Development of a mobile 100 kg/h plant for pyrolysis using a mechanically fluidized reactor

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Development of a Mobile, 100 kg/h Plant For Pyrolysis, Using a Mechanically Fluidized Reactor (MFR)

Dhiraj Kankariya, Stefano Tacchino, Dominic Pjontek, Franco Berruti, Cedric Briens

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Western University

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MFR

- 2 t/d
- 0.7 t/d Gases + Steam + Ac. Acid
- 0.8 t/d Dry Bio-oil
- 0.5 t/d Biochar
- Fertilizer
- Adhesives
- Pesticides
- Pharmaceuticals
- Fuel

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How does the MFR work?

Thesis from Valentina Lago
Reactor:
- Mechanical mixer
- Induction heating

Feeder:
- Arch breaker

Hot electrostatic precipitator:
- Fine char

Condenser & electrostatic demister:
- Dry bio-oil

Cooled auger:
- Coarse char

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<table>
<thead>
<tr>
<th>FEATURES</th>
<th>Compact</th>
<th>Easy to Operate</th>
<th>Rapid Heating (20 min)</th>
<th>Feed Flexibility</th>
<th>Pure Char</th>
<th>High value Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Mixing</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td></td>
<td>☑️</td>
<td></td>
</tr>
<tr>
<td>Induction Heating</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot Electrostatic Precipitator</td>
<td>☑️</td>
<td>☑️</td>
<td></td>
<td></td>
<td></td>
<td>☑️</td>
</tr>
<tr>
<td>Condensation</td>
<td>☑️</td>
<td>☑️</td>
<td></td>
<td></td>
<td></td>
<td>☑️</td>
</tr>
</tbody>
</table>
Measurement method for Wall-to-bed Transfer

• Set mixer RPM
• Constant flowrate of water added to MFR bed
• Wait for steady state
• Record:
  o Bed temperature
  o Wall temperature
Equations:

• (heat transfer from wall to bed) = (heat for evaporation) + (heat losses from bed)

• (heat for evaporation) = (liquid flowrate) x (water enthalpy change)

• Estimate of heat transfer coefficient:
  • Neglect heat losses
  • Underestimates heat transfer rate from wall to bed
Two different bed materials were tested:

<table>
<thead>
<tr>
<th>Properties</th>
<th>Units</th>
<th>Sand</th>
<th>Activated carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle diameter</td>
<td>µm</td>
<td>185</td>
<td>575</td>
</tr>
<tr>
<td>Particle density</td>
<td>kg/m³</td>
<td>2650</td>
<td>750</td>
</tr>
<tr>
<td>Heat capacity</td>
<td>J/kg/K</td>
<td>830</td>
<td>1300</td>
</tr>
</tbody>
</table>
Two different reactors were tested:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Units</th>
<th>Small MFR</th>
<th>MFR-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner Diameter</td>
<td>m</td>
<td>0.1015</td>
<td>0.15</td>
</tr>
<tr>
<td>Height</td>
<td>m</td>
<td>0.127</td>
<td>0.25</td>
</tr>
<tr>
<td>Volume</td>
<td>litre</td>
<td>1.03</td>
<td>4.42</td>
</tr>
</tbody>
</table>
Wall-to-bed Heat Transfer with Sand Bed

FOR SMALL MFR:
Wall-to-bed Heat Transfer with Sand Bed

FOR MFR-1:

![Graph showing heat transfer rate (U) vs RPM for two different velocities: 528 (mm/s) and 503 (mm/s).]
Results:

<table>
<thead>
<tr>
<th>Superficial Steam Velocity (mm/s)</th>
<th>FOR SMALL MFR</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U_{AVG} for all RPM (W/m².K)</td>
<td>U from Correlation (W/m².K)</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>66</td>
<td>142</td>
<td></td>
</tr>
<tr>
<td>82</td>
<td>154</td>
<td>344</td>
<td></td>
</tr>
<tr>
<td>112</td>
<td>307</td>
<td>428</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Superficial Steam Velocity (mm/s)</th>
<th>FOR MFR-1</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U_{AVG} for all RPM (W/m².K)</td>
<td>U from Correlation (W/m².K)</td>
<td></td>
</tr>
<tr>
<td>503</td>
<td>238</td>
<td>280</td>
<td></td>
</tr>
<tr>
<td>528</td>
<td>250</td>
<td>261</td>
<td></td>
</tr>
</tbody>
</table>
Wall-to-Bed Heat Transfer with Activated Carbon Bed

FOR MFR-1:

![Graph showing heat transfer with RPM]
Results:

<table>
<thead>
<tr>
<th>Superficial Steam Velocity (mm/s)</th>
<th>$U_{\text{AV}}$ for all RPM (W/m$^2$.K)</th>
<th>$U$ from Correlation (W/m$^2$.K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>168</td>
<td>73</td>
<td>104</td>
</tr>
<tr>
<td>398</td>
<td>182</td>
<td>124</td>
</tr>
</tbody>
</table>
Conclusions:

• High wall to bed heat transfer coefficient, comparable to regular fluidized beds

• Capability to produce high quality products

• Versatility of the products / process flexibility

• Easy operation

• Open avenues for new applications in biorefinery
Acknowledgement

THANK YOU!

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