Preliminary Tests with Birch Wood Pellets in Up-Draft Air Gasifier

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Abstract

Large variety of biomass types have been studied as raw materials for thermochemical processes to produce refined solid, liquid and gaseous fuels. Small-scale gasification is an attractive option for conversion of agricultural and forest residues into fuel gases suitable for heat and electricity production in rural areas.

The paper presents the initial work performed in a newly built fixed-bed up-draft gasifier. Densified woody biomass, birch, in form of pellets with a diameter of 8 mm and a length between 5 and 15 mm has been used as a raw material. The effect of the treatment conditions on the distribution of gaseous products and the temperature profile in the reactor are of primary interest for the study.

The research team includes participants from Argentina, Cuba and Sweden.

Keywords: Pellets; birch, wood, up draft air gasification.

INTRODUCTION

Biomass is an important source of energy. Its utilisation contributes to decrease of the emissions of CO_2 in the atmosphere and disposal of the municipal solid wastes. In some countries it also decreases the dependence on foreign energy sources, such as oil and coal, as well as the risk for sudden increase of their prices. Biomass is of particular importance in the developing countries and in some of them it is the only vastly available source of energy.

The growing energy demands make development of ways of using biomass for energy of great importance all over the world. (Kendall et all, 1997, Hall and Scrase, 1998. Fiedler, 2004, Erlich, 2004). Direct combustion is the most mature technology for utilization biomass for energy. Increasingly important are, however, the technologies converting biomass in gaseous and liquid fuels prior to combustion. Utilization of densified biomass in form of pellets and briquettes had also gained significant interest (Obernberger and Thek, 2003).

Pelletisation improves the quality of biomass as a fuel and decreases significantly the cost for package, transport and storage. Pelletisation causes a disorder in the anisotropic structure of biomass thus the fuel pellets are much more uniform compared to the initial biomass. Requirement for standardization in production of pellets have been introduced in several countries in Europe. The most strict standard requirements are applied in Austria (Fiedler, 2004).

Utilization of densified biomass in form of pellets has contributed significantly to the recent progress in wood combustion. Using wood pellets in improved combustion installations and better control of temperature and excess air ratios have resulted in combustion units with high efficiency and low emissions (Nussbaumer, 2003, Fiedler, 2004).

Pelletisation of voluminous non-uniform agricultural and forest residues increases the energy density of these materials and improves their fuel properties. Wood wastes from sawmills or bagasse from sugar industries are usually combusted to satisfy the local heat and energy demands. They may however, be utilised in more efficient conversion systems. Kayal, et al., 1994, Kurkela, et al., 1989. The largely available wastes from the seasonal sugar cane industry may be densified into pellets to facilitate the storage and the all-year utilization for electricity production via gasification. Biomass pellets have hardly been studied for gasification (Erlich, 2004)

The paper presents the initial work performed in a newly built fixed-bed up-draft gasifier. Densified woody biomass from birch, in form of pellets with a diameter of 8 mm. and a length of 5-15 mm., has been used as a raw material. Air is applied as an oxidation agent. The effect of the treatment conditions on the temperature profile in the reactor and the distribution of gaseous products is of primary interest in this study.

EXPERIMENTAL

Equipment

The fixed-bed up-draft gasifier and the auxiliary equipment used in the experiments are shown in Figure 1. The biomass is fed in the top of the reactor. It undergoes drying, devolatilisation, gasification and combustion as it moves to the bottom of the reactor against the gas flow of the oxidation agent and the gases obtained in the conversion of biomass.

The oxidation agent, air, is introduced in the bottom of the gasifier, under the grid supporting the biomass bed. The temperature in the gasifier decreases from the combustion zone through the gasification, devolatilisation and the drying zones. The product gas leaves the upper part of the reactor.

The product gas containing also fine solid particles passes through a cyclonic condenser (11) where the particles and part of the tar are separated from the gas stream and collected in the tar collector (10). The gas is further passed through a water tank (9) and a packed-bed filter (13). The flow rate of the exit gas is measured by a rotameter (12).

The temperature in the gasifier was measured at three levels: the combustion zone, the reduction zone and the gas outlet.

