SOLSTICE	Name of the PhD: **Kuo ZENG** Title of the PhD thesis: **Solar pyrolysis of biomass at laboratory scale** Dates (start/end): 03/2013 – 04/2016
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Collaboration	G. Mazza and J. Soria (PROBIEN, Argentina)

Context and objectives

Solar pyrolysis of biomass uses highly concentrated solar radiation as source of high-temperature process heat to drive biomass pyrolysis reactions in an inert atmosphere. Thus, solar energy in an amount equal to the enthalpy change of the pyrolysis reactions is chemically stored, which upgrades the feedstock energy. The products yields, composition and properties depend on pyrolysis parameters. Temperature, heating rate, pressure are the primary pyrolysis parameters.

Approach

This thesis's aim is to better understand the biomass pyrolysis in a solar reactor, to quantify the product distribution and composition as a function of the process parameters, and to determine the energetic upgrade factor due to solar input in the process. The energy upgrade factor quantifies the ratio of energy content of the pyrolysis products with respect to the energetic value of the initial biomass (if ≥ 1, solar energy is added to the products, meaning stored in the products). There were two steps for experiments, as follows: (1) one-factor-at-a-time (OFAT) approach and (2) response surface methodology (RSM). Firstly, the influences of single-factor: temperature (600-2000°C), heating rate (5-450°C/s), pressure (0.48-1.18bar) and argon flow rate (6-12NL/min) on product distribution were determined experimentally. Then the combined effects of temperature (800-2000°C), heating rate (50-450°C/s) and argon flow rate (4-8NL/min) were investigated. The gaseous product was characterized to determine the optimum parameters that are required to maximise the gas products LHV (lower heating value).

Main results

- The temperature is the governing parameter; it drastically affects the product distribution and gas composition in solar pyrolysis. Heat rate and argon flow rate have a significant influence but rather limited with respect to the temperature.
- High CO and H_2 yields are obtained at plateau temperature of 1200°C and heating rate of 50°C/s. Tar secondary cracking reactions are favored under these conditions.
- Total gas LHV increases about 5-fold with a temperature increase from 600°C to 1200°C mainly due to the formation of CO and H_2.
- The interaction between temperature and heating rate increases at both high ranges. The maximum gas product LHV of beech wood is obtained at 2000 °C and 450 °C/s.
- Temperature and heating rate strongly affect char properties. Plateau temperature of 1200°C and heating rate of 50°C/s result in the highest BET surface area and pore volume (highest reactivity).
- The energy upgrade factor is at least 1.2 depending of the water content in the tar (not measured). It reaches 1.5 if no water is assumed (Fig. 1).
- The 2D CFD model is in good agreement with experimental results (Fig. 2)

Figure 1. Experimental energy balance of wood solar pyrolysis

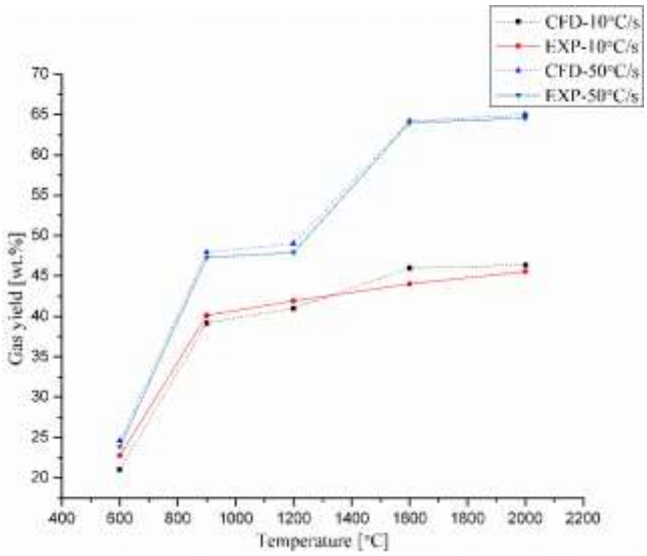

Figure 2. Gas yield comparison between the CFD model prediction values and experimental results

Publications in scientific journals

Zeng K., Minh D. P., Gauthier D., Weiss E., Nzihou A., Flamant G. “The coupling effect of temperature and heating rate on char properties obtained from solar pyrolysis of beech wood” Bioresource Technology (2015), 182, 114-119

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Zeng K., Gauthier D., Li R., Flamant G. “Solar pyrolysis of beech wood: Effect of pyrolysis parameters on products distribution and gas products composition “ Energy (2015), 93, 1648-1657

Zeng K., Soria J.., Gauthier D., Mazza G., Flamant G. “Modelling of beech wood pellet pyrolysis under concentrated solar radiation” Renewable Energy (2016) 99, pp. 721-729. 10.1016/j.renene.2016.07.051

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