Heterogeneous Cracking of Tar To Increase Efficiency of Power Plant

Carbon Price

Technology Option

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Outline of Presentation

Motivation

- Main Challenges Today

What we have done?

- Gasification Kinetics
- Importance of tar cracking
- Methodology
- Key Results

What we are planning to do?

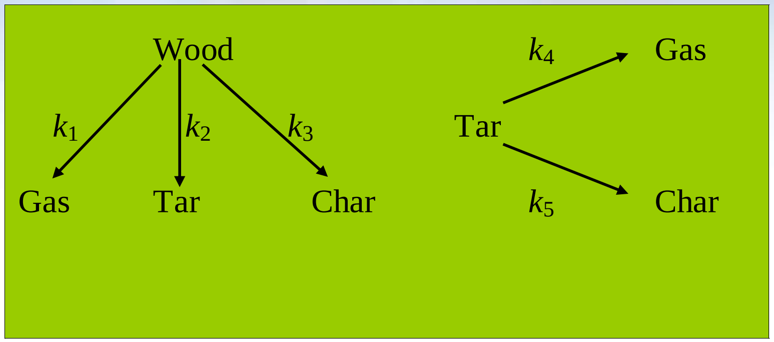
- Implications of present study on technology development

MAIN CHALLENGES TODAY!

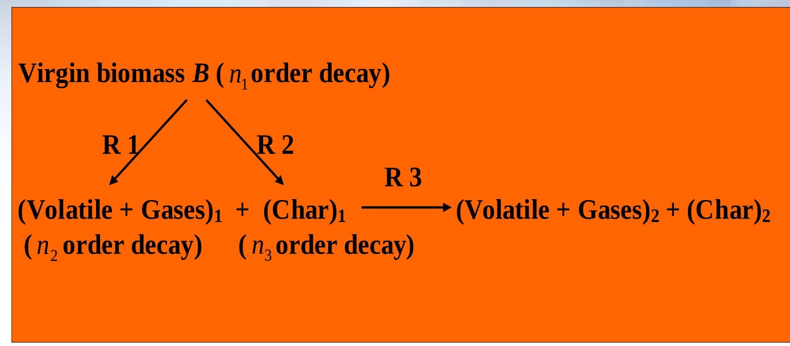
Why is tar cracking important?

- **Tar formation a major reason for unreliability of biomass gasifiers**
- **Need to understand mechanisms of formation and destruction**
- **Want to maximise yield (avoid over-combustion)**

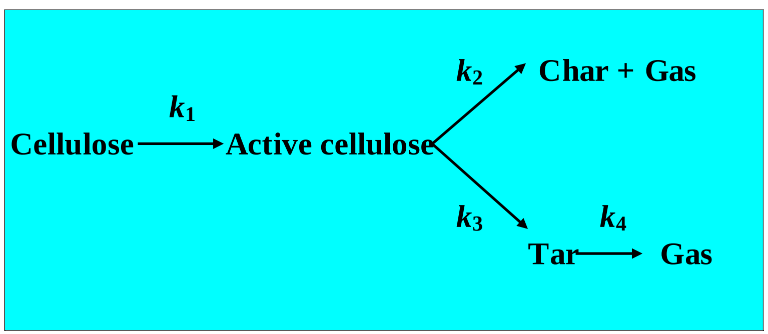
Gasification Kinetics



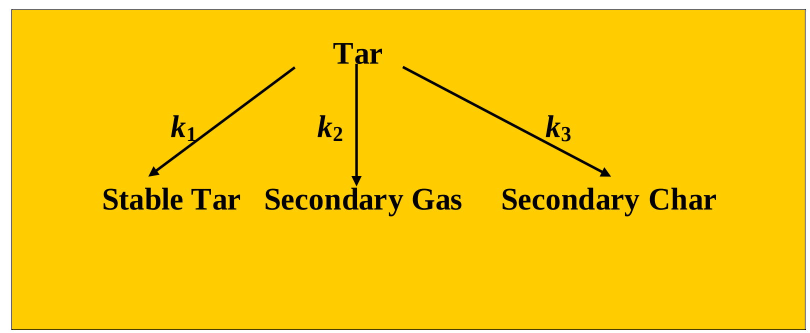
Kinetic scheme of Shafizadeh and Chin (1977)



Kinetic scheme of Koufopanos *et al*. (1999)



Kinetic scheme of Broido Shafizadeh (1979)



Proposed Kinetic scheme in the present study

Methodology

- Model development
  - Homogeneous kinetic model
  - Heterogeneous kinetic model
  - Downdraft gasifier model
- Approach (gPROMS)
  - Gaussian distribution
  - Set variance model (0.00001 – 100)
  - Optimisation tolerance (10^{-8} – 10^{-3})
  - Minimum line search step length (10^{-8} – 10^{-3})

