Supercritical water gasification of biomass model compounds and subsequent steam reforming to maximize H_2 yield

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Abstract

Hydrogen is considered as a promising alternative energy carrier. The supercritical water gasification (SCWG) of wet, dilute waste biomass resources is an efficient thermochemical process for sustainable hydrogen production. However, a significant amount of the produced hydrogen is found in the form of hydrocarbons, mainly methane. An innovative gas upgrading process has been developed and investigated to convert the carbon-bound hydrogen to diatomic hydrogen.

The process involves the subsequent steam reforming of the product derived from the SCWG of biomass model compounds. The present study involved the investigation of several operating parameters and their influence on the overall conversion of hydrocarbons to hydrogen. Ethanol was used as a biomass model compound dissolved in water with a concentration ranging from 5 to 20 wt.%. The SCWG of ethanol was performed at 600 °C and 265 bar in a tubular reactor. Downstream of the SCWG reactor, is a steam reforming (SR) reactor for the reforming of the produced hydrocarbons. The SR reactor is a fixed-bed catalytic reactor employing Ni-based commercial catalysts. The effect of temperature, pressure, and gas hourly space velocity in the SR reactor on the final SR product gas was investigated.

The SCWG of 8 wt% ethanol under the conditions applied here results in an average dry product gas with 47 vol% H_2, 22 vol% CH_4, 10 vol.% CO, 16 vol.% CO_2, and 5 vol.% C_{2+} hydrocarbons. The carbon gasification efficiency is between 99.6 and 99.9%. The investigation of temperature and pressure in the SR reactor showed that under industrially relevant pressures (20 – 40 bar), a temperature of at least 750 °C was required to achieve CH_4 conversions > 90% (Fig.1). Complete conversion of the C_{2+} was also observed under this operating regime. The experiments showed the importance of installing a steam reformer after a SCWG reactor for increased and sufficient hydrogen production.

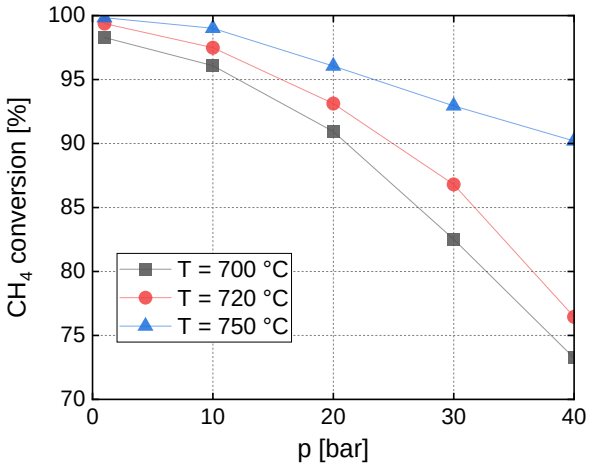

Figure 1: Conversion of CH_4 with pressure for different temperatures in the SR reactor (SCWG with 8 wt.% ethanol at 600°C and 265 bar, GHSV in SR reactor = 63500 h^{-1}.