Citrus Peel Gasification using Molten Sodium Heat Pipes

Anindra Mazumdar and Rajiv Srivastava,
Hemispheric Center for Environmental Technology, Florida International University, Miami, Florida 33174

Key Words: Pyrolysis, Gasification, Biomass, Hydrogen, Citrus peel, Sustainable Energy

Extended Abstract Prepared for Presentation at the AIChE 2004 Annual Meeting, Austin, Texas

Session: [3] – Sustainable Energy

Abstract

Florida is one of the largest biomass producers in the country and citrus peel constitutes a significant bulk of agricultural waste. Citrus peel has volatile organic components, which makes it an attractive feedstock for gasification.

In traditional gasification processes, non-uniform temperature gradients lead to the degradation of the pyrolysis products. Heat Pipes increase the heat flux by orders of magnitude thereby providing an effective pyrolyzing atmosphere.

Experimental results and analysis will be presented on the pyrolysis of Citrus Peel using an Innovative Molten Sodium Heat Pipe. Insitu Reformation data will also be included in the presentation.

Background

Concerns about the depletion of fossil fuel reserves, energy security, and pollution caused by continuously increasing energy demands make biomass and hydrogen attractive alternative energy sources. Recently, there has been an increasing interest in taking the necessary steps to move towards a hydrogen-based economy. Furthermore, the NASA Kennedy Space Center (KSC) and the Cape Canaveral Air Force Station (CCAFS) will eventually be required to manufacture the hydrogen they use locally. Local production of hydrogen is necessitated by economic, transportation safety, and energy security considerations. It is therefore desirable to investigate what improvements can be made to hydrogen operations at the spaceport facilities considering new hydrogen production and storage technologies under research and development at universities, federal facilities and industrial research laboratories through the auspices of the NASA Hydrogen Research Program.

Hydrogen is currently derived from nonrenewable resources by steam reforming in which fossil fuels, primarily natural gas, react with steam at high pressures and temperatures in the presence of a nickel-based catalyst. In principle, hydrogen can also be generated from renewable resources such as biomass by gasification. Gasification yields clean fuel gas that makes a wide array of power options possible, including traditional internal combustion engines and fuel cells.

Heat pipes have an effective thermal conductivity, which is often an order of magnitude more than conductive metals. Heat pipes are containers filled with a small amount of working fluid. For high temperature applications the fluid is typically a low melting point metal. The fluid transfers heat by evaporating at the hot section and condensing at the cooler section, thereby maintaining almost an isothermal condition in the working space.

We have designed, fabricated, and are validating a pilot-scale biomass gasification unit using local citrus peel. The system's performance, efficiency, economics, and reliability as a sustainable hydrogen source for NASA in Florida, is being studied. Citrus peel has been identified as a promising local fuel source due to its overabundance and depressed market value. The farmland acreage dedicated to citrus almost exceeds 800,000. The citrus industry generates more than 1 million tons/yr of citrus waste residue on a dry basis. Because the disposition of citrus peel is an unattractive venture, the Florida Citrus Processors Association has expressed strong interest in finding alternate uses for the citrus peel. The proposed work focuses on utilizing waste residue from juice production to co-produce hydrogen and heat.

Objectives

The objectives of this research are to optimize hydrogen production via pyrolysis of citrus peel. The specific objectives are the following:

1> Design and operate a bench scale Sodium Heat Pipe Pyrolysis system.

2> Obtain reaction kinetics and product composition for different compositions and operating temperatures.

3> Optimize Hydrogen production using the data obtained in Step 2.

Experimental Setup

The system consists of basically an isothermal well in an annular furnace and is illustrated in Figure 1. Advanced Cooling Technologies, Inc manufactured the system.

The furnace is electrically heated. The system has the capability to be run in both batch and continuous mode. The pyrolysis gas is cooled and analyzed for gasification products. The inner diameter of the system is 4 inches and the length is 30 inches. Figure 2 shows a picture of the furnace system and Figure 3 illustrates the citrus peel used for the experiments.

