Abstract

Project Summary: This project aims to develop a compact reactor unit that can be readily transported and installed for distributed hydrogen production from biomass-derived liquids at competitive costs.

Name of Applicant: Pacific Northwest National Laboratory

Project Director/Principal Investigators: Dr. Wei Liu

Project Title: Monolithic Piston-Type Reactor for Hydrogen Production through Rapid Swing of Reforming/Combustion Reactions

Project Objectives: Demonstrate the technology on an integrated reactor system

Project Description:

We propose to develop monolith reactors that integrate steam reforming reactions with in-situ CO_2 capture and heat transfer as a compact, high throughput unit for hydrogen production from bio-oils or biomass feedstock. Porous reaction channel walls in a monolith support are coated with a steam-reforming catalyst and alternate channels of the monolith are filled with a CO_2 sorbent. Two identical reactors are used. While the reforming is occurring in one reactor, the other is undergoing an exothermic regeneration. In the reforming reactor, CO_2 is captured as carbonates upon its formation from steam reforming reactions of bio-oil so that nearly pure H_2 gas is produced in one step. The heat released from the carbonation reaction is supplied to the endothermic steam-reforming reaction. Once the CO_2 sorbent is saturated and the hydrogen yield starts decreasing in the reforming reaction, reactor feed is switched to hot air for regeneration. During regeneration, coke on the catalyst is burned out, CO_2 is released from the carbonate, and the reactor is re-heated up. Heat released from coke combustion is supplied to endothermic the carbonate decomposition reaction. Frequent regeneration overcomes the catalyst deactivation - a major problem associated with catalytic reforming of bio-oils. As a result, the catalyst is maintained in a highly active state and the reforming reaction can be run at high space velocity to achieve high reactor throughput. Compared to conventional methane reforming processes, the proposed reactor system eliminates the high-temperature furnace and water-gas-shift reaction step. Direct production of high concentration H_2 from the reforming reaction substantially reduces the size of downstream hydrogen purification unit. The compact monolith reactor can be used as a stand-alone unit for hydrogen production from bio-oils. The projected reactor size is about 2 x 150 liters for a production capacity of 1500 kg H_2/day, which can be readily transported and installed. H2A analysis shows significant reduction to the capital cost and enhancement of carbon conversion efficiency.

Potential Impact:

Distributed H_2 production from biomass-derived feedstock is important to long-term energy and environmental sustainability in the USA. Conventional hydrogen production technologies are cost-prohibitive due to small processing capacity. The revolutionary reactor technology described here will make the economic utilization of this renewable resource become possible if successful developed.

Major Participants:

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