KEY RESULTS

Product Yields from Different Extents of Homogeneous Secondary Tar Cracking

Sr. No.	Temperature (K)	Stable tar yield (wt. % of wood)	Secondary gas yield (wt. % of wood)
1.	1073	5.6	41.4
		4.9	42.1
		5.1	41.9
		5.5	41.5
		5.3 (Avg.)	
2.	1173	1.8	45.2
		1.8	45.2
		1.8 (Avg.)	
3.	1273	0.7	46.3
		0.7	46.3
		0.7 (Avg.)	
Primary tar yield (wt. % of wood) at 773 K from first stage reactor = 47%			

Product Yields from Different Extents of Heterogeneous Secondary Tar Cracking

Sr. No.	Temperature (K)	Stable tar yield (wt. % of wood)	Secondary gas yield (wt. % of wood)	Secondary char yield (wt. % of wood)
1.	1073	0.8	41.4	4.8
		0.8	41.5	4.7
		0.8 (Avg.)		
2.	1173	0.2	45.2	1.6
		0.2	45.2	1.6
		0.2 (Avg.)		
3.	1273	0.1	46.3	0.6
		0.1	46.3	0.6
		0.1 (Avg.)		
Primary tar yield (wt. % of wood) at 773 K from first stage reactor = 47%				

Comparison of predicted value from homogeneous cracking model with experimental data (gPROMS)

RT (sec)	ST (Exp.)	ST (Pred.)	SG (Exp.)	SG (Pred.)
Experiment 1 (1073 K)				
0.1	5.6	5.2748	41.4	41.725
0.1	4.9	5.2748	42.1	41.725
0.1	5.1	5.2748	41.9	41.725
0.1	5.5	5.2748	41.5	41.725
Experiment 2 (1173 K)				
0.1	1.8	1.7991	45.2	45.201
0.1	1.8	1.7991	45.2	45.201
Experiment 3 (1273 K)				
0.1	0.7	0.70189	46.3	46.298
0.1	0.7	0.70189	46.3	46.298

RT = Residence time; ST = Stable tar yield; SG = Secondary gas yield; Exp. = Experimental value; Pred. = Predicted value

Comparison of predicted value from heterogeneous cracking model with experimental data (gPROMS)

RT (sec)	ST (Exp.)	ST (Pred.)	SG (Exp.)	SG (Pred.)	SC (Exp.)	SC (Pred.)
Experiment 1 (1073 K)						
0.082	0.8	1.1685	41.4	41.396	4.8	4.4356
0.082	0.8	1.1685	41.5	41.396	4.7	4.4356
Experiment 2 (1173 K)						
0.082	0.2	0.87829	45.2	44.523	1.6	1.5992
0.082	0.2	0.87829	45.2	44.523	1.6	1.5992
Experiment 3 (1273 K)						
0.082	0.1	0.4039	46.3	46.23	0.367	0.36647
0.082	0.1	0.4039	46.3	46.23	0.367	0.36647

RT = Residence time; ST = Stable tar yield; SG = Secondary gas yield; SC = Secondary char yield; Exp. = Experimental value; Pred. = Predicted value

Estimated Kinetic Parameters

A_{ST} (s^{-1})	A_{SG} (s^{-1})	A_{SC} (s^{-1})	E_{0ST} (kJ mol^{-1})	E_{0SG} (kJ mol^{-1})	E_{0SC} (kJ mol^{-1})	σ_{ST} (kJ mol^{-1})	σ_{ST} (kJ mol^{-1})	σ_{ST} (kJ mol^{-1})
1.5838×10^{9}	1.0×10^{13}	1.8469×10^{6}	166.28	175.0	62.5	8.2	1.3247×10^{-5}	2.7571×10^{-4}

Implications in general

Gas compositions (% vol, db) and calorific values

Gas Species	Senelwa (Experimental)	Chee (Experimental)	Present model
CO	24.29	23.33	24.60
H_2	12.86	14.29	11.16
CH_4	2.86	2.38	2.07
CO_2	9.52	11.9	15.21
N_2	50.48	47.62	45.35
GCV (MJ/m^3) = $-\sum n_i \Delta H_{combustion}$			4.903
NCV (MJ/m^3) = GCV – LT lost in water vapour			4.628

Applications of syngas:

- Gas turbine to produce heat and power (CHP)
- H_2 to power fuel cells to increase overall power plant efficiency (DOE Fuel Cell Program)

