

The Need of Biomass Refinement

Utilization of pre-treatment facilities for biomass is totally dependent on the biomass-to-energy efficiency. Thus, the interest for torrefaction today lies in energy densification of biomass to a high energy efficient, easy fed fuel for combustion, co-combustion and gasification applications. Gasification of biomass that in many ways is a more efficient use of the feedstock is nowadays an interesting alternative to combustion for many industries but is still limited.

Many of the problems with wood gasification are related to the properties of the fuel that is thermally unstable, which may lead to formation of condensable tars. Other disadvantages are the relatively low energy content typically around 18 MJ/kg, and its hydroscopic character often around 10wt.% after drying [1]. Additionally, Prins et al. have shown that higher gasification efficiency can be achieved by fuels with lower O/C ratio [2].

Torrefaction is a process that effectively lowering the O/C ratio of biomass in a simple way. Also the power cost during milling are reduced at the same time as sharp edges and splinters are avoided in the milled powder which greatly enhances the feeding properties. The torrefied biomass has also proven to have hydrophobic properties which are welcome during storage. Therefore a well developed biomass refinement method must be interacted to obtain a BTL process with high well-to-wheel efficiency.

Process Technique

The thermochemical process of torrefaction is actually an interaction of a drying process and an incomplete pyrolysis process, and is characterized by the following parameters.

- Reaction temperature 200-300°C
- Heating rate < 50°C/min
- Absence of oxygen
- Residence time < 30min at T > 200°C
- Ambient pressure
- Flexible feedstock

High well-to-wheel efficiency requires Biomass refinement

Absence of oxygen in the reactor is of great importance to avoid oxidation and ignition [3].

Biomass reactions

The cell in woody biomass is a rather complex construction of several building blocks. Polysaccharides are arranged in long chains called microfibrils enclosed in even structures of amorphous lignin and building the core of the crystalline cellulose. The cellulose is encased in a shell of hemicellulose. All these building blocks are more or less influenced by heat but in different temperature ranges, and therefore converted by specific reactions.

Process reactions

- Drying: - 200°C
- Torrefaction reactions: 200-300°C
 - Devolatilization and carbonization of hemicellulose
 - Depolymerization and devolatilization/softening of lignin
 - Depolymerization and devolatilization of cellulose

[1] See figure 1 for details.

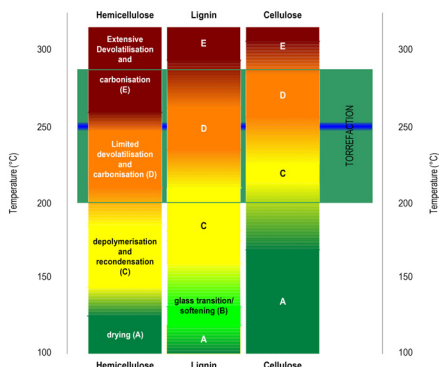


Figure 1. Main physicochemical phenomena during heating of biomass at torrefaction [4]

Process Results

The torrefaction process has shown very promising results, summarized below:

- Mass yield ~70%
- Energy yield ~90%
- Net calorific value (LHV) 17-19MJ/kg → 18-23 MJ/kg
- Moisture content 1-2%
- Hydrophobic, max 1-6% moisture uptake
- Brittle, 70-90% milling power savings

[4,5] 10% of the energy is volatilized but can easily be recovered.

A energy densification of approximately 30% makes the total logistic chain more effective by transport of less moisture. The hydrophobic property and the very low moisture content make the storing more secure due to low risk of organic breakdown causing self-ignition and mould growth. The brittle characteristic of the torrefied biomass results in a product after grinding with less splinters, simplifying burner feeding. Size reduction results are presented in figure 2.

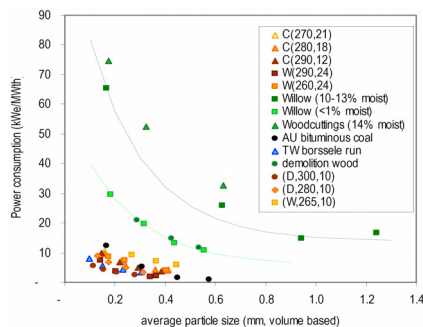


Figure 2. Size reduction results of various torrefied biomass and feed biomass. Coding: Biomass (torrefaction temperature, reaction time), W=willow, C=woodcuttings, D=demolition wood. [6]

A combination of torrefaction and pelletisation has been introduced by ECN (the Netherlands) as TOP-pellets. It is a high energy dense and mechanical strong fuel with saved hydrophobic characteristics [3].

Process Concepts

Today no commercial plant is in use only lab-scale reactors, but tested concepts are quite a few and most of them are some kind of rotary kiln or screw reactor indirectly or directly heated, commonly with recovery of the torrefaction gases. Wyssmont has manufactured a reactor with alternative technique which has shown good torrefaction results in spite of the fact it is built only for drying (see figure 3).

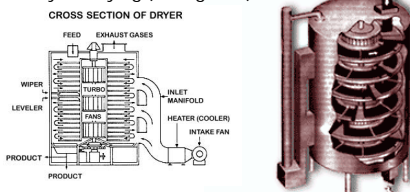


Figure 3. (Right) cutaway view and (left) cross section view of the Wyssmont TURBO-dryer [7]

Persson and Olofsson et. Al. have with summarized literary knowledge developed a combined direct and indirect torrefaction concept plant with torrefaction gas recovery. The reactor is directly heated by superheated steam produced in the boiler fuelled with dry torrefaction gases, and if necessary some utility fuel. The flue gas from the boiler is used for indirect heating of the reactor. See figure 4.

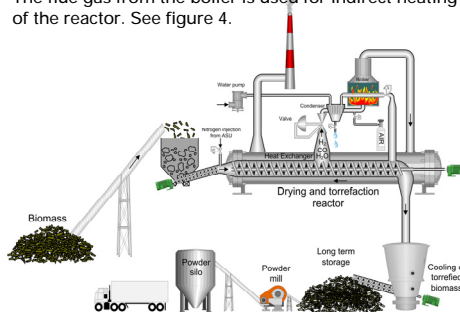


Figure 4. A directly/indirectly torrefaction concept

The process gives great possibilities for interaction with heat and power plants for enhanced efficiency.

References

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- [5] Ouwens, C.D. and Küpers, G. *Lowering the Cost of Large-Scale, Biomass Based Production of Fischer-Tropsch Liquids*. 2003. Jyväskylä, Finland: Eindhoven University of Technology.
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Further torrefaction research projects are under progress at ETPC



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