Energy and exergy evaluation of beech wood pyrolysis for bio-oil production in an Auger reactor

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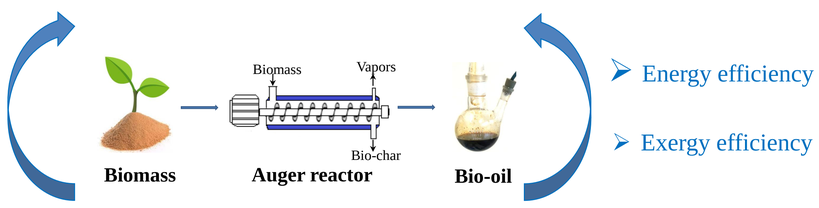
Introduction

In this study, an energetic and exergetic analysis for bio-oil production from biomass pyrolysis has been carried out, with the aim of estimate the energy consumption, exergy destruction and losses in an Auger reactor, as well as the energy and exergy efficiency, in order to increase the efficiency of the system and evaluate the sustainability of the overall process.



Configuration set up

The raw material was pyrolyzed at a temperature range of 450-600 °C, in an inert atmosphere of 200 mL/min of Nitrogen used as carrier gas. The screw speed was set to 6 rpm for a solid residence time of 5 minutes and a feed rate of 1.32 g/min.

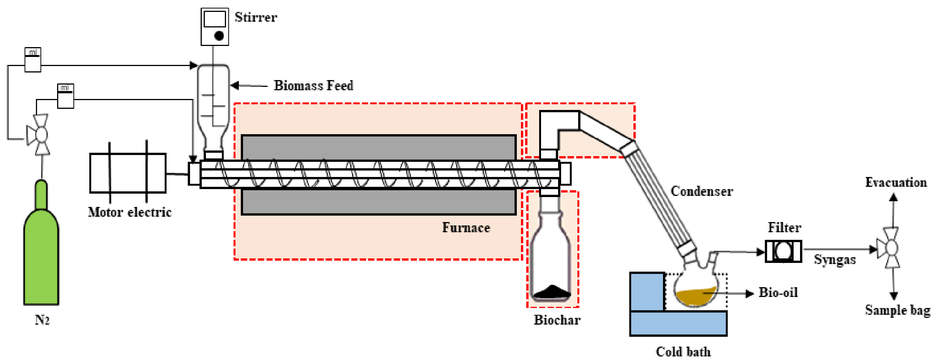


Fig. 1 Schematic diagram of Auger reactor

Energy and Exergy Analysis

The experimental data used for the thermodynamic measurements were obtained at steady-state conditions. Only the input and output energy flows of the pyrolyser were considered (Fig. 2).

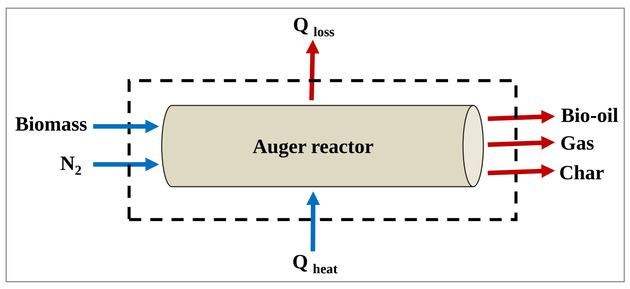


Fig. 2 Input and output flows of Auger pyrolysis system.

➢ **Energy evaluation:**

$$\sum En_{in} = \sum En_{out} + Q_{loss}$$

The heat loss through the walls of the reactor was neglected, then $Q_{loss} = 0$.

$$En_{biomass} + En_{N_2} + Q_{heat} = En_{bio-oil} + En_{gas} + En_{char}$$

➢ **Exergy evaluation:**

$$\sum Ex_{in} = \sum Ex_{out} + I$$

Where, I represents irreversibly.

$$Ex_{biomass} + Ex_{N_2} + Q_{heat} = Ex_{bio-oil} + Ex_{gas} + Ex_{char} + I$$

Energy and exergy efficiency can be calculated using the following equations, respectively:

$$\eta = \frac{En_i}{\sum En_{in}} \qquad \psi = \frac{Ex_i}{\sum Ex_{in}}$$

Results

The evolution of all pyrolysis products at different temperatures are shown in Fig. 3. The maximum yield of 51.7% bio-oil is obtained at 500°C.

The bio-oil recovered was analyzed by GC-MS and GC-FID and the non-condensable gases by GC-TCD/FID. Fig. 4 is that of the compositions of the gases and bio-oil at 500 °C.

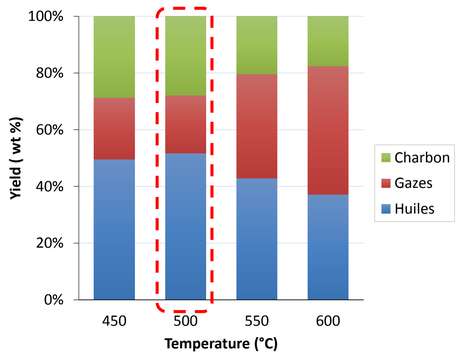


Fig. 3 Mass balances for Beech wood pyrolysis at different temperatures

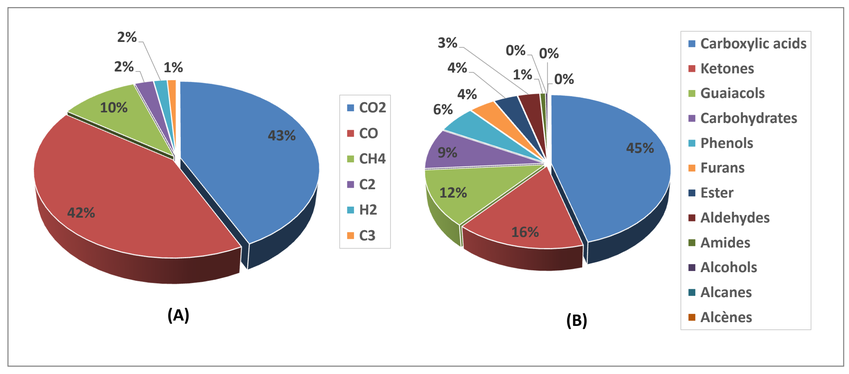


Fig. 4 Composition of gases (a) and bio-oil (b) obtained from the beech wood pyrolysis at 500 °C.

