Production of Hydrocarbon Fuels from Biomass by Catalytic Fast Pyrolysis

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Energy Consumption for Transportation

- Oil primary source of energy for transportation
- Possible to convert to other energy sources for some sectors (e.g. electric cars) but not for others (e.g. aviation)
- Biomass only source of renewable carbon
- Need for drop-in fuels that are compatible with current fuels and infrastructure

EIA International Energy outlook 2011
**Non-Edible Constituents of Biomass**

**Lignin:** 15%–25%
- Complex aromatic structure
- Very high energy content
- Resists biochemical conversion

**Hemicellulose:** 23%–32%
- Polymer of 5- and 6-carbon sugars, marginal biochemical feed

**Cellulose:** 38%–50%
- Most abundant form of carbon in biosphere, polymer of glucose,
- Good biochemical feedstock
Biofuels by Fast Pyrolysis

• Important to be able to convert all fractions of biomass including lignin
  o Biochemical methods can convert only the sugar fraction (cellulose + hemicellulose)

• One method to convert biomass to a liquid fuel is fast pyrolysis
  o Rapid heating to temperatures of 500°C and rapid cooling of the resulting oil
  o Possible to convert up to 70% of mass and energy into a liquid product, pyrolysis oil
Bio-oil is composed of many oxygenated organic chemicals with water-miscible and oil-miscible fractions.

- Dark brown, mobile liquid
- Combustible
- Not 100% miscible with hydrocarbons
- Modest heating value ~17 MJ/kg
- High density ~1.2 kg/l
- Acidic, pH ~2.5
- Pungent odour
- Ages, viscosity increases with time
Upgrading of Bio-Oil

• Bio-oil needs to be deoxygenated to produce a fungible liquid transportation fuel

• Catalytic fast pyrolysis or vapor phase upgrading over zeolite catalysts one option
  o Deoxygenation through loss of $\text{CO}_2$, CO, and $\text{H}_2\text{O}$
  o Formation of aromatic hydrocarbons

• Objective of current work:
  o Study hydrocarbon yields from biomass with emphasis on ability to convert all biomass fractions
Experimental Procedures

Micro-Scale Experiments

• Pyroprobe connected to a GC-MS for identification of products in vapor phase
• Identification of optimum conditions and catalysts
• <1 mg biomass

Fluidized bed experiments

• Testing of best conditions
• Collection of oil for analysis
• 125 g biomass/h
Hydrocarbon Yields over ZSM-5

Hydrocarbon Yield

Catalyst:Biomass

2:1  5:1  10:1

cellulose  lignin  pine

NATIONAL RENEWABLE ENERGY LABORATORY
Carbon Conversions to Hydrocarbons

Catalyst:Biomass
cellulose  lignin  pine

Carbon Conversion

Catalyst:Biomass

2:1

5:1

10:1
Bench-Scale Experiments in Fluidized Bed

- Obtained oil with 2.7% organic oxygen
- Optimum conditions: 500°C
- Oil consisted of aromatic hydrocarbons similar to products from pyroprobe tests
Conclusions

• Thermochemical processes can utilize all major fractions of biomass including lignin
• Fast pyrolysis with vapor phase upgrading can produce hydrocarbons compatible with current transportation fuels
  o High carbon conversions
• Similar yields of hydrocarbons from cellulose and lignin
• Potential to produce a highly deoxygenated liquid product
• Future work is required in minimizing coke formation and increasing yields.
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