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BTG-BTL's pyrolysis technology

Revision	Date	Prepared
1.0	28 November 2011	Elwin Gansekoele

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TABLE OF CONTENTS

1 COMPARISON OF THE TECHNOLOGIES

Table 1.1 shows an overview of the different pyrolysis technologies.

Technologies	Status	Max. Yield Wt.%	Comp-lexity	Particle size feed	Flexibility feedstock	Equipm Size	Scale-up	Inert gas	Particles in oil
Fluid bed	Commercial	75	Medium	Medium	Low	Medium	Medium	High	High
CFB	Commercial	75	High	Small	Low	Large	Easy	High	High
RCR* 1995 – 2001	Pilot	70	High	Small	High	Small	Medium	Low	Low
Ablative	Lab	75	High	Large	High	Small	Hard	Low	Low
Screw reactor	Pilot	60	Low	Medium	High	**Small**	Medium	Low	Low
Vacuum	On hold	60	High	Large	Medium	Large	Hard	Low	Low
BTG-BTL's Modified RCR	**Commercial**	**70**	**Medium**	**Medium**	**High**	**Small**	**Easy**	**Low**	**Low**

***RCR: Rotating Cone Reactor**
Table 1.1: Comparisons of technologies

A comparison of the commercially available technologies CFB, fluid bed and rotating cone is described in more detail in the paragraphs below.

1.1 Compact design of the reactor

The rotating cone reactor is based on mechanical mixing of sand and biomass. The system is developed such that heating of biomass by inert material (sand) is physically separated from the location where pyrolysis reaction is being carried out. No inert gas is required and an optimal configuration is chosen to fulfill all relevant aspects related to fast pyrolysis. The reactor can be very compact and has low investment costs. A 5 t/h reactor has a diameter of 1 meter only with a height of 1 m.

CFB and fluid bed reactors must be much larger, need inert gas for transportation and/or fluidization and mixing, and are (much) more expensive. In addition, mixing in those reactors is rather poor due to the limited momentum of the gas-solid mixture. This is important in case fibrous biomass sources (such as palm derived EFB) are used, which might easily lead to blocking of fluid bed reactor vessels. This is overcome by the mechanical mixing as applied in BTG's technology.

The compact design of the rotating cone reactor has the advantage that scaling-up to capacities larger than 5 t/h is straightforward by adding more reactors to a single char combustor, riser and main dip leg. For fluid beds the heat is either indirectly transferred through submersed coils limiting the scaling up possibilities and requiring high temperatures of the coils, or alternative designs in which heat transfer medium is taken from another fluid bed. In the latter case a single bed is used for combustion of char (and / or incondensable gases) and another as the actual pyrolysis reactor. CFB systems are relatively easy to scale up, but again require excessive amounts of inert gases.

1.2 Absence of inert carrier gas

No inert carrier gas is required as explained in paragraph 1.1, and mixing of biomass and heat carrier is secured by mechanical mixing. The pyrolysis process layout remains relatively simple in comparison to CFB and fluid bed.

(Pyrolysis) Gas (combustible, explosive) recycles are required in CFB and fluid bed processes, but these require intense cleaning to be able to pressurize and heat the gas. A significant amount of inert(ising) gas (usually nitrogen) is required for starting-up and shutting down purposes.

Because of the simplicity of the rotating cone process, investment costs can thus be much lower in comparison to other technologies. CFB and fluid bed systems are more capital intensive, also because of the larger down-stream equipment, including the extensive ATEX and other safety issues.

As an example, the size of the oil condenser is determined by the total amount of gases to be treated, which includes the inert gases. Therefore the condensor for CFB / Fluid bed must be considerably larger than for a rotating cone unit. In addition, more heat must be removed from inert gas and condensing liquids, requiring more cooling water and resulting in (as the heat is lost) lower energy efficiency. Due to the larger gas flow the condensation efficiency will be lower, in particular for the smaller organic molecules which are required to obtain a stable oil with low viscosity.

1.3 High energy efficiency

BTL's standard design includes recovery of all excess heat (where possible). With the rotating cone process, electricity can be produced or a combination of electricity and steam for industrial appliances. Also a part of the steam is often used for drying the biomass. There is enough heat available to dry biomass with a moisture content up to 55 wt.% (wet basis).

Energy efficiencies of 85 – 90% can be achieved (biomass in, oil, heat, E out)

In the other technologies some or most of the heat can be recovered as well. However it is not sure, if it is included in their standard package and at which costs.

1.4 High flexibility on feedstock

Due to the forced mechanical mixing, intensive heat transfer between biomass and inert heat carrier is guaranteed. Low density biomass materials have been successfully processed in a commercial unit.

Sand from the combustor to the reactor is cooled in a separated sand cooler, and in this way reactor conditions are independent of the combustor operating conditions.

Because of the feed flexibility (related to combustor operation), BTL's technology can also handle biomasses with low ash melting temperatures such as palm derived EFB. The BTL combustor and therefore all units in the plant can be operated at relatively low temperatures while in general fluid bed and CFB technologies must be operated at higher combustion temperatures to compensate for the low sand to biomass ratio.