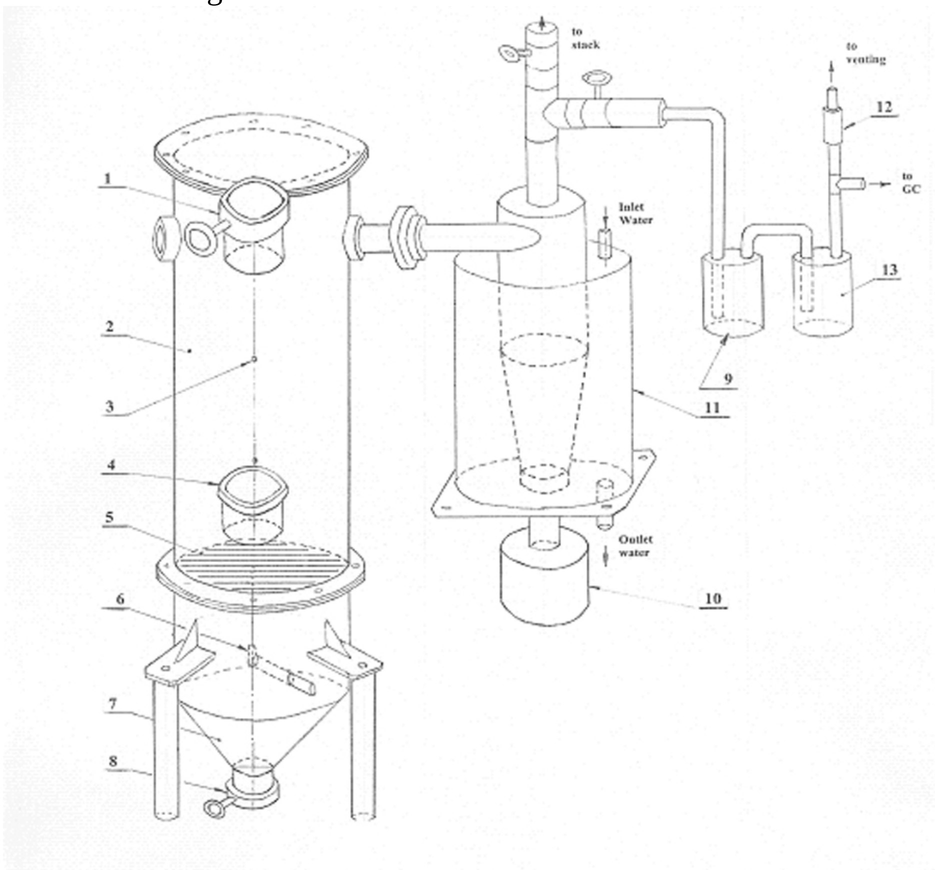

Figure 1. *Up-draft gasifier: (1) feeder, (2) gasifier, (3) thermocouples, (4) observation window, (5) distributor, (6) air inlet, (7) conic bottom (8), ash valve, (9) gas scrubbing with acetone, (10) tar and fine char particles collector, (11) cyclonic condenser, (12) rotameter, (13) packed-bed filter.*

Procedure

The weighed amount of biomass pellets (2 Kg) is fed in the reactor through the feeder over 0,2 Kg burning charcoal on the distributor (1). The flow of air, used as oxidation agent, was varied among 2, 1.5 or 1.1m^3/h.

The flow rate of the gasification agent was measured using a rotameter and it was introduced in the gasifier under the grid.

The gaseous products are analyzed immediately after collection of the samples to avoid diffusion of hydrogen through the walls of the polyethylene sample bags. Gas chromatograph was used to measure the concentrations of CO, CH_4, CO_2, C_2H_y, H_2 and N_2 (diffeence).

The liquid product (tar and tar-water) was collected in the cyclone and condensed by water cooling. The remaining gas passes through three acetone-containing flasks to trap the residual tar. The acetone solutions were filtered and evaporated in room temperature, 25–30^0C, for several hours. The quantity of the trapped tar was then determined by weight.

