Co-processing of Heavy Oil and Bio-oil in a Continuous Mechanically Fluidized Reactor

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Objectives

• Co-pyrolysis of bio-oil or biomass and heavy oil

• Can we get interesting chemicals and fuels from the combination of radicals from bio-oil/biomass and heavy oil?

• Operate at conditions relevant to industrial fluid cokers, which are currently used to convert heavy oil into synthetic crude
  • 350 000 B/d in Fort Mc Murray, Alberta
  • 100 000 B/d in Sarnia, Ontario
Rotating Air Cooling

Rotating Rods, driven by the motor

Air Cooling

Heavy Oil Injection

Bio-oil Injection

Gas/Vapors Exit

Rotating Blades

Sparger Distributor
Feeding System

2 Syringe Pumps

Combined Feeding Rate: 5 mL/min
Initial Reactor Temperature: 550°C

Viscosities:
Heavy Oil - 700cp @ 500°C
Sawdust Bio-Oil - 27.7 cp @ 25°C

High Heating Values:
Heavy Oil - 43.63 kJ/g
Sawdust Bio-Oil - 16.50 kJ/g

Moisture Content
Heavy Oil - 0%
Sawdust Bio-Oil - 28.68%
Experimental Results

% Recovered Liquid Hydrocarbons

% Bio-Oil Injected (Dry Basis)

% Yield of Recovered Hydrocarbons
Experimental Results

Solid Yield

% Solid Yield

% Bio-Oil Injected
Experimental Results

Product Moisture Content

\[ \% \text{H}_2\text{O} \sim 0.4219 \times (\% \text{Bio-Oil Injected}) + 2.5656 \]

\[ R^2 = 0.9808 \]
Experimental Results

% Water Formed in Pyrolysis Reactions

% Water Formed in Pyrolysis Reactions vs. % Bio-Oil Injected
Experimental Results

High Heating Value of Liquid Product

HHV = -0.282*(% Bio-Oil Injected) + 41.663

R^2 = 0.9966
High Heating Value (Dry Basis)

Experimental Results

HHV ~ -0.18*(% Bio-Oil Injected (Dry Basis)) + 42.56

$R^2 = 0.9871$

Experimental Results

HHV (Dry Basis) (kJ/g)

% Bio-Oil Injected (Dry Basis)
Experimental Results

% Energy Yield vs % Bio-Oil Injected

% Energy Yield:
- 70
- 68
- 66
- 64
- 62
- 60
- 58
- 56
- 54
- 52

% Bio-Oil Injected:
- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100

The graph shows the energy yield percentage (%) against the percentage of bio-oil injected. There are data points indicating a trend, but they are not clearly defined due to the limited data shown. The data points are at (0,58), (30,64), and (100,54).
Experimental Results

Elemental Analysis

- Hydrogen
- Oxygen
- Sulfur

Graph showing the percentage of Bio-Oil Injected (Dry Basis) vs. the percentage of each element (Dry Basis).
Experimental Results

H/C Ratio of Liquid Product (Dry Basis)

- Liquid Product H/C Ratio
- 11 API Oil H/C Ratio
- Bio-Oil H/C Ratio
Conclusions

The mechanically fluidized reactor has been successfully modified to operate using with heavy oil and sawdust bio-oil.

Pyrolysis of bio-oil with or without heavy oil removes oxygenated compounds from the bio-oil and forms water.

Co-processing heavy oil with bio-oil reduces the yield of coke.

Co-processing heavy oil with bio-oil may increase the yield of recovered liquid hydrocarbons. Further investigations must be done to confirm this.
Continuous Plan

**Operating Temperatures**: 520, 540, 560°C

**Nitrogen Flowrate**: [0.75-5 SLM]

**Total Liquid Feed**: 10 mL/min

**Heater Types**
- Band
- Ceramic
- Induction Heater.

**Mixing Ratios**: 0%, 5%, 10%, 15%, 20% Bio-oil

**Water Removal Using CaO**

**Co-processing with Lignin Injected Using Solvents**
Rotating Air Cooling

Rotating Rods, driven by the motor

Air Cooling

Heavy Oil Injection

Bio-oil Injection

Gas/Vapors Exit

Rotating Blades

Sparger Distributor
Current Batch Problems

- Ceramic Heaters
- Reactor
- Pad Filter
- GC Analysis
- Air Cooling
- Motor
- Gas Flow Control Panel
- Cyclonic Condenser
- Electrostatic Precipitator
Batch Plan

Nitrogen Flowrate: [0.75-5 SLM]

Batch Mass: 200 g

Heater Types
- Band
- Ceramic
- Induction Heater

Mixing Ratios: 0%, 5%, 10%, 15%, 20% Bio-oil

Temperature Cuts:
- 25-110°C
- 110-200°C
- 200-300°C
- 300-350°C
- 350-400°C
- 400-450°C
- 450-500°C
- 500-550°C
- 550-600°C
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