

PROCESS ANALYSIS AND CONTROL DESIGN FOR A TWO-CHAMBER BIOMASS GASIFICATION REACTOR PRODUCING “GREEN HYDROGEN”

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Abstract: Hydrogen production through coal gasification, utilizing pure oxygen to partially combust the feed and supply the required heat, has been practiced for nearly a century. Approximately forty years ago, Judd and his collaborators proposed an innovative concept involving two concentric reactors with solid particles (either inert or catalytic) recirculating between them.

In this design, the central reactor operates in a fast fluidized bed regime, using air to combust a portion of the feed and heat the solid particles to high temperatures. These hot particles are transported to the outer reactor, where they descend through a packed bed of solid particles. Fresh coal feed is injected into this packed bed, and high-temperature steam is introduced, facilitating the gasification reaction between the coal and steam. The heat required for the reaction is supplied by the hot solid particles. The resulting gasified product, primarily hydrogen, exits the system through a cyclone as the desired output. Meanwhile, the cooled solid particles and any unconverted or partially converted feed descend together, eventually recirculating back to the bottom of the central reactor to provide fuel for combustion. This separation of combustion and gasification, achieved by circulating solid particles to transfer heat between reactors, enables the use of air instead of costly pure oxygen. Over the past four decades, numerous variations of this concept, including designs with two distinct fluidized bed reactors operating at different flow rates, have been proposed and tested (References). A modification of Judd's original idea, replacing the concentric configuration with two side-by-side chambers connected at the top via a cyclone, was developed at the Technion. This arrangement offers a safer and potentially better-controlled process for the gasification of biomass and similar organic waste. It also provides a straightforward and scalable approach for scaleup.

A lumped-parameter model for the system has been developed, incorporating heat and mass balance equations and several simplifying assumptions. The optimal steady state, maximizing the gasification rate, has been identified, and the model has been linearized around this state. The system has been demonstrated to be asymptotically stable, controllable, and observable. An LQG controller has been designed to reject input disturbances and measurement noise, thereby improving the system's dynamic response.

Keywords: controllability, observability, reduced order process, LQG design, fluidization, gasification.