Implications for technology development

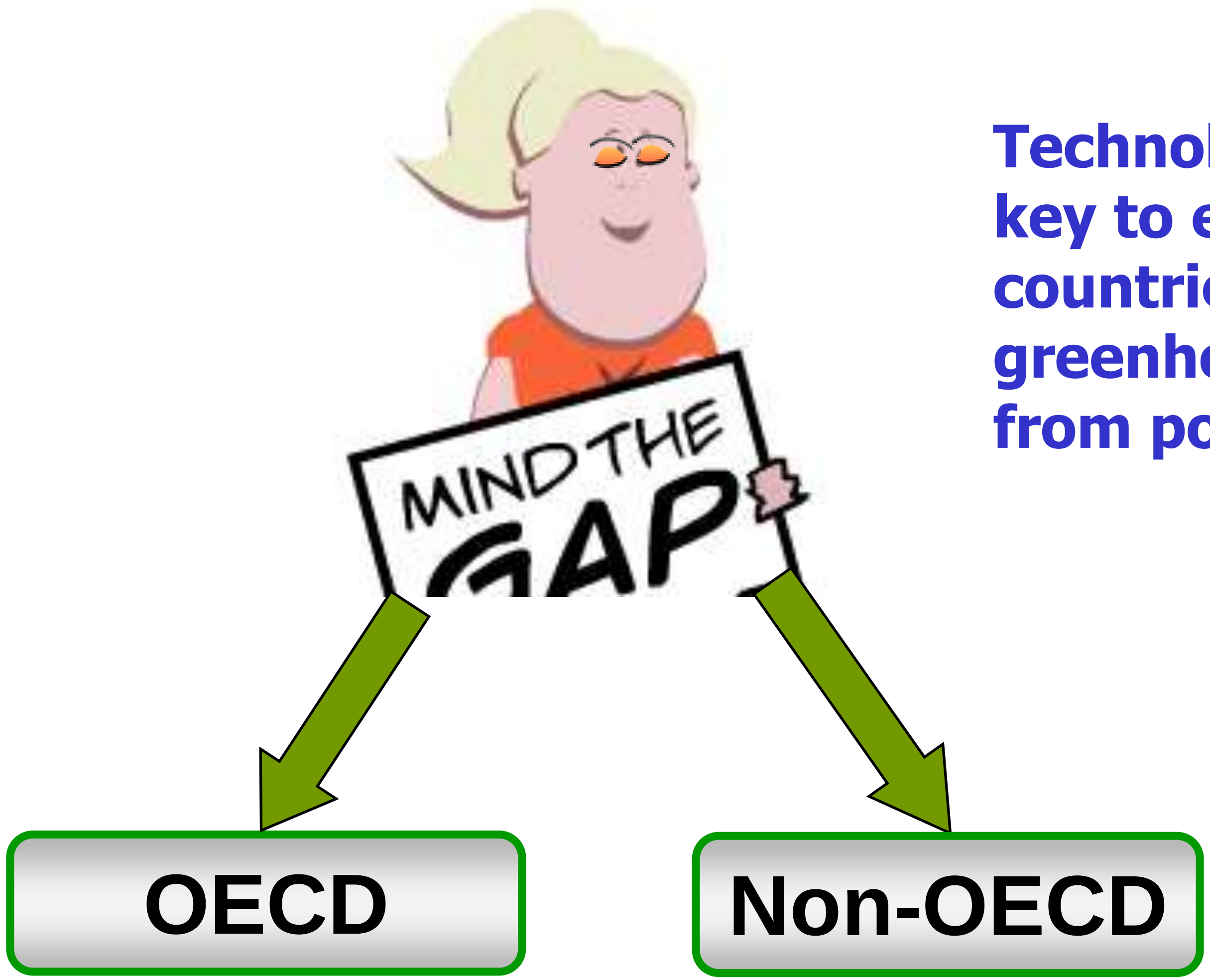
INDIA CONTEXT

- Installation of supercritical PCC has begun. A 3x660 MWe plant at Sipat is due for completion by 2009 (steam conditions 24.7 MPa/540^0C/565^0C).
- Further plan for 20 GWe supercritical capacity.
- BHEL operated 6 MWe fluidised bed gasifier IGCC during the late 1990s. Now seeking partners for 100 MWe demonstration plant.
- Lignite-fuelled IGCC based on pressurized fluidized bed concept also planned at Tiruchinapalli.

Implications of present study in technology development

- Efficiency improvement (LHV)
- Sharing of information
- Technical know-how

Key Message



Technology transfer is the key to enabling non-OECD countries to reduce greenhouse gas emissions from power generation.

Thank you for your attention

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