Noteworthy, BTG is the only supplier in the world, who has experience in handling feed stocks with low ash melting temperature such as EFB on a scale of 2 t/h.

Another advantage of BTL's technology compared to others is that the mechanical reactor allows high sand to biomass ratios. Lignin rich biomass resources have a tendency to form melts in the reactor that will eventually block reactors in CFB and fluid bed technologies due to the agglomeration with the (usually applied) sand. In the rotating cone there is much less tendency to form agglomerates, and if formed, they will be broken down by the mechanical actions.

BTL's technology has shown to handle particles with a diameter of 3 mm, as the processes heating up of biomass and actual pyrolysis reactions are physically separated. Fluid bed technologies may use similar sized particles, while CFB technology must use smaller ones, as residence times are limited.

1.5 Quality of the oil

In comparison with fluid bed and CFB technologies, fewer solids are entrained from the reactor due to absence of carrier gas. Advantageously, cyclones, applied after the pyrolysis reactor, are less sensitive for blockage. As less char is entrained, most minerals remain in the char and collected in the combustion section. Due to a unique and patented cyclone designs used in BTL's plant, risks of blockages of cyclones are further reduced.

The rotating cone reactor can operate at high sand biomass ratios, while CFB and fluid bed technologies are limited, because of limitation of the amount of inert gas. To allow for a relative low sand flow in CFB / FB, such technologies thus operate on a higher temperature of the sand. This can result in a lower quality of oil, because of significant further vapours cracking in the presence of ash containing char particles. BTL's pyrolysis reactor is much closer to isothermal operation.

As already mentioned in paragraph 1.2 due to larger gas flow the condensation efficiency will be lower for in particular smaller organic molecules in the other technologies, which appear very important for lower viscous and stable oil.

Several clients from BTL already mentioned that BTL's oil has a high quality and very low solids content.

1.6 Economics

Due to the characteristics of the process of BTL, lower CAPEX and lower OPEX can be obtained with the BTL technology. It also means that a BTL pyrolysis production plant can be economic at lower capacities already and at large scales much higher margins can be realized.

2 BTL AS A COMPANY

BTL's mother company BTG is an independent and privately owned company and is more than 25 years active in the biomass conversion technologies. BTL can therefore offer more than solely the advantages of the Fast Pyrolysis Technology as explained. The mother company BTG also offers sustainable development experts, laboratory and R&D possibilities, experts on all other biomass conversion techniques (like gasification, digestion etc.) and CDM Experts.

BTG's RTD department of BTG has significant experience in the application of pyrolysis oil. BTG's RTD efforts on the processing of pyrolysis liquids are summarized in table 2.1.

Application	**RTD facilities**	**Purpose**
Gasification and further processing	5 kg/hr stand-alone (catalytic) gasification unit 5 kg/hr two-stage (catalytic) gasification 1 kg/hr high pressure gasification unit (300 bar, > 650^{o}C)	Producing clean fuel gas Producing clean syngas at high pressure for further syngas processing (methanol, FT)
Combustion	hot-water boiler fuelled with pyrolysis oil	Investigation of ash deposits Steady state combustion Burner design and optimization
Engine – Turbine	5 kW high speed diesel engines 25 kW medium speed diesel engine	diesel engine for stationary operation
Chemical Upgrading	100 g/hr + 1 kg/hr high pressure hydro treating unit	Producing hydro treated oil (HDO) Hydrothermal processing of oils
Physical Upgrading	10 kg/hr filtration unit (<10 μm)	Removing char particulates
Physical Upgrading	500 kg/hr centrifuge unit	Removing char particulates
Chemicals (eg. bitumen)	1 - 20 kg/hr separation units	Extraction / separation / isolation of chemicals

Table 2.1.: RTD efforts on application of pyrolysis oil

BTG possesses significant and world class experience in hydrotreating. Direct upgrading of pyrolysis oil is subject in several (national and European) projects initiated by BTG. BTL's parent company is involved in the BioCoup project. Pyrolysis oil typically has oxygen contents of about 45-50% and cannot be processed in standard refinery units. Research in this project has demonstrated on laboratory scale that up to 20 % of mild hydrotreated pyrolysis oil can be mixed in a standard refinery.

Pyrolysis oil derived products with an oxygen content lower than 2 wt.% have been produced, by a combination of mild hydrotreating and further hydrotreating in a second step using dedicated catalysts.

The proposed hydrogenation routes and catalysts, for which patents have been applied for, require substantially less hydrogen than anticipated on basis of earlier work published.

To summarize all advantages of cooperation with BTL:

- Access to knowledge and know-how of BTG:
    - Sustainable development experts.
    - Experts on all other biomass conversion techniques.
    - CDM Experts (Kyoto Protocol).
- Access to the facilities of the RTD department. (table 2.1)
- Availability of laboratory and R&D facilities what means that BTG can test your specific biomass and design the pyrolysis plant accordingly.
- RTD department are specialists in hydrotreating of pyrolysis oil.
- Reputation and track record of BTG which ensures that client has the right balance between a new technology with a sound technical foundation based on experience.
- BTL and BTG are independent companies.

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