### Condensation Stages

<table>
<thead>
<tr>
<th>Stage</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>300</td>
</tr>
<tr>
<td>2</td>
<td>115</td>
</tr>
<tr>
<td>3</td>
<td>87</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
</tr>
</tbody>
</table>

### Condensate Composition

<table>
<thead>
<tr>
<th>Component</th>
<th>Condensation 1</th>
<th>Condensation 2</th>
<th>Condensation 3</th>
<th>Total Condensate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>2%</td>
<td>8%</td>
<td>70%</td>
<td>46%</td>
</tr>
<tr>
<td>Acids</td>
<td>1%</td>
<td>6%</td>
<td>9%</td>
<td>7%</td>
</tr>
<tr>
<td>Nonaromatic Aldehydes</td>
<td>0%</td>
<td>3%</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Nonaromatic Ketones</td>
<td>1%</td>
<td>12%</td>
<td>7%</td>
<td>7%</td>
</tr>
<tr>
<td>Phenols</td>
<td>11%</td>
<td>20%</td>
<td>1%</td>
<td>5%</td>
</tr>
<tr>
<td>Sugars</td>
<td>6%</td>
<td>5%</td>
<td>0%</td>
<td>2%</td>
</tr>
<tr>
<td>Not Detected Substances</td>
<td>79%</td>
<td>38%</td>
<td>10%</td>
<td>30%</td>
</tr>
</tbody>
</table>

**Heating Value (LHV)**

- Condensate of wheat/barley straw at 550°C, 50 bar pressure
  - 28 MJ/kg
  - 22 MJ/kg
  - 6 MJ/kg

---

2 based on the fraction
1 based on the raw material
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Staged Condensation – Creation of Value

- Higher boiling fraction (2 staged condensation)
  black viscous liquid, high heating value
  - Sugars, Phenolics  ➔ raw material for rigid PU foams
  - Fraction as a whole  ➔ Gasification (Synthesis gas)
    ➔ energetic utilization (heat, bunker fuel)

substitution rate of polyalcohol: 0 %, 50 %, 80 %
Staged Condensation – Creation of Value

- **Highly viscous fraction (3 staged condensation)**
  - black pasty liquid, high heating value
  - Sugar (Levoglucosan) ➔ raw material for chem. Industry
  - Fraction as a whole ➔ Gasification (Synthesis gas)
  - ➔ energetic utilization (heat)

- **Medium viscous fraction (3 staged condensation)**
  - dark brown, honey-like liquid, medium heating value
  - Phenols (Syringols) ➔ raw material for Phenoplastic
  - Aldehydes (Acetaldehyde) ➔ raw material for Phenoplastic
  - Fraction as a whole ➔ Refinery (transportation fuels)
  - ➔ energetic utilization (power, heat)
Staged Condensation – Creation of Value

- **Medium viscous fraction (3 staged condensation)**
  dark brown, honey-like liquid, medium heating value

<table>
<thead>
<tr>
<th>specimen</th>
<th>max. load [N]</th>
<th>area [mm²]</th>
<th>tensile strength [N/mm²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1551</td>
<td>221</td>
<td>7.02</td>
</tr>
<tr>
<td>2</td>
<td>1274</td>
<td>255</td>
<td>5.00</td>
</tr>
<tr>
<td>3</td>
<td>1015</td>
<td>221</td>
<td>4.59</td>
</tr>
<tr>
<td>4</td>
<td>1338</td>
<td>187</td>
<td>7.16</td>
</tr>
<tr>
<td>5</td>
<td>1350</td>
<td>170</td>
<td>7.94</td>
</tr>
</tbody>
</table>
Staged Condensation – Creation of Value

- Aqueous fraction (2 and 3 staged condensation)
  reddish brown aqueous liquid, low heating value
  - Water
  - org. acids (acetic acid) → pure acid (raw material for chem. Industry)
  - Alcohols, Ketones (Acetol) → Solvents
  - Fraction as a whole → Fermentation (biogas)
Staged Condensation – Creation of Value

- Aqueous fraction (2 and 3 staged condensation)
  reddish brown aqueous liquid, low heating value
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1. Summary
Summary

**Flash pyrolysis ...**
- makes biomass available in liquid form
- makes material use possible
  - the pyrolysis temperature has influence on the formation of individual substances

**Staged condensation of pyrolysis vapors ...**
- represents an uprating-method
  - Preliminary separation of material groups
  - Enrichment of material groups with similar characteristics
  - enables an efficient processing of the fractions

**Target**
- Comprehensive (economic) value creation from the individual fractions
Thank you for your kind attention!

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