



Energy from Biofuels: Steam-Air Gasification of Biomass



Adela Khor, Changkook Ryu, Yao-bin Yang, Vida N Sharifi and Jim Swithenbank

Sheffield University Waste Incineration Centre (SUWIC), Sheffield University

Introduction

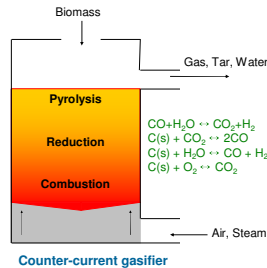
Biomass is an important source of renewable energy for securing a sustainable and diverse energy supply and for tackling climate change.

Gasification

- Conversion of biomass into H₂ and CO rich gases for feedstock or energy production.
- The end-use of the product gas and economic factor govern the selection of a particular gasification process.
- The counter-current gasification used in this work has been traditionally ruled out in gas turbine application due to the high level of contaminants.

Research Objectives:

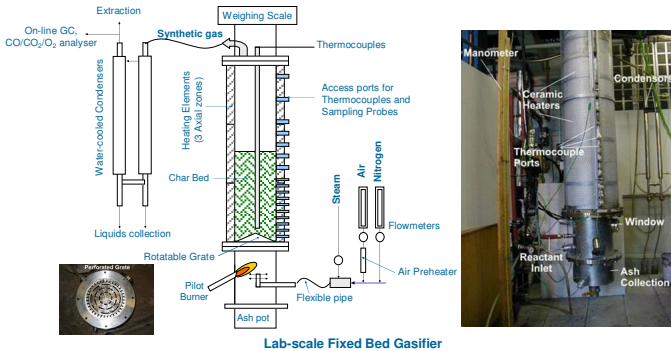
- Investigate the influence of operating parameters such as temperature, gasifying agents and equivalence ratio on the formation of producer gas and higher hydrocarbon.
- Application of mathematical models to the gasification process for comprehensive understanding of the controlling mechanism.



Experimental Methods

Fixed Bed Gasifier

- Batch type counter-current reactor (1.5m in height and 0.2m in diameter)
- Electrically heated and maintained at temperature $\approx 750^\circ C$.
- Perforated and rotatable grate allows ash removal during operation.
- Measurement: weight, temperature, gases (CO, CO₂, O₂, H₂, CH₄, C₂H₆, NH₃, H₂S etc.)
- This reactor will be part of a novel gasifier to produce tar-free gases from biomass



Fuel Preparation

- Commercial lump-wood charcoal (particle size: $\sim 3-4$ cm)
- Charcoal is preheated in the reactor to a temperature over $700^\circ C$ before gasification tests.

Samples	Before Preheating		After Preheating	
	Moisture	2.59	0.86	
Proximate analysis (%wt)	Volatile matter	20.45	3.86	
	Fixed carbon	74.15	3.47	
	Ash	2.81	91.81	
Ultimate analysis (%wt)	C	75.32	90.66	
	H	3.39	0.71	
	O (by difference)	15.89	4.30	
Gross Calorific Value (MJ/kg)		15.89	30.32	



Charcoal samples

Fuel analysis for charcoal

Test Conditions

- The test runs are named according to the flow rate of each reactant supplied. For example, the 'A90-S30' run refers to the gasification using 90l/min (220kg/m²hr) of air and with steam making up 30%wt of the total input reactant.
- The effect of air flow rate was investigated for air flow rates ranging from 90l/min (220kg/m²hr) to 120l/min (294kg/m²hr).

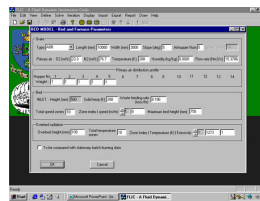
Chemical Equilibrium and Comprehensive Modelling

Chemical Equilibrium Modelling

- investigates the theoretical limits of gasification based on the chemical equilibrium of gasification reactions (minimisation of Gibbs free energy).
- Using NASA Glenn's computer programme, Chemical Equilibrium with Application (CEA) (v. 2)

Comprehensive Mathematical Modelling by FLIC

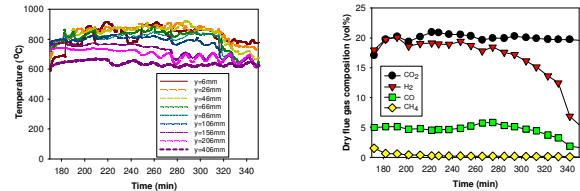
- Unsteady 1D modelling of a two phase reacting bed
- includes reactions, heat and mass transfer for the gas and solid (fuel) phases.
- Reaction kinetics given by Hobbs et al [1] for char/CO₂, char/H₂O, char/H₂ and char/O₂.
- Kinetics for water gas-shift reaction based on values given by Biba et al [2].



