Heterogeneous Cracking of Biomass Tar for Use in a Single-Stage Gasification System

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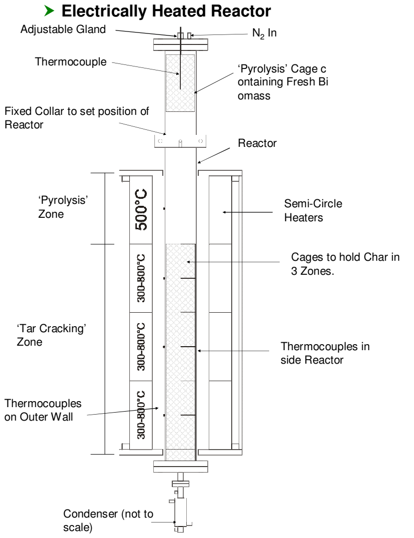
Introduction

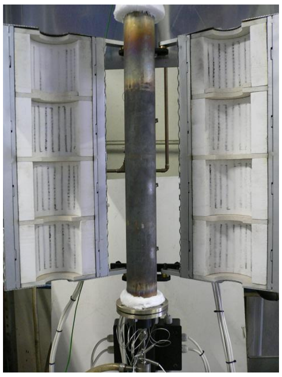
- Gasification is a significant means of converting biomass fuel into a more useful, efficient form of energy, a syngas. Nevertheless, coupled with gasification comes the release of the unwanted by-product, tar
  - Tar is the major factor inhibiting the coupling of biomass gasifiers with gas engines, a compact gasifier with a very low level of tar is essential for small-scale applications to produce heat and electricity
- The objective of this study was to understand the effect of heterogeneous cracking of heavy tar molecules produced from the pyrolysis of wood chip over a hot biomass char bed
  - The work carried out was part of a research programme to develop a single-stage gasifier integrating an efficient tar cracking process
- A new experimental rig was designed to determine the extent at which both homogeneous and heterogeneous secondary tar reactions occurred within a reactor
  - Fresh pyrolysis liquid was produced from the pyrolysis of woodchip then,
  - Swept through the reactor into a heated (char) zone where,
  - Depending on the setup, homogeneous and/or heterogeneous reactions took place
- Coupled with the experimental work will be a closely matched kinetic, single order mathematical model, which is currently being validated alongside the experimental results

Experimental Setup

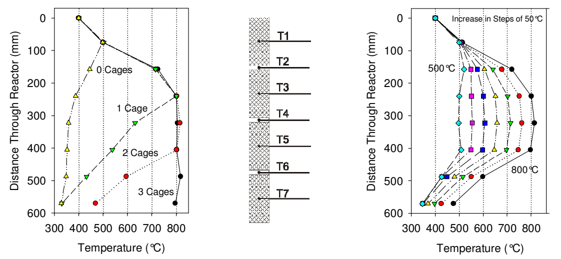
- **Electrically Heated Reactor**



- Stainless Steel Reactor Length, 1050mm
  - Inner Diameter, 72mm
- Three Cages of Hot Char (150mm Each)
  - Diameter, 63mm



- **Thermal Homogeneity of Reactor when investigating Effect of Char Bed Length and Temperature**



Experimental Procedure

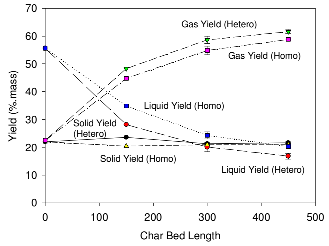
- **Effect of char cracking via varying active bed length from 0 cages to 3 cages**
  - Heterogeneous and Homogeneous (no char) cracking investigated
- **Effect of temperature**
  - Temperature range examined → 500 – 800°C
- **Effect of moisture content (MC)**
  - MC originally ~8%
  - Drying ~2% and addition of moisture up to ~50%
- **Effect of vapour residence time (RT) and particle size (PS)**
  - RT altered by adjusting N_2 flowrate from 2l/min to 0.5 & 4l/min
  - Decrease PS from 15mm to 10mm to increase active char surface area

