A novel technology for fast pyrolysis of biomass: PyRos reactor

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Introduction

Fast pyrolysis is a thermo chemical process that converts biomass into a liquid product: bio-oil. This bio-oil can be burned in a diesel engine, a gas turbine, a furnace or be used as a feedstock for chemical plants such as FT-synthesis. The main product within the fast pyrolysis process is a fuel with a high density and a high heating value. This product can be transported and stored easily. This gives the possibility to decouple the primary biomass conversion process and the prime mover, regarding the time, location, and scale of the process. The fast pyrolysis technology can have relatively low investment costs and high energy efficiencies compared to other processes, especially on a small scale. It can be shown that fast pyrolysis in combination with an engine results, for the range up to 15 MW_e, in the highest efficiency and the lowest capital and electricity costs compared to other thermal conversion processes.

The main goal of fast pyrolysis is to convert the solid biomass into a liquid bio-oil. In practice about 40-75% of the (dry) biomass is converted into oil vapour, which after condensation yields the liquid bio-oil. About 10-20% of the biomass is converted into char (solid porous carbon particles) and 10-30% is converted into an uncondensable gas. The water content of the fuel usually is limited to about 15 wt-%. Present fast pyrolysis reactors are based on fluidized bed, entrained flow, ablative vortex, and rotating cone technology.

The major problem of the present reactors for flash pyrolysis are the quality and the stability of the produced oil, both are strongly affected by the char/ash content of the bio-oil. Besides the known problems concerning solid particles in the bio-oil, the char fines will catalyze the repolymerization reactions inside the oil resulting in a higher viscosity. The char can be removed by after treatment of the condensed products like filtering the oil. The disadvantage of this is that the alkali, concentrated in the char, will dissolve in the bio-oil because high acidity the oil (pH = 2-3). Another option to remove the char is hot gas cleaning of the oil vapor. For both options additional capital investments are required.

TNO, a Dutch contract research organization and the University of Twente have invented and developed a novel reactor in which the fast pyrolysis and the gas cleaning take place simultaneously: PyRos reactor, This reactor is patented by TNO.

PyRos-reactor

The novel reactor, denoted by PyRos -reactor, integrates fast-pyrolysis and high temperature gas cleaning in one unit. This integrated unit consists of a vortex reactor (e.g. a cyclone) with a rotating particle separator (figure 1). The biomass is fed into the cyclone via a transport medium consisting of an inert gas with a solid that acts as a heat carrier. By the centrifugal force in the reactor the particles are swept out of the gas stream and are sliding along the cyclone wall downwards to the particle exit. In the reactor the biomass and the heat carrier are in direct contact, so efficient heat transfer can take place. During the transport downwards in the reactor the biomass particles are dried, heated up and devolatilized. The average process temperature is 450-550 °C. The typical gas residence time in the reactor is 0.5 to 1 sec, so secondary cracking in the reactor is prevented. In the gas outlet, in the middle of the cyclone reactor, the fine solid particles are removed from the oil vapor by the rotational particle separator. In this separator the micron particles are captured in a bundle of channels with small diameters, rotating around a common axis. The collected particles stick to the channel walls until they periodically removed on-line and leave the reactor with the main solid stream at the lower outlet of the cyclone. A scheme of the novel reactor is given figure 1.

This PyRos -reactor is integrated in a complete system consisting of a biomass feeding system, a combustor for the char to heat up the solid heat carrier, a gas cleaning system and a condenser for quick oil separation.

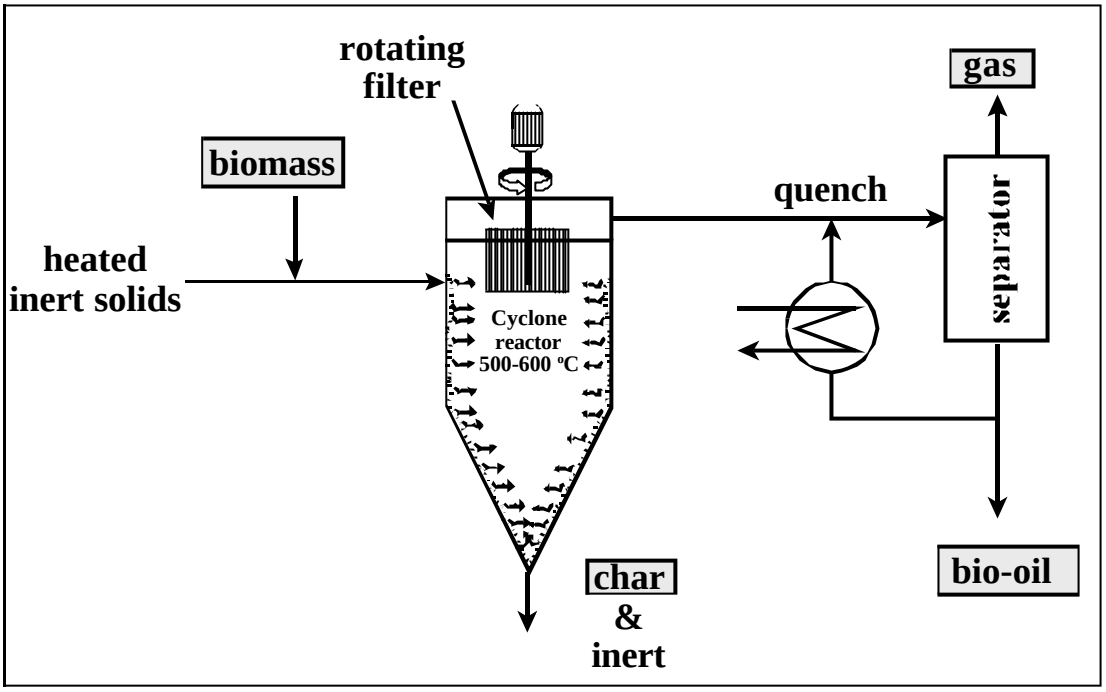

Figure 1 a simplified scheme of the PyRos-reactor.

Present status

The present status of the PyRos-reactor is that a small unit with a fuel capacity of 1 kg/h has been built and operated. A preliminary research program has been carried out to determine the key parameters of the process such as the reactor temperature, the solids and gas residence time, particle size of the wood, etc. First results were very promising: A high heating value and low viscosity oil, with a yield of more than 50% based on dry basis was produced. At the moment a mathematical model is being developed to obtain scaling rules for the reactor. After the first promising results a complete heat integrated fast pyrolysis system for 30 kg/h biomass is now built and first experiments are planned for this summer.

In full paper more details of the PyRos reactor are given and the preliminary experimental results are shown.