Experimental Investigation of the Decomposition Process and Products During Gasification of Various Biomass and Coal Fuels

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Abstract

This study investigates the nature of the decomposition of various biomass feedstocks and pulverized coal particles to be used as fuels in a novel gasification reactor. The data will be used in the design and development of a zero-emission gasification reactor that uses a type of steam reforming to catalytically combust such fuels as biomass, coal or municipal solid wastes. The combustion process is decoupled from the gasification process enabling optimization of each. The products of combustion result in synthesis gas, a part of which can be used to generate heat for running the gasification reaction.

Using Thermogravimetric Analysis, Gas Chromatography and Atomic Absorption Spectrophotometric Analyses, we studied the nature of the fuel composition and char residue and the mass decay of coal having varying particle sizes and of various biomass sources including several pulverized woods and grasses such as poplar, oak, pine, spruce, maple, green Douglas fir, pine needles, maple bark, alfalfa and cordgrass. Each specimen feedstock was slowly heated in a N_2 atmosphere with injected steam and the gaseous evolution of H_2, CO, CO_2 and CH_4 as a function of temperature was sampled and analyzed by the GC. CO_2 was then fed into the system to test whether various levels of CO_2 recycle might enhance the H_2 production from the gasification process. The gas evolution and recycle enrichment is currently being investigated.

Experimental Setup

Thermal Analyzer and Steam Pump

Thermogravimetric Analyzer and Digital Voltmeter

Gas Chromatograph

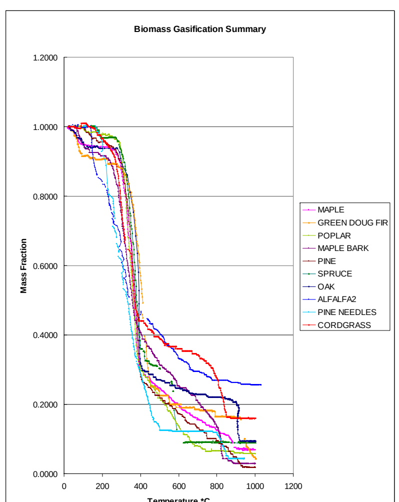
Results and Discussion

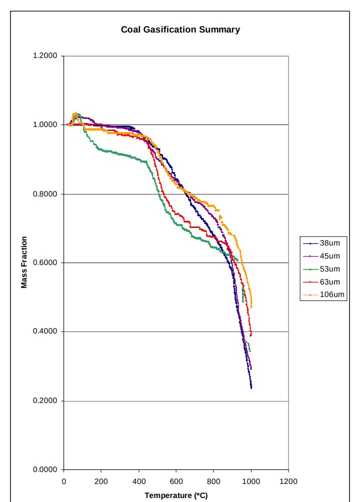
- Woods and grasses had similar TGA curves with a third constant mass step during gasification
- Mass loss was completed for biomass by 900-1000*C
- 3 plateaus corresponding to evolution of volatiles, decomposition of cellulose, hemi-cellulose and lignin and char and tar burnout at high T
- 2 plateaus for coal since they were still experiencing mass loss at 1000*C
- CO was found to give the strongest signal (other than the carrier gases) on the Gas Chromatogram
- Species favored at lower gasification temperatures are CH_4 and CO_2
- Species favored at higher temperatures are CO and H_2 from the steam reformation and Boudouard reactions
- Equal volumes of each fuel were combusted in a 1000*C furnace for 30 minutes and the relative weight of the residues measured
- Biomass sources were found to have varying levels of copper and a significant level of potassium was identified in the grass chars
- Strong corrosive behavior exhibited by the grasses during gasification in the TGA and combustion in the furnace

Conclusions and Ongoing Further Investigations

- Biomass gasification residue was dependent on whether feedstock type was grass (~20%) or wood (~3-7%)
- By 950*C the biomass fuel experienced maximum burnout
- Rapid mass decay of coal particles was observed commencing at about 850*C and still progressing past 1000*C
- Higher amount of mineral residue (~4-6%) was observed for the combusted grasses as compared to the woods (<1%)
- Half of the bulk mass coal volume in the porcelain crucible remained unburned since only the surface combusted
- TGA quartz rod was found to consistently crumble under corrosive activity of the alkali salts contained in the grasses
- High levels of these salts, particularly K_2O, acted as fluxes for the quartz
- Residue of the pine needles, alfalfa and maple bark were particularly reactive with the high temperature porcelain dishes
- Alkali salts had eaten through the porcelain surface and reacted with the ceramic glaze
- Mineral composition, particularly high alkaline content, of many grasses is an important consideration when designing fuel processing equipment to minimize corrosion in the operating system
- CO_2 recycle for the gasification of 45um coal particles was investigated to test the feasibility of enhanced H_2 fuel production and decreased CO demand needed for combustion to drive the gasification reactions
- Total N_2 + CO_2 carrier flow rate remained fixed at 60ml/min with the proportion of CO_2 to N_2 varying from 0% to 75%
- Initial calculations showed that an optimum of about 25% CO_2 recycle should result in approximately 15% more H_2 produced and 20% less CO needed for combustion
- These calculations agree with the experimental trend displayed in the CO gas evolution graph
- Further gas analysis of CH_4 and H_2 evolution for various CO_2 recycle ratios is currently underway
- Additional gas evolution data will be collected to test the simulation model and design the optimum specifications for the reaction gasifier

Mass Fraction vs. Temperature Decay





Mass % Residue	Feedstock	Furnace Combustion Residue
0.253	Poplar	
0.110	Oak	
0.316	Pine	
0.240	Maple	
0.338	Spruce	
0.086	Green Douglas Fir	
4.76	Maple Bark	
5.89	Alfalfa	
4.13	Pine Needles	
4.36	Cordgrass	
52.59	Pulverized Coal (63um)	

CO Gas Evolution By Gasification of 45um Coal Particles