High Throughput Membrane Reactor for On-board Hydrogen Generation

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Highlights

- High through-put membrane reactors (HT-MR) were developed.
- Methanol steam reforming was integrated with Pd-Ag membranes.
- Integrated MR performance was investigated for multiple arrangements
- Up to 80% H_2 recovery was observed with HT-MR performance as separator.

1. Introduction

In-situ hydrogen generation and separation with methanol fed membrane reformers are widely considered as a suitable alternative to stored H_2 based vehicles. However, utilization of hydrogen energy to electrical energy through PEM fuel cell requires up to 99.999% pure hydrogen in order to attain a stable power output. This poses the major challenge, as commonly used methods to produce hydrogen, steam reforming, gasification, etc., produces other by products (CO, CO_2, CH_4 etc.) Hence, an integrated hydrogen generation and separation technology such as membrane reactor is considered a feasible choice. Membrane reactors combine hydrogen generation and separation in a single unit using a highly hydrogen selective palladium based membrane. This integration results in an increase in performance of a thermodynamically limiting reaction such as steam reforming on the basis of Le Chatelier's principle due to, selective removal of hydrogen from the reaction product side. Hence, provides both higher conversion and high purity hydrogen. Several researchers have tried to optimize the performance of the membrane reformer which uses methanol as a fuel. However, most of the works reported in literature are for low through-put system.

The current study investigates high throughput (HT) technology to optimize hydrogen production using membrane reactors (MR) to power 1kW fuel cell. For this purpose, a prototype HT-MR consisting of three parallel modules was developed. Each module comprise of catalysts placed in the shell with membrane tubes hanging on top representing a shell and tube assembly separated with longitudinal baffles. The three modules indicate the inlet side, center and the outlet zone of the reactor. A total 10 membranes were parallelly tested using this system with distinct catalysts in each zone. The integrated system performance was determined in terms of permeate hydrogen flux and hydrogen recovery by comparing synthesized Pd-Ag membranes with commercial self-supported Pd-Ag membrane. With reference to the previous studies performed [1], this comparison allowed to evaluate HT performance of the developed system in lesser time.

2. Methods

Figure 1a shows the compartmentalization done using baffles in the membrane reactor designed and installed in our facility. Figure1b and 1c displays the tube sheet for hanging the membranes with the hood and a complete set up respectively. Hydrogen selective Pd-Ag membranes supported on porous SS (PSS) was synthesized using electroless plating [2-4] at pH 11 and temperature 60°C. All integration studies were performed using low CO selective Cu-Fe supported on Al_2O_3-Zn-ZrO_2 (AZZ) catalysts developed in the lab for steam reforming of methanol. Integration using varying multiple membrane arrangements was investigated to quantify the HT-MR performance. Further, reaction and permeate components were continuous analyzed using gas chromatography (GC) at constant temperature with porapak Q column connected in parallel with molecular sieve.

Figure 1. Photograph of HT-MR setup

3. Results and discussion

Figure 2 shows the behavior of HT-MR with four membrane assembly as a separator, where membranes are placed at different locations inside the HT-MR setup. Results clearly indicate that the membrane arrangements inside can significantly affect the hydrogen recovery as well as flux. Using 100μm commercial Pd-Ag membrane a maximum 80% of hydrogen recovery was observed with MR as a separator. Using the similar arrangements, integrated MR performance with the commercial as well as synthesized Pd-Ag membrane with Cu-Fe bi-metallic catalyst supported on AZZ will be shown in the final manuscript. Further, data for different membrane and catalyst arrangements will be presented to provide a proper design of HT-MR.

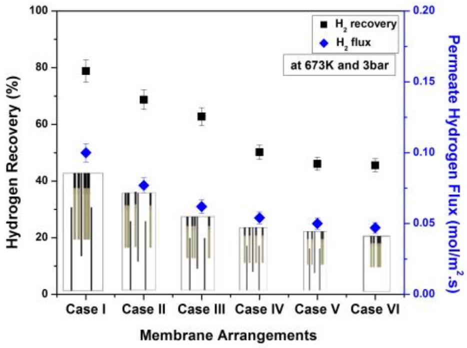

Figure 2. HT-MR performance as a separator

4. Conclusions

The current study demonstrates the investigation on membrane reactor performance using high throughput technology. Optimization of HT-MR was performed using series of membrane arrangements and was initially tested as a separator. Thereafter, the optimized design of HT membrane separator was integrated with the synthesized methanol reforming catalyst (Cu-Fe on AZZ). Different arrangements of catalyst and membrane were tried to achieve maximum hydrogen recovery and flux from permeate side. Hydrogen flow rate sufficient for 1 kW power production was found for optimized design when integrated with PEM fuel cell.

References

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Keywords

"Pd-Ag membranes; Integrated HT-MR; Methanol steam reforming; Low CO selective Cu-Fe catalyst."