METHANOL PRODUCTION FROM REFUSE DERIVED FUEL: A PRELIMINARY ANALYSIS ON THE INFLUENCE OF THE RDF COMPOSITION ON PROCESS YIELD

Gaetano Iaquaniello
Annarita Salladini
Processi Innovativi srl, Roma

Maria Cristina Annesini
Alessia Borgogna
Dip. Ingegneria Chimica, La Sapienza, Roma

Luca Spadacini
Antonio Pitrelli
OESA srl, Roma
AGENDA

1. Introduction
2. RDF characterization
3. ASPEN Simulation Model
4. Results Discussion
5. Conclusions
In recent years, efforts to replace conventional linear production of chemicals with circular one have been promoted.
THE WASTE TO METHANOL

Environmental advantages:

- Low CO₂ emissions
- Sustainable alternative to other waste treatment

Strategic and economic advantages:

- (Bio)MeOH more flexible and manageable product than energy
- Bio-fuels market growing trends
- (Bio)MeOH from Waste double counting as regards biofuel transport target (EU Directive)
THE WASTE TO METHANOL PROCESS

- **High Temperature Gasification**
  - Hot raw syngas

- **Cooling and Cleaning system**
  - Clean raw syngas

- **Syngas conditioning unit**
  - Suitable syngas

- **Methanol Synthesis**
  - Crude Methanol

- Supplied by OESA srl
- Reference experimental data from Malagrotta (Italy) plant

Malagrotta gasification plant
PROCESS ISSUES

- Refuse Derived Fuel marked composition variability
- Raw syngas composition not directly suitable for methanol synthesis, thus efforts of conditioning step are required

WORK AIMS

- Obtain a spread of raw syngas composition depending on RDF variability comparable with Malagrotta experimental data, thus allowing a preliminary validation of our simulation tool
- Recognize influence of RDF characteristic on raw syngas composition and as consequence on methanol yield
## COMBUSTIBLE CONTENT COMPOSITION

<table>
<thead>
<tr>
<th>Material</th>
<th>C/H</th>
<th>C/O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper &amp; Cardboards</td>
<td>7.75</td>
<td>1.8</td>
</tr>
<tr>
<td>Composite Material</td>
<td>7.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Wood</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Carpet</td>
<td>7.25</td>
<td>4</td>
</tr>
<tr>
<td>Carcass Meal</td>
<td>6.9</td>
<td>2</td>
</tr>
<tr>
<td>Mattresses</td>
<td>7.3</td>
<td>3</td>
</tr>
</tbody>
</table>

**Ternary diagram of LHV in function of C, H, and O mass fraction of combustible waste content**

- Moisture = 0.15
- Ash & In = 0.2
Ternary diagram of LHV in function of CHO, Ash&In, and Moisture waste contents

LHV from 14 to 18 MJ/kg
GASIFICATION - COOLING AND CLEANING SYNGAS UNIT

High Temperature Gasification

Hot raw syngas

Cooling and Cleaning system

Clean raw syngas

Syngas conditioning unit

Suitable syngas

Methanol Synthesis

Methanol

RAW TEXT START
GASIFICATION – COOLING AND CLEANING SYNGAS UNIT

High Temperature Gasification

Hot raw syngas

Cooling and Cleaning system

Clean raw syngas

Syngas conditioning unit

Suitable syngas

Methanol Synthesis

Methanol

RAW TEXT END
HIGH TEMPERATURE GASIFIER

ASPN SIMULATION MODEL

Diagram showing the process flow of a high-temperature gasifier.
RESULT - SYNGAS COMPOSITION

Ternary diagram of syngas composition in function of CHO, Ash&In, and Moisture waste contents
Simulated range values are similar to related values of Malagrotta experimental data, which correspond to an enough long period during which RDF composition could be sensibly varied.
dividi in due e metti le formule delle yield

Alessia Borgogna, 4/6/2017
RESULT - SYNGAS YIELD, O\textsubscript{2} CONSUMPTION, AND EFFICIENCY

**Syngas yield**

\[
\frac{\text{Syngas}}{\text{RDF}} = \frac{\text{kg}}{\text{kg}}
\]

**O\textsubscript{2} consumption [kg]**

\[
\frac{\text{O}_2}{\text{CHO}}
\]

