Effects of Temperature and Residence Time on the Thermal Cracking of Bio-oil for Syngas Production

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Introduction

- **Syngas:**
  - Mix of H$_2$ and CO
  - Can be used to synthesize chemicals and clean fuels
  - Now produced from fossil fuels such as natural gas

- **Producing syngas from biomass:**
  - Renewable resource
  - No net greenhouse gas emissions
Introduction

• Direct conversion of biomass to syngas:
  • Simple
  • Transportation of biomass is expensive

• Two stage process:
  1) Local plants convert biomass to bio-oil
  2) Central plant converts bio-oil to syngas
  • Transportation is much easier
  • Valuable chemicals extracted from bio-oil
Research Objectives

- Convert to syngas a bio-oil produced by Dynamotive from sawdust
- Thermal cracking of bio-oil in a hot fluidized bed of attrition-resistant silica sand
Gasification Reactions

- **Thermal cracking**
  \[ C_n H_m O_k \leftrightarrow C_x H_y O_z + \text{gases} (H_2, H_2O, CO, CO_2, CH_4, \ldots) + \text{coke} \]

- **Steam reforming reaction**
  \[ C_n H_m O_k + (n - k)H_2O \leftrightarrow nCO + \left[ \left( n + \frac{m}{2} - k \right) \right] H_2 \]

- **Water gas shift reaction**
  \[ CO + H_2O \leftrightarrow CO_2 + H_2 \]

- **Methane formation**
  \[ CO + 3H_2 \leftrightarrow CH_4 + H_2O \]
  \[ CO_2 + 4H_2 \leftrightarrow CH_4 + 2H_2O \]
Pilot Plant for Bio-oil Gasification

- Bubbling fluidized reactor
- TIC & Power Panel
- Gas sampling bag
- Vent
- Demister
- Gas sampling bag
- ESP
- GC
- Atomization
- Fluidization preheater
- Nozzle for bio-oil injection
- Bio-oil
- Hydraulic cylinder with internal two way piston
- Hydraulic oil
- Condenser
- Ice-water tank
- Fluidization
- N2
Experimental conditions

- Atomization and fluidization gas: Nitrogen
- Source of steam: Water in bio-oil
- Temperature: 500 °C - 700 °C
- Pressure: atmospheric
- Two silica sands: $d_{psm} = 80 \mu m$ and 200 $\mu m$
- Mass of bed: 1.5 kg and 3.0 kg
- Residence time varied by changing the reactor volume
Experimental results- Effect of Residence Time

Yield of Syngas ($H_2+CO$) for 1.5 kg sand ($d_{psm}=200 \mu m$)
Experimental results - Effect of Residence Time

Yield of molar ratio of $\text{H}_2/\text{CO}$ for 1.5 kg sand ($d_{\text{psm}}=200 \, \mu\text{m}$)
Yield of Total gas ($\text{H}_2$, CO, CO$_2$ and CH$_4$) for 1.5 kg sand ($d_{\text{psm}} = 200 \, \mu\text{m}$)
Experimental results - Effect of Temperature

Yield of $\text{H}_2$ for 1.5 kg sand ($d_{\text{psm}} = 200 \mu\text{m}$)
Experimental results - Effect of Temperature

Yield of CO for 1.5 kg sand ($d_{psm} = 200 \mu m$)
Experimental results- Effect of Particle Size

Yield of Total gas ($H_2$, $CO$, $CO_2$ and $CH_4$) for 1.5 kg and 3.0 kg sand beds ($d_{psm}=80 \mu m$ and $200 \mu m$)
Experimental results - Syngas ($\text{H}_2+\text{CO}$) Production

Yield of syngas for 1.5 kg (open symbols) and 3.0 kg (closed symbols) sand ($d_{\text{psm}} = 200 \mu\text{m}$)
Experimental results- H\textsubscript{2}/CO

\begin{figure}
\centering
\includegraphics[width=\textwidth]{image}
\caption{H\textsubscript{2}/CO molar ratio for 1.5 kg (open symbols) and 3.0 kg (closed) sand (d\textsubscript{psm} = 200\textmu m)}
\end{figure}
Conclusions

- Similar results obtained with two particle sizes:
  - sand has no catalytic effect
  - no significant heat or mass transfer limitations

- Coke formation:
  - reduction with time of the gasification yield

- Longer residence times and higher temperatures
  - better syngas yield and quality