Pressurized Pyrolysis and Gasification of Biomass-Coal Blends

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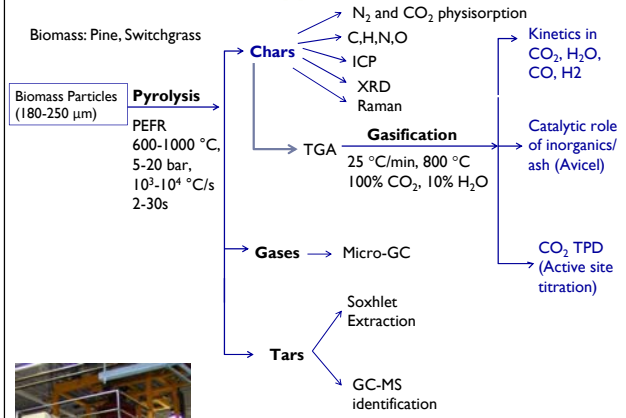
Motivation and Objectives

Motivation:
Coal, with high inorganic content in the form of Ca, Mg, Al, Si, Fe etc requires high temperatures for gasification. Biomass, a carbon-neutral, renewable feedstock, has higher gasification reactivity, attributed to its higher alkali content. Thus a blend of biomass and coal offers the potential of enhanced gasification reactivity while reducing carbon footprint. In addition, existing coal gasification infrastructure can be retrofitted to incorporate biomass as a co-feed.

Objectives:
- To explore conditions under which gasification synergies in co-feeding coal and biomass may be achieved
- To define the role of operating parameters on the evolution of char morphology which would facilitate gasification rate enhancement
- To develop intrinsic L-H kinetic models for gasification that predict the effect of steam, CO_2, CO, and H_2

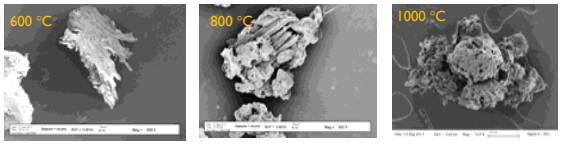
Approach



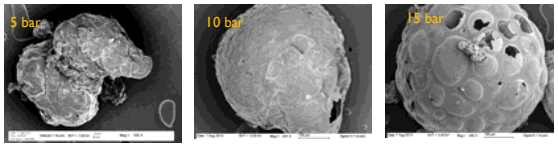
Results

Evolution of biomass char morphology

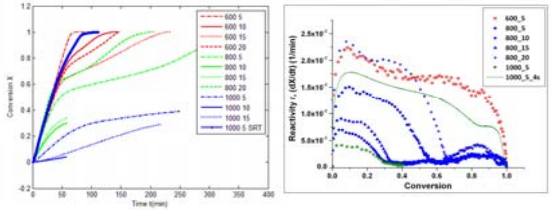
Effect of temperature at constant pressure (5 bars)



Effect of pressure at constant temperature (600 °C)



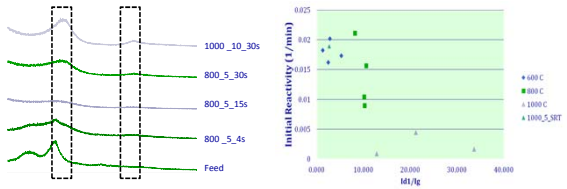
Effect of pyrolysis conditions on char gasification reactivity



Three gasification regimes:
- Fast reaction: amorphous carbon/ high reactivity
- Very slow reaction: carbon deactivation/graphitization
- Small bounce in rate: collapse of carbon structure/exposure of active sites

XRD spectra of Pine chars

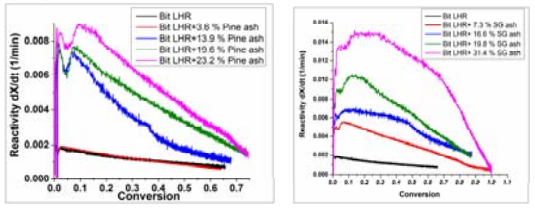
Raman spectroscopy



Both XRD and Raman spectroscopy results correlate well with the observed gasification reactivities

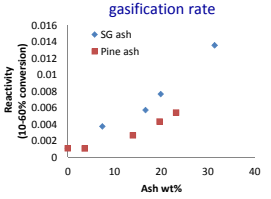
Results

Synergistic Effect of Biomass on Coal Gasification

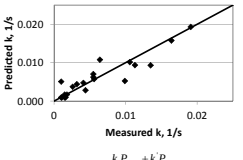


Physical mixtures of coal char and biomass char show synergy during gasification.

Effect of biomass ash on bituminous coal gasification rate



Rate constants
Predicted vs. Experimental Rate
All Experiments at 800°C



	Al_2O_3	CaO	Fe_2O_3	K_2O	SiO_2
SG Ash	0.25	7.80	0.21	23.7	52.4
Pine Ash	2.22	30.0	1.75	11.1	22.6

$$r_c = \frac{k_1 P_{CO2} + k_1' P_{H2O}}{1 + K_2 P_{CO} + K_3 P_{H2O} + K_4 P_{CO2} + K_5 P_{H2}}$$

k_1, min^{-1}	k_1', min^{-1}	K_2, bar^{-1}	K_3, bar^{-1}	K_4, bar^{-1}	K_5, bar^{-1}
0.018	0.12	6.39	0	0.19	87.9

Hydrogen inhibition:
$C(O) + H_2 \rightarrow C_f + H_2O$ (C_f is free carbon); $C_f + \frac{1}{2} H_2 \leftrightarrow C(H)$

Conclusions

- Pyrolysis operating conditions (heating rate, temperature, pressure) lead to drastic differences in char morphology and reactivity.
- PAHs (polyaromatic hydrocarbons) are secondary and tertiary tar species formed via olefin oligomerization within the char particles at high pressures.
- High temperature char is mainly carbonaceous with large aromatic/ graphene like sheets.
- Both alkali and Ca catalyze char gasification using steam or CO_2 and provide synergy during gasification of coal – biomass blends.
- Coal gasification rates can be enhanced by blending with biomass chars or ash, but good contact between the two components is essential.

Acknowledgements

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