RESULTS AND DISCUSSION

The processes in a fixed-bed up draft gasifiers are stratified along the reactor height in the order (from the bottom): combustion, gasification, devolatilization and drying.
Major advantages of updraft gasifiers are simplicity, ability to process wet fuels, high carbon conversions, high efficiency, and internal heat exchange, leading to low temperatures of the gaseous products leaving the gasifier.

A disadvantage is the large amount of tar produced in the gasifier, due to the lower temperatures in the upper zones in the up-draft gasifier hampering thermal cracking of tar. This is of minor importance if the product is used for heat application and the tar-rich gas is directly burnt. For electricity-producing gas engines, however, gas cleaning is required (McKendry, 2002).

Temperature profile in the gasifier and distribution of gaseous products

The temperature profile and the distribution of gaseous products obtained using various flows of oxidation agent are shown in Figures 3-5.

The flow rate of the oxidation agent has influenced both the temperature profile and the distribution of gaseous products.

In the selected experimental conditions the time for maximum concentrations of the gaseous products was between 5 and 20 minutes depending on the gas flow rate of the air. The higher the flow rate of air introduced in the gasifier the shorter the time required to rich high temperatures and maximum concentrations of the gaseous products.

The initial experiments are performed using a single feeding of biomass in the reactor (batch experiments). Hence the higher the flow rate of the oxidation agent the shorter the period for high temperatures and high concentrations of gaseous products are. The curves showing the temperatures at different levels in the rector, T_1, T_2 and $T_{3,}$ converged at the highest flow rate of air used here (Figure 2).

The quick consumption of biomass in combustion at high flow rate of air causes fast decrease in the concentrations of gaseous products (Figure 2).

At lower flow rates of air (Figure 3 and 4) the time needed to heat up the reactor and to obtain maximum concentrations of gaseous products is longer, the consumption of biomass is also slower and the curves illustrating the concentrations of gaseous products show slower decrease.

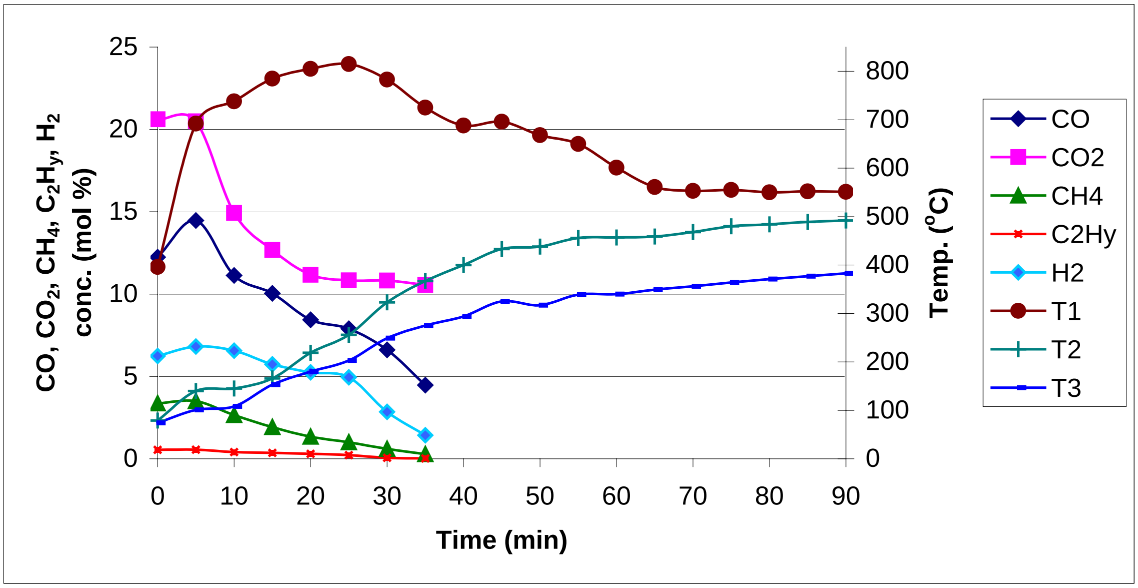

Figure 2. *Temperature profile and concentration of gaseous products obtained in gasification of 2 kg wood pellets with a flow rate of oxidation agent (air) 2 m^3/h.*

