

## Optimizing Hydrogen Production from Biomass Pyro-Gasification in a Multi-Staged Fluidized Bed Reactor

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**Abstract :** In the transition to sustainability and the increasing use of renewable energy, hydrogen will play a key role as an energy carrier. Biomass has the potential to accelerate the realization of hydrogen as a major fuel of the future. Pyro-gasification allows the conversion of organic matter mainly into synthesis gas, or "syngas", majorly constituted by CO, H<sub>2</sub>, CH<sub>4</sub>, and CO<sub>2</sub>. A second, condensable fraction of biomass pyro-gasification products are "tars". Under certain conditions, tars may decompose into hydrogen and other light hydrocarbons. These conditions include two types of cracking: homogeneous cracking, where tars decompose under the effect of temperature ( $> 1000$  °C), and heterogeneous cracking, where catalysts such as olivine, dolomite or biochar are used. The latter process favors cracking of tars at temperatures close to pyro-gasification temperatures ( $\sim 850$  °C). Pyro-gasification of biomass coupled with water-gas shift is the most widely practiced process route for biomass to hydrogen today. In this work, an innovating solution will be proposed for this conversion route, in that all the pyro-gasification products, not only methane, will undergo processes that aim to optimize hydrogen production. First, a heterogeneous cracking step was included in the reaction scheme, using biochar (remaining solid from the pyro-gasification reaction) as catalyst and CO<sub>2</sub> and H<sub>2</sub>O as gasifying agents. This process was followed by a catalytic steam methane reforming (SMR) step. For this, a Ni-based catalyst was tested under different reaction conditions to optimize H<sub>2</sub> yield. Finally, a water-gas shift (WGS) reaction step with a Fe-based catalyst was added to optimize the H<sub>2</sub> yield from CO. The reactor used for cracking was a fluidized bed reactor, and the one used for SMR and WGS was a fixed bed reactor. The gaseous products were analyzed continuously using a  $\mu$ -GC (Fusion PN 074-594-P1F). With biochar as bed material, it was seen that more H<sub>2</sub> was obtained with steam as a gasifying agent (32 mol. % vs. 15 mol. % with CO<sub>2</sub> at 900 °C). CO and CH<sub>4</sub> productions were also higher with steam than with CO<sub>2</sub>. Steam as gasifying agent and biochar as bed material were hence deemed efficient parameters for the first step. Among all parameters tested, CH<sub>4</sub> conversions approaching 100 % were obtained from SMR reactions using Ni/ $\gamma$ -Al<sub>2</sub>O<sub>3</sub> as a catalyst, 800 °C, and a steam/methane ratio of 5. This gave rise to about 45 mol % H<sub>2</sub>. Experiments about WGS reaction are currently being conducted. At the end of this phase, the four reactions are performed consecutively, and the results analyzed. The final aim is the development of a global kinetic model of the whole system in a multi-stage fluidized bed reactor that can be transferred on ASPEN PlusTM.

**Keywords :** multi-staged fluidized bed reactor, pyro-gasification, steam methane reforming, water-gas shift

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