UNIVERSITY OF FLORIDA

Solar Thermal Power for Bulk Power and Distributed Generation

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Description: While there are many different approaches to hydrogen generation, the most attractive means is to split water molecules using solar energy. The current approach is to develop highly reactive metal oxide materials to produce intermediary reactions that result in the splitting of water to produce hydrogen at moderate temperatures (<1000 K). It is envisioned that the metal oxide reactors will ultimately be mounted within a solar concentrating reactor, and irradiated via heliostats. This Task is structured toward the overall goals of solar-driven, thermochemical hydrogen production, with associated efforts toward the enabling surface science, catalysis, particle science, material synthesis, nano-structures, multiscale-multiphase physics modeling, and process simulation that will enable the realization of solar hydrogen-based fuels to power the transportation economy. Successful efforts as targeted in this project are a critical step toward increased renewable-resource based fuels and energy, reduction of GHG emissions, and establishment of a new power industry in Florida.

Budget: $446,400

Universities: UF

Progress Summary

Research Objectives for Current Reporting Period: The main research objectives for the current reporting period include setting up a high temperature iron powder fluidized bed reactor facility for the measurement of hydrogen production rates at various operating conditions, the development of a high temperature bench-scale reactor for fundamental kinetic studies, the preliminary testing of experimental facilities, and the development of fundamental reactor design methodologies.

Progress Made Toward Objectives During Reporting Period: A bench scale hydrogen production process that utilizes a fluidized bed reactor was fabricated and tested at temperatures of 450, 650, and 850^{o}C. The reaction utilizes porous iron powder with a mean particle diameter of 91 μm. The reaction chamber includes a 0.6 m long fused quartz tube, capable of operating up to temperatures of 1200^{o}C. The quartz fluidization chamber extends through an electric furnace with a range of 100 to 1200^{o}C. A steam generator, consisting of four 200W (maximum) cartridge heaters inside an aluminum chamber, is used in a boiling mode to produce superheated steam at 200 ^{o}C. The mass flow rate of steam to the reactor is 0.075 g/s for all experiments considered.

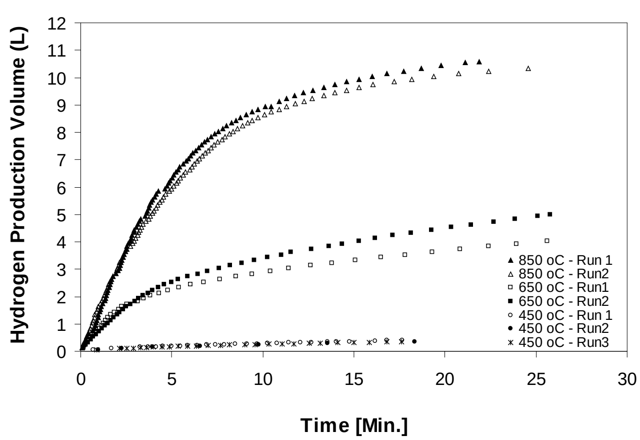

Fig. 1 Hydrogen Production at Various Bed Temperatures

For the current reactor configuration steam is introduced to a fluidized bed of iron particles. These particles are porous and have a mean particle size of 91 μm.

The powder has a particle density of 7800 kg/m^3 and an estimated surface area of 60 cm^2/g. This powder is classified as Geldart B and 25 g of powder are used for each experiment.

The measured volumetric hydrogen production at three different reaction temperatures is shown in Figure 1. As the temperature of the reactor increases, the amount of hydrogen produced increases. The total volume of hydrogen produced for 25g of iron is 0.35, 4.5 and 10.5 L for 450, 650 and 850 ^oC respectively. All volumes are measured at atmospheric conditions. The hydrogen production for different powder batches is shown to be repeatable. The trend of increasing hydrogen production with increasing temperature is expected since the reaction rate increases exponentially with temperature, according to the Arrhenius equation. Clearly, the rate of hydrogen production decreases exponentially, and this is due to the fact that an iron oxide (magnetite) layer forms over the particles as hydrogen is liberated from the steam, thus reducing available surface area for reaction.

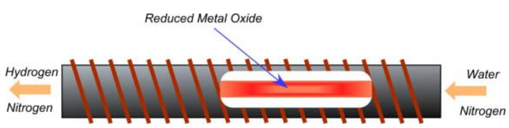

Fig. 2 Monolithic Reactor for Fundamental Reaction Kinetic Studies

In order to develop a scaling methodology and analytical reactor design tool, conservation of species and energy transport equations have been derived for the current fluidized bed reactor configuration. Evolution of the hydrogen concentration and bed temperature with time are described by the resulting partial differential equations. A necessary input to the species conservation equation is the intrinsic heterogeneous reaction rate law and accompanying reaction rate constant. Figure 2 shows a diagram of the monolithic reactor that is used to measure the intrinsic reaction rate constant for different operating temperatures. A cylindrical iron rod with a precisely known surface area is situated at the centerline of the reactor. Due to the slow rate of reaction, a quasi-steady plug flow analysis is used to extract the precise reaction rate constants from the rate of hydrogen production, measured with a mass spectrometer.

Research activities for the next reporting period will focus on making extensive measurements of the reaction rate constants and scale-up of the fluidized bed reactor for testing within the solar simulator, which is under construction.