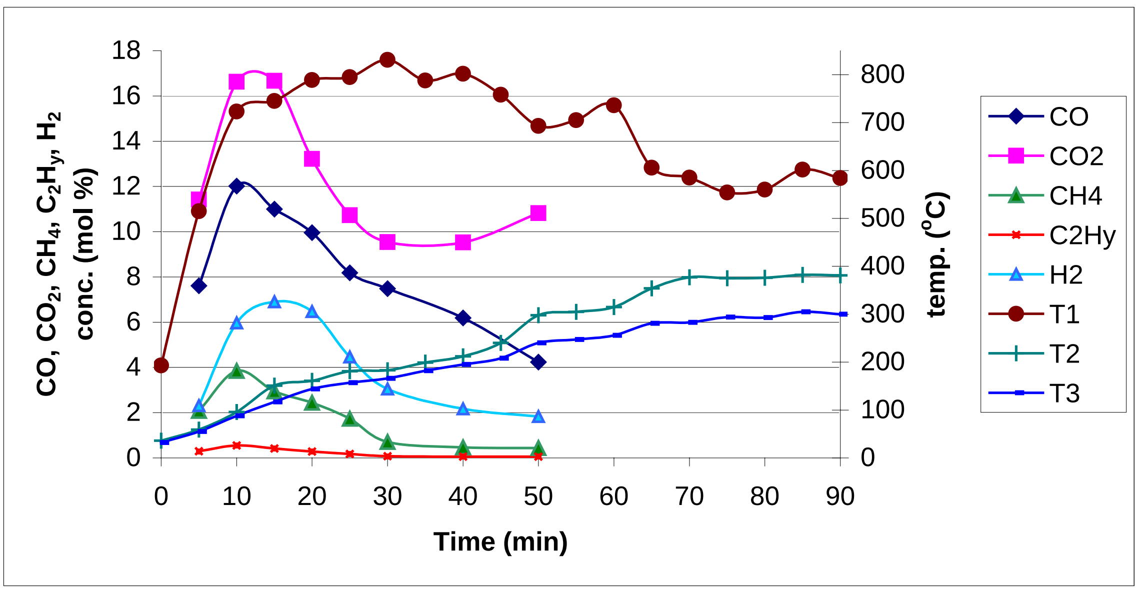

Figure 3. *Temperature profile and concentration of gaseous products obtained in gasification of 2 kg wood pellets with a flow rate of oxidation agent 1.5 m^3/h.*

