ETIP Bioenergy
European Technology and Innovation Platform

Fast pyrolysis

LAB SCALE | BENCH SCALE | PILOT PLANT | DEMONSTRATION | PRODUCTION

DEFINITION

Pyrolysis is the decomposition of organic material, for example lignocellulosic biomass, caused by addition of heat in a non-oxidizing environment. The addition of heat leads to decomposition of the polymeric material into several products: pyrolysis oil, char and gas. A general illustration of a pyrolysis process is seen in Figure 1. The gas product consists of for example CO, CO_2, CH_4, and H_2, whereas the char product is typically a solid carbonaceous residue. By allowing *fast* heating of biomass (known as *fast pyrolysis*) to 450 – 600 °C followed by rapid condensation of pyrolysis vapours, the production of pyrolysis oil is favoured with a yield of 60-75 %. Fast pyrolysis has gained commercial attention for converting lignocellulosic biomass into pyrolysis oil which can be upgraded to liquid biofuels and renewable chemicals. To achieve fast pyrolysis and to maximize the pyrolysis oil production, several technical criteria should be fulfilled:
- high heating rate (>100 °C/s)
- small biomass particles (< 2 mm)
- short vapor residence time before condensation (< 2 s)

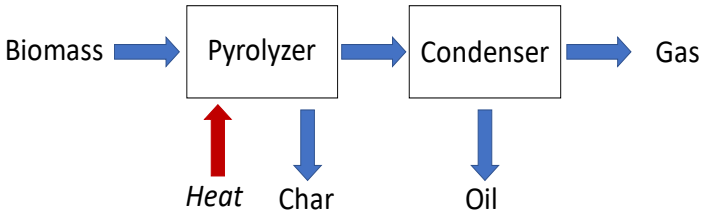

Figure 1: General illustration of a pyrolysis process

PYROLYSIS OIL

Pyrolysis oil is a dark brown and highly viscous liquid which consists of condensed vapours formed during pyrolysis. The oil is typically present as a one-phase liquid. Pyrolysis oil is also known by other names such as pyrolysis liquid, bio-oil, bio-crude, pyrolytic lignin and tar. Since the oil is produced from depolymerization of lignocellulosic biomass, its chemical composition reflects the chemical structure of the feedstock. Also, the elemental composition of pyrolysis oil reflects lignocellulosic biomass, meaning that it has a relatively high oxygen content compared to most liquid biofuels. Its composition is therefore dissimilar to other oils such as fossil oil and vegetable oil as well as the fuels that are based on these. Pyrolysis oil consists of hundreds of chemical compounds. The main compounds are oxygenated organic compounds, aromatic hydrocarbons, tar and water. The water content is influenced by the moisture content of biomass. Other compounds that exist in pyrolysis oil are for example aldehydes, sugars, carboxylic acids, phenolic compounds, and oligomers. Pyrolysis oil is acidic which makes it corrosive.

Properties	Pyrolysis oil
Density (kg/L at 20°C)	1.2
Water content (wt%)	10-30
Acidity (pH)	2.5
C (wt%, db)	46
H (wt%, db)	7
O (wt%, db)	47
LHV (MJ/kg)	17

Table 1: Composition of pyrolysis oil (db, dry basis)

Also, the oil is polar due to its high content of water and oxygenated compounds. The composition of pyrolysis oil may change during storage. Pyrolysis oil is not chemically stable, which leads to aging. When the oil is heated, the aging rate increases. However, the oil can be stabilized by catalytic (hydrogen) treatment, addition of solvent, and esterification.

Figure 2: Empyro factory (copyright: BTG BioLiquids)

Figure 3: KIT facility (copyright: KIT)

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PYROLYSIS OIL APPLICATIONS

Pyrolysis oil can be used as a fuel oil in different applications for heat and power production, for example in stationary units such as boilers, furnaces, turbines and engines. Also, the pyrolysis oil can be used as an intermediate for producing transportation biofuels and biochemicals. One example is co-processing pyrolysis oil with fossil feedstocks in the existing petrochemical industry such as co-feeding to catalytic cracking processes. Pyrolysis oil can also be upgraded in standalone processes for producing advanced biofuels, for example by using catalytic treatment and/or hydrotreatment, and thereafter act as a drop-in fuel for producing gasoline and diesel. Based on the pyrolysis oil's diverse chemical composition, it can also be used for producing high-value biochemicals, for example phenolic compounds, aromatic hydrocarbons, and vanillin. Chemicals can be produced from pyrolysis oil by utilizing upgrading and separation processes.

EXAMPLES OF PYROLYSIS DEMOPLANTS

Operator:	Twence Hengelo, Netherlands Fast pyrolysis
Application:	Heat and power production
El. power:	2200 MWh annually
Pyrolysis oil:	3200 kg/h
Technology:	Rotating cone reactor
Fuels:	Wood chips, bagasse, empty fruit bunch etc.

Operator:	Fortum Joensuu, Finland Fast pyrolysis
Application:	Heat and power production
El. power:	52 MW_{el}
Thermal capacity:	180 MW_{th}
Pyrolysis oil:	6300 kg/h
Technology:	Fluidized bed

Operator:	KIT Karlsruhe Intitut für Technologie Karlsruhe, Germany Fast pyrolysis
Application:	Biocrude and syngas for transportation fuel production
El. power:	-
Thermal capacity:	5 MW_{th}
Pyrolysis oil:	500 kg/h
Technology:	Bioliq: Twin-screw reactor

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SOURCES

- http://task34.ieabioenergy.com/technology-resources/
- https://www.sciencedirect.com/topics/engineering/fast-pyrolysis
- https://demoplants21.bioenergy2020.eu/projects/displaymap/twhWVt

FURTHER INFORMATION

- https://www.btg-btl.com/en/fast-pyrolysis
- https://www.fortum.com/about-us/our-company/our-energy-production/our-power-plants/joensuu-chp-plant
- https://www.bioliq.de/
- http://task34.ieabioenergy.com/