**Efficiency**

\[
\frac{LHV_{\text{Syngas}}}{LHV_{\text{CH}_4} + LHV_{\text{RDF}}}
\]

*Ternary diagram of syngas yield, O\textsubscript{2} consumption, and Efficiency in function of CHO, Ash&In, and Moisture waste contents*
dividi in due e metti le formule delle yield
Alessia Borgogna, 4/6/2017
RESULT - EFFECT ON METHANOL PRODUCTION

Suitable syngas composition for methanol production must present the following conditions:

- Methanol Module
  \[ \frac{H_2 - CO_2}{CO_2 + CO} = 2.1 \]

- \[ 0.2 < \frac{CO_2}{CO + CO_2} < 0.5 \]

- \[ CO_2 < 12\% \]

RESULTS

DISCUSSION
RESULT - LHV AS DESIGN PARAMETER

- LHV of RDF is a characteristic value for this process and it can be used as reference design parameter.

- Methanol module strictly depends on LHV of RDF
- and CO₂ are instead also affected by different waste composition at fixed LHV

- Colored points represent average values of range corresponding to LHV equals to 14-16-18 MJ/kg
RESULT - LHV AS DESIGN PARAMETER

Efficiency
\[
\frac{LHV \cdot Syngas}{LHV \cdot CH_4 + LHV \cdot RDF}
\]

Syngas yield
\[
\frac{Syngas [kg]}{RDF [kg]}
\]

- Also Efficiency is mainly correlated with LHV of RDF

- Syngas yield is instead also affected by different waste composition at fixed LHV, however the average values seem to present a linear trend.
Syngas composition is strongly influenced by composition of waste at fixed LHV
Results confirm that LHV it could be considered a reference design parameter, indeed methanol module and efficiency strictly depende on it.

However influence of RDF composition observed on other important values must be also considered, in order to achieve an accurate and efficient equipment design.

To have a suggestion of methanol yield a simplified approach has been carry out obtaining yields for different LHV values (14-16-18 MJ/kg)
RESULT - METHANOL YIELD

To have a suggestion of methanol yield a simplified approach has been carry out obtaining yields for different LHV values (14-16-18 MJ/kg).

<table>
<thead>
<tr>
<th>LHV_{RDF} [MJ/kg]</th>
<th>14</th>
<th>16</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>H_{2}%</td>
<td>37,09</td>
<td>37,58</td>
<td>37,93</td>
</tr>
<tr>
<td>CO%</td>
<td>38,29</td>
<td>40,57</td>
<td>42,42</td>
</tr>
<tr>
<td>CO_{2}%</td>
<td>15,04</td>
<td>12,06</td>
<td>9,67</td>
</tr>
<tr>
<td>H_{2}O%</td>
<td>5,52</td>
<td>5,73</td>
<td>5,92</td>
</tr>
<tr>
<td>MM</td>
<td>0,414</td>
<td>0,485</td>
<td>0,542</td>
</tr>
<tr>
<td></td>
<td>0,282</td>
<td>0,229</td>
<td>0,186</td>
</tr>
<tr>
<td>Syngas Yield [kg/kg]</td>
<td>1,087</td>
<td>1,235</td>
<td>1,335</td>
</tr>
<tr>
<td>[kg/kg]</td>
<td>0,416</td>
<td>0,501</td>
<td>0,577</td>
</tr>
<tr>
<td></td>
<td>54,0</td>
<td>0,573</td>
<td>0,589</td>
</tr>
</tbody>
</table>
CONCLUSION

- Range of syngas composition obtained from simulation is consistent with the experimental Malagrotta data range, thus validating simulation tool.

- Syngas compositions from direct RDF gasification does not fit requirements for methanol production.

- Thanks to the developed simulation tool, different operating conditions and control strategies can be approached in order to obtain a more suitable syngas composition.

- Syngas composition and some process parameters are strongly influenced by waste composition, even at fixed LHV, while Methanol Module and efficiency depends strictly on LHV.

- Lower Heating Value could be used as reference parameter for design steps keeping in mind the variability exhibited by syngas composition and other process values as consequence of moisture and ash waste contents.
1. a better validation with punctual data could be approached
WASTE TO CHEMICALS: UN ESEMPIO DI ECONOMIA CIRCOLARE | Gennaio 2017