Influence of reactor type on production cost of fast pyrolysis bio-oil

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Influence of reactor type on production cost of fast pyrolysis bio-oil

A. Funke, C. Pfitzer, A. Niebel, N. Dahmen, J. Sauer

Pyroliq 2019, Cork, Ireland
Outline

- Fast pyrolysis within the bioliq® process concept
- Comparison of reactor concepts
- Cost estimate and sensitivity in regard to product yield
- Conclusions

Essentially, the bioliq project asks for large scale, industrial use of the variety of distributed lignocellulosic biomass.

In addition, it requires that as much of the biomass carbon should be maintained in the final product!
Economy-of-scale vs. logistics

Economy of scale vs. Logistic costs

scaling exponent 0.7

How large or how small should the plants be?

Graphics: Syncom
bioliq® concept

Biomass production and supply

Regional energy densification

Biosyncrude transportation

Large scale, central further conversion to syngas/fuels
Fast pyrolysis in the context of the bioliq concept aims at production of gasification fuels from pyrolysis condensates and carbonisate.
The twin-screw mixer fast pyrolysis reactor

Reasons to select twin-screw transported bed reactor:
→ Industrial expertise available
→ Scale-up ability proven

Experience in industry
- Devolatilization of coal (1952)
- Pyrolysis of oil shale and tar sand (1970ies)
- Pyrolysis of refinery residues (1990ies)
- Adaption to biomass (since ca. 2000 at KIT)

P. Schmalfeld, Quaterly, Colorado School of Mines Vol. 3, 70 (1975) 129-145

Erdölchemie, Dormagen, D
Exxon Mobile, Ingolstadt, 50 t/h

Cost estimates for bioliq fast pyrolysis plant

- Collected from different sources since 2006 (no adaption to CE index)
- Ranging EUR 20-70 Mio. for 100 MW\(_{th}\) depending on calculation method, plant boundary, assumptions for equipment and installation factors
Cost estimates for bioliq fast pyrolysis plant

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Cost estimates for bioliq fast pyrolysis plant

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- Ranging EUR 20-70 Mio. for 100 MW$_{th}$ depending on calculation method, plant boundary, assumptions for equipment and installation factors
- Type of reaction system not clear in all cases

Degression coefficient: 0.5
Heat supply bioliq FP plant

- Biomass
- Reactor
- Cyclone
- Condensation
- Combustion chamber
- Non-condensables
- Heat carrier (with some remaining pyrolysis char)
- Heat demand around < 1.25 MJ/kg (dry basis)

Heat supply circulated fluid bed (CFB)

- Biomass

  → Reactor

  / Sand & pyrolysis char

  / Combustion chamber

  / Non-condensables

  / Cyclone

  / Condensation

  ↓ Bio-oil
Heat supply bubbling fluid bed (BFB)

Required, when pyrolysis char is recovered as product.

Biomass → Reactor → Cyclone → Condensation

- Combustion chamber
- Non-condensables
- Pyrolysis char
- Bio-oil

?
### Mass balance wheat straw

#### from fast pyrolysis process development unit (10 kg/h) and pilot plant

<table>
<thead>
<tr>
<th></th>
<th>PDU</th>
<th>Pilot Plant</th>
</tr>
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<tbody>
<tr>
<td>Mass yield</td>
<td>23</td>
<td>22</td>
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<tr>
<td>Carbon yield</td>
<td>32</td>
<td>41</td>
</tr>
<tr>
<td>Char</td>
<td>41</td>
<td>22</td>
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<tr>
<td>Organic condensate</td>
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<tr>
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<td>Gas</td>
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<td>22</td>
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<tr>
<td>Deficit</td>
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#### Key Points:
- High ash content → lower yield of condensates
- Pyrolysis char important for maximum carbon utilization
Comparison of condensate yields

- No significant differences between FBR and bioliq moving bed reactor

Capital cost contributions for reactors systems

*no practical data available causing uncertainties!
In literature product losses between 10-30 % are reported

→ partial oxidation appears to be no longer cost-efficient
→ only by use of all condensed products cost remain reasonably low

Summary on conclusion

- Similar product distribution in fast pyrolysis of wheat straw for
  - Twin-screw reactor
  - Fluid bed reactor
- Significant cost benefits for bubbling fluid bed
  - Problematic scale-up of heat supply
  - ‘Autothermal pyrolysis‘ interesting, but may be not cost efficient
  - Other types of heat supply systems need to be investigated (dual bed powered by non-condensable gas, hog gas cycle…)
- Beyond, significant uncertainties in techno-economic assessment exist
  - Process design and simulation needs to be on process developer’s side!
  - Demand for additional methods or measures on early stage TEA?

AMBITION & BRISK2 Workshop on Early stage Techno-Economic Assessment on September 17, 2019 in Birmingham, UK
Organization: A.V. Bridgwater
Thanks to …

Axel Funke,

Daniel Richter, Norbert Sickinger, Pia Griesheimer,

Jessica Heinrich, Petra Janke and Melany Frank
Estimation of heat transfer coefficient

… by DEM simulations using LIGGGHTS for heat transfer model

→ High heat transfer rate through dense packing in the transported bed up to 350 W m\(^{-2}\)K\(^{-1}\), comparable to fluid bed reactors