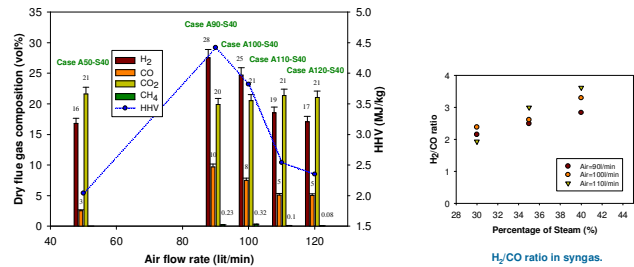
FLIC developed by SUWIC

Experimental Results

- **Bed Height Matters!** Bed temperature and syngas evolution decreases at bed height <106mm.
- **Low over-bed temperature affects the flue gas composition.**
- **Mass conversion rate ≈ 27 kg/m²hr for Case A100-S40 (air flow rate of 100l/min (245kg/m²hr) and 40wt% steam)**



Temperature history at several locations along the gasifier (Case A100-S40). Dry flue gas composition (Case A100-S40).



Dry syngas composition and HHV for cases with 40wt steam at various air flow rates.

Case	H ₂ from char (kg/m ² hr)	Syngas from char (kg/m ² hr)	H ₂ production ratio (%)	Syngas production ratio (%)
A50-S40	1.81	5.70	10.83	34
A90-S40	7.39	44.37	14.56	87.5
A100-S40	7.00	37.43	13.90	74.3
A110-S40	4.52	22.03	10.90	54
A120-S40	4.42	22.44	10.30	52

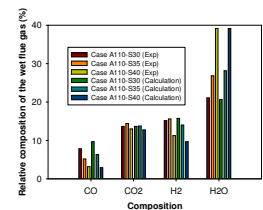
Conversion ratios of char to hydrogen gases.

- The ratio of H₂/CO could be manipulated by adjusting the flow rate of the reactants.

Modelling Results

Chemical Equilibrium Modelling

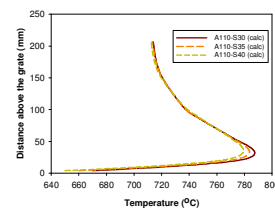
- Provides an insight into the chemical equilibrium based on the carbon conversion rate of the gasification experiments.
- An increase of steam input causes a drop in CO and H₂ and a step up in H₂O concentration for cases carried out under an air flow rate of 110l/min (270kg/m²hr).



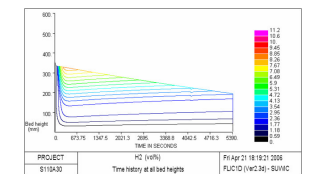
Chemical Equilibrium Modelling: gas composition (air: 110l/min, steam: 30%, 35% or 40%)

FLIC Modelling

- Calculation gave a close representation of the dynamic change in temperature and gas composition along the stratified gasifier.



FLIC: Calculated bed temperature along the bed height (air: 110l/min, steam: 30%, 35% or 40%).



FLIC: Calculated dry hydrogen composition in the bed vs. reaction time.

Conclusions

- The production of producer gas was influenced by the air to steam ratio and total feed flow rate. By entering more air in the oxidation zone, the production of H₂ and CO decreased as combustion occurred in the reactor bed.
- Addition of steam increases the production of H₂ at the expense of a lower bed temperature and slower char conversion rate.
- Hydrogen yield obtained was about 10-14kg of hydrogen from 100kg of char.
- Concentration of methane was negligible and no higher hydrocarbons was detected.

References

- [1] Hobbs, M. L., Predrag, T., Smoot, D. L., Modelling Fixed-Bed Coal Gasifier, *AIChE Journal*, 38(5): p. 681-703. 1992.
- [2] Biba, V. M., Jiri, K., Erhard, M. J., Mathematical Model for the Gasification of Coal under Pressure. *Industrial & Engineering Chemistry Process Design and Development*, 17(1): p. 92-98. 1978.

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