Influence of pyrolysis temperature on Energy and Exergy values

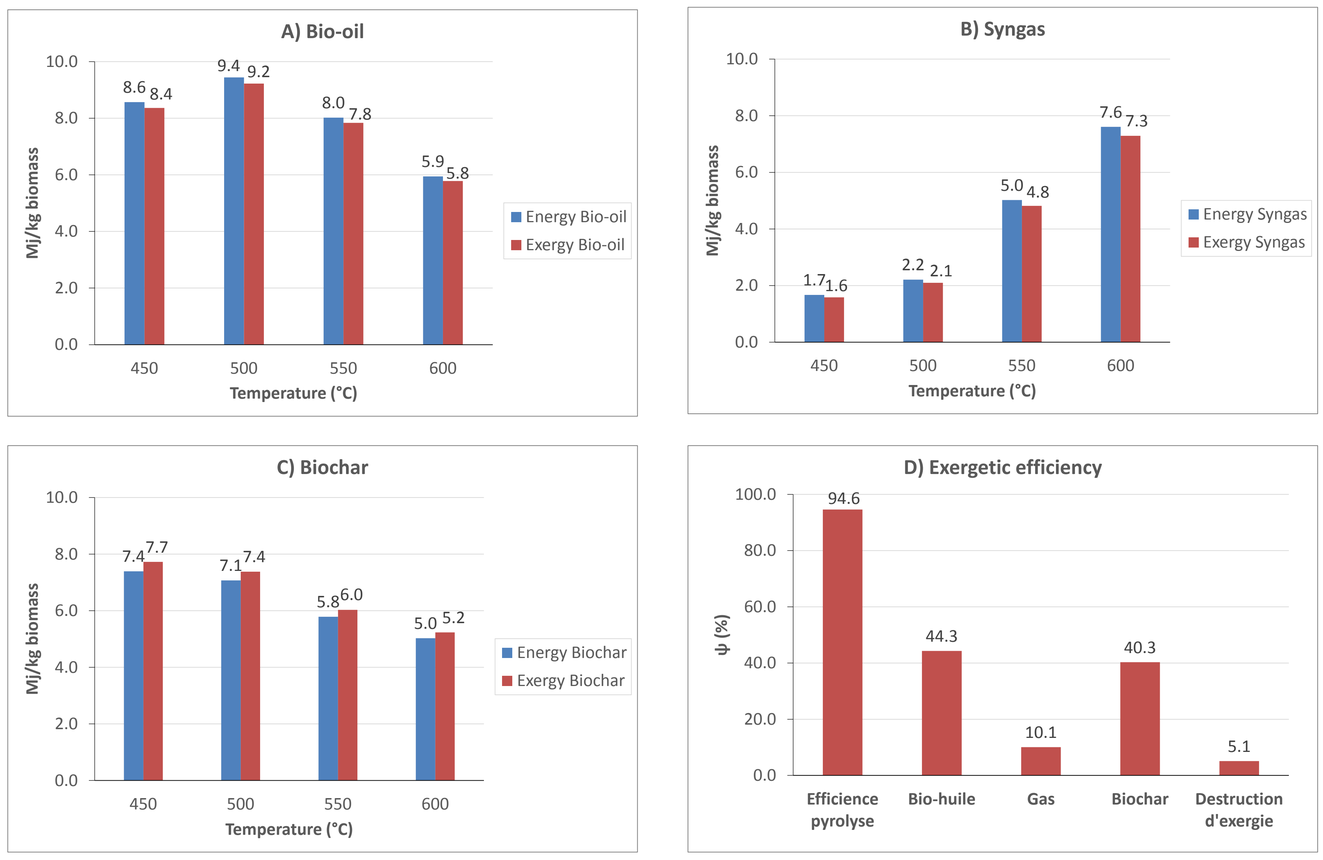


Fig. 5 Energy and exergy value of A) Bio-oil, B) Syngas C) Bio-char at different temperatures and D) Exergetic efficiency at 500 °C

The energy and exergy of gas and biochar increased and decreased with pyrolysis temperature, respectively. This is due to the yield of each at those temperatures.

The highest exergetic value of bio-oil was 9.2 $Mj/Kg_{biomass}$ at a temperature of 500 °C. And then decreases from 7.8 to 5.9 when the temperature increases from 550 to 600 °C. This reduction of bio-oil is due to the thermal cracking reactions favored by the high temperatures.

Conclusion

- The main components present in the bio-oil, grouped by families, were carboxylic acids, ketones and guaiacols at 500 °C.
- The heat for pyrolysis was 2.81 $MJ/Kg_{biomass}$ and exergy destruction of 1.06 $MJ/Kg_{biomass}$.
- The exergetic efficiency of the bio-oil was 44.3 % and the overall exergetic efficiency of the pyrolysis was 94.6 %, for beech wood at 500 °C.
- Bio-oil production by pyrolysis in an Auger reactor shows significantly higher exergy efficiency than those reported in the literature for other technologies.

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