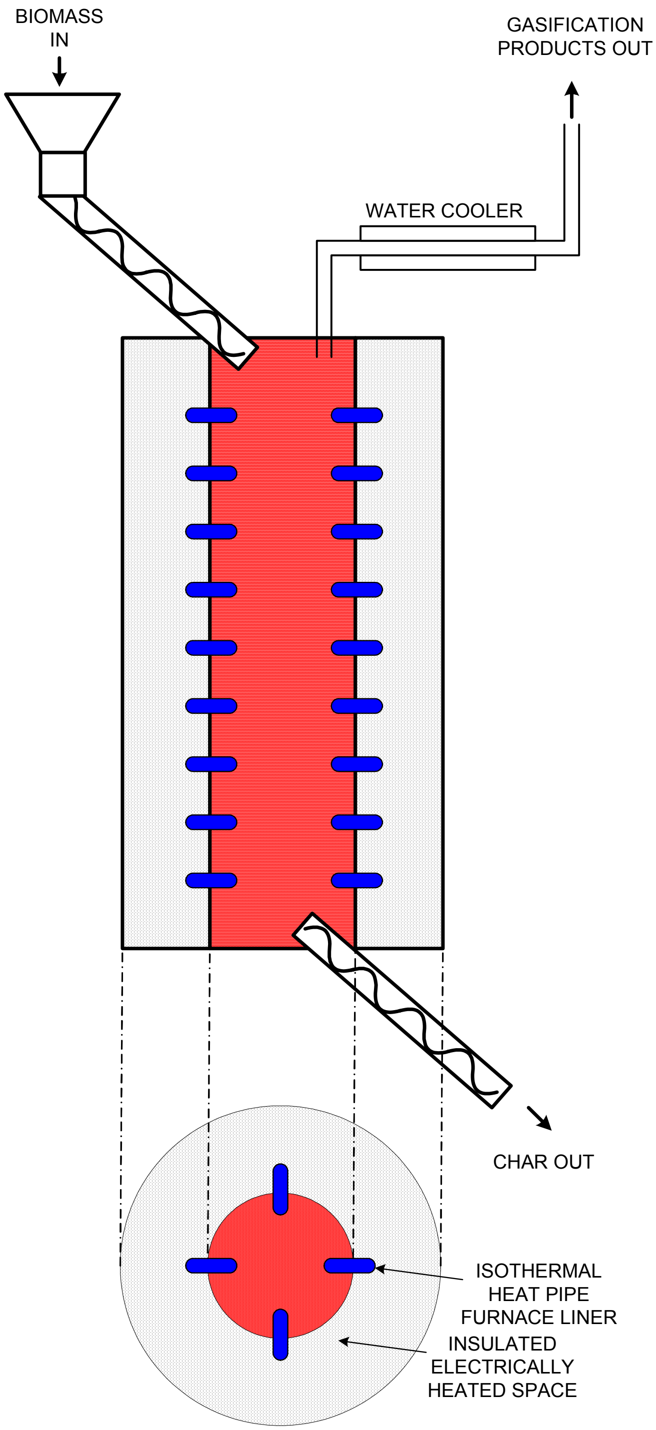

Figure 1 – Heat Pipe Furnace System for Citrus Peel Gasification

Figure 2: The Sodium Isothermal Furnace Liner being displayed outside the Furnace

Figure 3: Citrus Peel pellets used for Gasification

Experimental Results

At the time of preparation of this manuscript, experiments were still under progress. We have noticed yields of hydrogen, which are far greater than the conventional gasification/pyrolysis systems. However, detailed results will be presented at the AIChE Annual Meeting in 2004.

Acknowledgements

This Research is supported by the The Florida Solar Energy Center, under the hydrogen research grant from NASA Glenn Research Center.

References:

1. X. T. Li, J. R. Grace, C. J. Lim, A. P. Watkinson, H. P. Chen and J. R. Kim, Biomass gasification in a circulating fluidized bed, Biomass and Bioenergy, Volume 26, Issue 2, February 2004, Pages 171-193.

2. Jacobs, Kevin L., An analytical model of the gasification of biomass charcoal in an isothermal, well-mixed reactor, Dissertation: Thesis (M.S.)--Tennessee Technological University, 1997

3. Czernik, S., D. Wang, D. Montané, E. Chornet, 1997, Catalytic Steam Reforming ofBiomass-Derived Fractions from Pyrolysis Processes. Developments in Thermochemical Biomass Conversion", Eds. Bridgwater, A.V. and Boocock, D.G.B., Blackie Academic & Professional, pp.672-686.