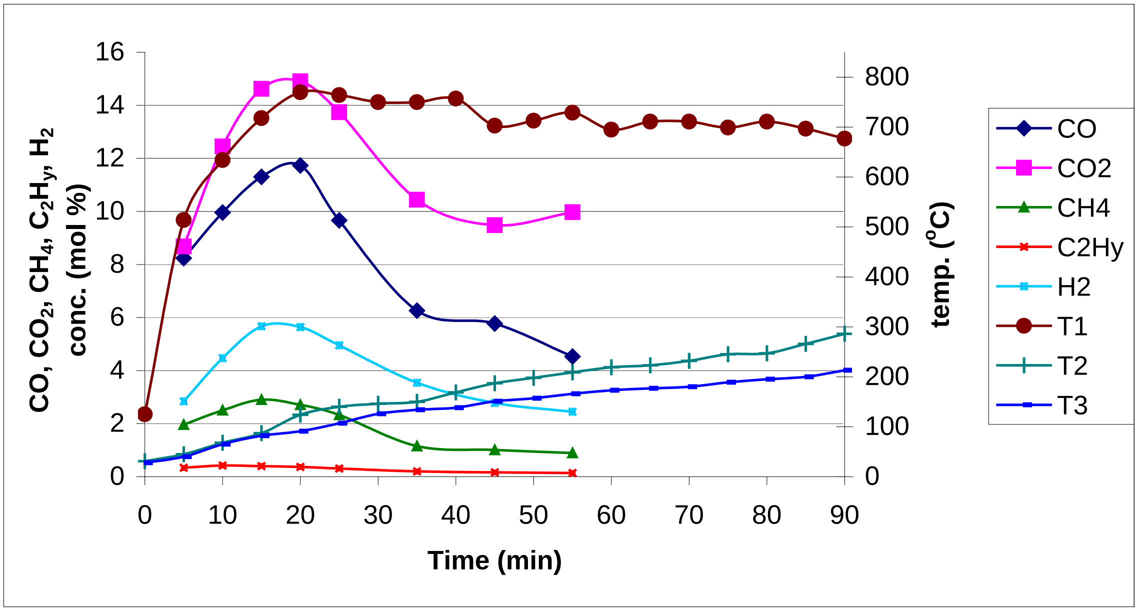

Figure 4. *Temperature profile and concentration of gaseous products obtained in gasification of 2 kg wood pellets with a flow rate of oxidation agent 1.1 m^3/h.*

Highest concentrations of gaseous products in this study are obtained using a flow rate of air 2 m^3/h. Carbon dioxide and carbon monoxide dominate in the gaseous product. The concentrations of other gaseous products such as hydrogen, methane and particularly C_{2-} hydrocarbons are much lower.

Liquid product

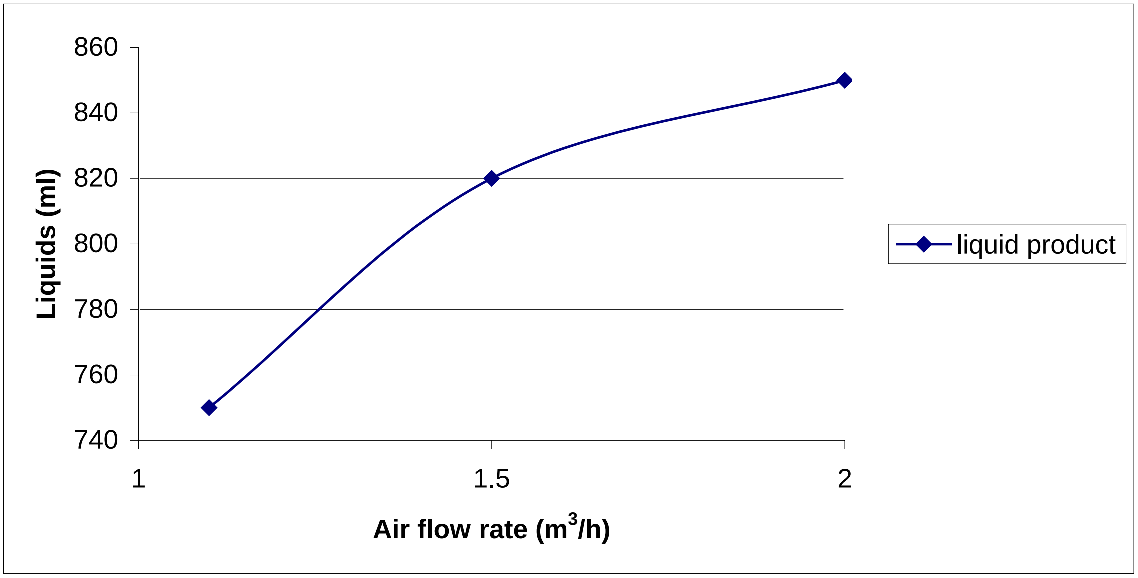

Figure 5. *Liquid product (tar and water) obtained at varying rate of air flow*

Figure 5 shows the dependence of the volume of liquid products on the rate of the air flow. The higher the rate the larger the amount of liquid products is. The large amount of tar obtained at high rate of air flow may be attributed to the low residence time of the tar in the reactor hampering the thermal cracking.

CONCLUSIONS

In the selected experimental conditions the flow rate of the oxidation agent, the air, has strong effect both on the temperature profile in the gasifier and on the distribution of products.

The higher the flow rate of air introduced in the gasifier the shorter the time required to rich high temperatures and maximum concentrations of the gaseous products. High rates of gas flow favor formation of high concentrations of gaseous products and large amounts of tar. Carbon dioxide and carbon monoxide dominate among the gaseous products. The concentrations of hydrogen, methane and particularly C_2-hydrocarbons are much lower. The low residence time of the volatiles in the gasifier and the insufficient thermal cracking of the tar at high flow rate of the air contribute to increased tar yield.

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