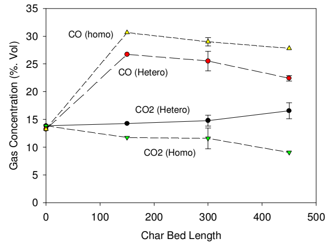
Analysis of Results

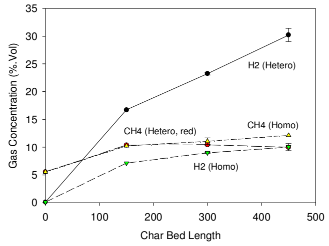
- Mass Balance for wood input against the resulting char, liquid and gas yield
- CHO Balance and Gas Chromatography Mass Spectroscopy on the Liquid Phase
- Evolved Gas Detection
  - CO and CO_2
- Evolved Gas Analysis at set intervals
  - H_2, Light HC's, CO and CO_2
- Results obtained will be used to validate mathematical modelling work

Experimental Results

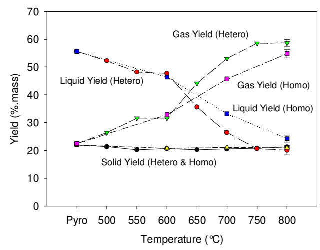
- **Effect of Char Bed Length**
- As active char bed length increased, gas yield increased
  - Larger residence time in heated zone for secondary tar reactions to take place
- H_2 concentration higher in heterogeneous experiments
  - Due to inclusion of steam gasification reactions with carbon ($C + H_2O \rightarrow H_2 + CO$)
  - Consequently, steady increase in CO_2 ($CO + H_2O \rightarrow H_2 + CO_2$)



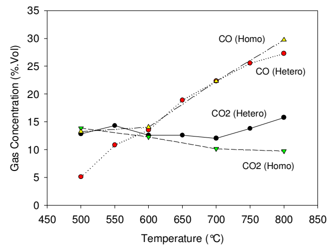


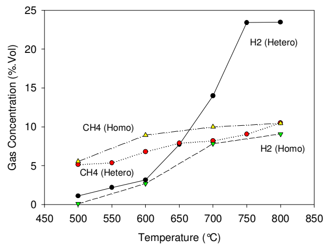


- **Effect of Temperature**



- As temperature increases, gas yield increases exponentially for heterogeneous cracking and linearly for homogeneous cracking
  - Due to influence of steam gasification reactions at temperatures above 650°C (see below)
- CO increases linearly with increasing temperature
- CO_2 concentration increases at temperatures above 700°C due to water gas shift reaction





- **Effect of Moisture Content**
  - Early indications show MC having a significant effect on destruction of tar
  - Increased presence of reactive steam results in a tar free gas being produced, as well as increased rate of H_2 production
- **Effect of Residence Time and Particle Size**
  - Larger RT results in higher gas yields and a reduction in heavy tar particles
  - Decreasing particle size has insignificant impact on results

Computer Modelling

- **The core of the kinetic, single order mathematical model has been written in Microsoft Visual Basic**
  - Aim is to model the destruction of tar simulating conditions similar to that of the experimental rig
  - Currently, the specific equations have been derived however, the activation energies and so on have been based on results from studies in the literature
  - Next step is to manipulate the experimental data further to assist the validation of the mathematical model for use in predicting the destruction of tar at different operating conditions and to help aid the scale-up of the tar cracking system

Conclusions

- **Heterogeneous cracking utilising char as a bed medium is effective at reducing tar in the syngas**
  - Char is seen to work as both a heterogeneous medium and a catalytic medium
  - Compared to homogeneous, gas-phase cracking, gas yields are higher due to a combination of steam gasification reactions and temperature
  - Steam gasification reactions become notable at temperatures above 650°C
  - Increasing the moisture content aids the solution of producing a virtually tar-free syngas

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More Information on SUWIC can be found at our websites: http://www.suwic.group.shef.ac.uk/

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