537c Thermochemical Hydrogen Production from Biomass Using Core-in-Shell Catalyst/Sorbent Materials

Justinus A. Satrio, Brent H. Shanks, and Thomas D. Wheelock

The gasification of renewable materials, such as switchgrass and corn stover, provides a promising means of obtaining hydrogen from renewable resources. Air-blown gasification in fluidized bed reactors typically produces relatively low concentrations of hydrogen (9-17%). Other components are CO (14 - 24%), CO2 (9-20), CH4 (1-7%), and tars (1-10 g/nm3). More hydrogen can be produced by steam reforming tars and methane and converting CO via high and low temperature water-gas-shift reactions followed by CO2 separation. The multisteps involved in the making of additional hydrogen make the process inefficient and costly. Combining the steam reforming of tars and CH4 with water-gas-shifting of CO and CO2 removal into a single step process would be attractive. We have developed a novel material, which is a combined catalyst and sorbent, for promoting and improving the efficiency of hydrogen generation from biomass gasification. The improvement in performance is accomplished by utilizing core-in-shell pellets in which a CaO core is surrounded by a porous shell that supports a nickel catalyst for the steam reforming (SR) and the water gas shift (WGS) reactions. By using the pellets, simultaneous reaction rate improvement from the catalyst function and separation of H2 and CO2 via selective absorption of CO2 by CaO can be achieved. The CO2 absorption also drives the reactions, which are otherwise limited by thermodynamic equilibriums, to completion producing more H2 and less CO and CO2. Proof of concept tests showed that using the core-in-shell catalyst/sorbent material, hydrogen product streams with purity between 95-99% were achieved from reacting methane, toluene, carbon monoxide, and their combinations at temperatures lower than 600oC.

The ultimate performance testing of the core-in-shell catalyst/sorbent materials is when actual producer gas from biomass gasification is used. Discussed will be results from tests conducted using a pilot scale fluidized bed reactor to generate the producer gas. A slipstream from the producer gas stream is drawn and passed through the catalytic conversion system containing the core-in-shell catalyst/sorbent material. Effects of operating conditions of the product stream compositions will be addressed.

Finally, an operation and energy analysis of a gas treatment system for generating hydrogen from biomass using the core-in-shell catalyst/sorbent technology is developed. This gas treatment system will be compared with the "conventional" gas treatment approach. This conventional gas treatment, following the gasifier, consists of a reformer followed by both high and low temperature WGS reactors to reduce the CO content and produce additional H2, and finally by a preferential oxidation reactor to selectively convert all remaining CO to CO2 followed by CO2 separation. To be discussed is the energy utilization of these two approaches.