Fast pyrolysis: conversion of biomass to bio-oil

Glen R. Unwin, Tannon Daugaard, Mitch Amundson, Dr. Mark Wright; Department of Mechanical Engineering; Iowa State University July 2014

Background / Introduction

Around the world there is growing desire for energy due to population increases and industrialization. These factors have led to a heavy dependence on fossil fuels. In the mid 20th century Hubbert predicted the United States would hit its peak oil production before the 2000’s. Historical data has shown this to be true, as shown in Figure 1.

Renewable energy sources must be investigated in order to do the following:
- Reduce the dependency on foreign oil
- Maintain national security
- Establish sustainable bioeconomy
- Promote rural economic development
- Meet Renewable Fuels Standard (RFS)
- Reduce greenhouse gas emissions

One promising method is the thermochemical processing of lignocellulosic biomass into bio-fuels. The utilization of biomass as a feedstock to the conversion of bio-fuels provides the opportunity for a net carbon-neutral life cycle. Biomass is defined as an organic material of recent biological origin. Examples of biomass include switchgrass, corn stover, Miscanthus, algae, fast growing poplar trees, and pine. Pyrolysis converts biomass through heat into a liquid (bio-oil), solid (char), and gas as shown in Figure 2. Fast pyrolysis primarily promotes the production of bio-oil with char and non-condensable gases co-products. Fractionation is used to produce stage fractions of high energy dense bio-oil. Further processing of the bio-oil is needed in order to convert into transportation fuels and commodity chemicals.

![Figure 1: Hubbert's Peak Oil Plot](image)

![Figure 2: Bio mass conversion](image)

![Figure 3: Fluidized Bed Reactor](image)

![Figure 4: Mr. Unwin with bio-oil](image)

Project Objective

- To convert lignocellulosic biomass (pine) into bio-oil through fast pyrolysis
- Determine the quality and composition of the bio-products

Methods

Fast pyrolysis for this research was conducted under these operating conditions:

- The biomass utilized was pine
- The size of the biomass was 250-500 microns
- Absence of oxygen
- Reactor temperature: 500 degrees centigrade
- Condensers for stage fraction one: 200 degrees centigrade
- Liquid cold gas flow quench
- Condensers for stage fraction two: -10 degrees centigrade
- Non condensible gases were quantified using a micro gas chromatograph at the end of the system

Note: Figure 3 is a schematic of the fluidized bed utilized in this research

Analytical Equipment:
- TGA: Thermal gravimetric Analysis
- CHNS: Carbon, Hydrogen, Nitrogen, Sulfur & Oxygen (by difference)
- Karl Fischer Moisture Titration
- Solid testing for sand and char

Results

A mass balance calculation on the system resulted in a 98.9% mass closure.

Bio-Oil Yield = 60.4 wt.%  Char Yield = 11.2 wt.%  Gas Yield = 27.5 wt.%

The elemental analysis from the CHNS analysis method results are below in Table 1. Proximate analysis results from the Thermo-Gravimetric Analysis method are shown below in Figure 6 and Table 1.

The Karl Fischer moisture titrator results for SF1 were between 2-4 wt.% and 45-55 wt.% for SF2.

![Figure 5: Product Yield Chart](image)

![Figure 6: TGA Plot (SF2)](image)

Table 1: CHNS

<table>
<thead>
<tr>
<th></th>
<th>Nitrogen (vol. %)</th>
<th>Carbon (vol. %)</th>
<th>Hydrogen (vol. %)</th>
<th>Oxygen (vol. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF1</td>
<td>0.15</td>
<td>59.80</td>
<td>5.22</td>
<td>34.83</td>
</tr>
<tr>
<td>SF2</td>
<td>0.11</td>
<td>23.48</td>
<td>6.86</td>
<td>69.55</td>
</tr>
<tr>
<td>Char</td>
<td>0.19</td>
<td>76.36</td>
<td>3.41</td>
<td>20.04</td>
</tr>
</tbody>
</table>

Table 2: TGA Data

<table>
<thead>
<tr>
<th></th>
<th>Moisture &amp; Volatiles (wt. %)</th>
<th>Fixed Carbon (wt. %)</th>
<th>Ash (wt. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF1</td>
<td>73.3</td>
<td>26.8</td>
<td>0.0</td>
</tr>
<tr>
<td>SF2</td>
<td>95.6</td>
<td>4.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Char</td>
<td>34.2</td>
<td>63.6</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Discussion

American society has determined that renewable and sustainable energy production are top priorities for the nation to help provide economic, environmental and national security. In order for America to retain its competitive edge in a global market place it must provide inexpensive, domestically produced and environmentally friendly forms of energy. Pyrolysis research has proven to be a promising route for biomass utilization to reach an end goal of shifting away from fossil fuels.

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