Hydrogen-burning power plant with hydrogen produced by catalytic decomposition of methane: techno-economic perspectives

Yifu Li, John Z. Wen, Zhongchao Tan*
Department of Mechanical and Mechatronics Engineering, University of Waterloo, Waterloo, Canada
*Corresponding author: tanz@uwaterloo.ca

ABSTRACT

The power industry is upgrading the current technologies to produce clean and low-carbon electric energy. One of the options is to introduce hydrogen to power generation with H2-enriched fuels. However, the utilization of H2 in power generation raises safety concerns due to the intrinsic properties of H2, e.g., low molecular weight (2.016 g/mol), low density (0.089 g/L), and wide flammable limit range (4-75% in air). Thus, it would be safer to produce H2 onsite compared to offsite H2 production because it eliminates H2 transportation and storage.

This work proposes a rational process design of a hydrogen-burning power plant integrated with an onsite hydrogen production unit. Methane catalytic decomposition (MCD) is selected among different technologies for hydrogen production for integration with power generation. The advantages of MCD are as follows: 1) It produces the least CO2 compared to competing technologies for H2 production, which is less than 1/3 of adopting methane steam reforming coupled with carbon capture technologies; 2) It produces valuable solid carbon as a by-product, which can enhance the profitability of the power plant.

This presentation reports a comprehensive investigation on the proposed hydrogen-burning power plant based on process simulations using Aspen Plus software. First, Fe-based catalyst is identified as the most cost-effective catalyst for MCD compared to Ni-based and activated carbon (AC) catalysts. The former leads to the lowest net-levelized cost of electricity (net-LCOE) of -123.4 USD/MWh, which makes the power plant profitable even without the electricity sale. Then, further study shows that the modelled power plant reduces the CO2 emission by 80.2% compared to direct power generation from burning natural gas when the bypass ratio and conversion rate are set to 100%. However, the power output decreases sharply from 373.7 to 211.7 MW due to the reduced heating value of H2 compared to CH4. Finally, this study suggests a set of natural gas bypass ratios and CH4 conversion rates that ensure (a) the power plant produces at least 80% of the electricity compared to the direct power generation from natural gas and (b) achieves a more competitive net-LCOE even under the price fluctuations of raw materials.