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A Heat Integrated Steam Reforming Membrane Reactor for Fuel Cell Vehicles

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Highlights

- Steam reforming process intensification for hydrogen fuel cell vehicle application
- Catalytic heat exchange reactor with palladium alloy membrane and recycle
- Experimental results in good agreement with modeling predictions

1. Introduction

A heat integrated steam reforming membrane reactor was investigated for the development of a gasoline fuel processor for fuel cell vehicles. This reactor utilizes Le Chatelier's Principle for driving thermodynamically equilibrium limited steam reforming reactions at higher pressures. Steam reforming at higher pressures also reduces the palladium alloy membrane area required. Coupling steam reforming with a hydrogen selective membrane provides essentially pure hydrogen for optimal fuel cell performance.

2. Methods

Engineering models were used extensively to help define and refine the fuel processor design. The catalytic heat exchange reactor was coupled to a separate palladium-alloy membrane and used recycle of hydrogen depleted reformate to achieve high efficiencies at moderate operating temperatures and pressures (650ºC, 20 Bar). Recycle was achieved by using a steam ejector. Catalytic combustion of the hydrogen depleted reformate with lean air fuel cell cathode exhaust (11% O2) supplied the heat required for steam reforming.

3. Results and discussion

In laboratory studies, excellent heat transfer was observed when conducting catalytic combustion and steam reforming co-currently on opposing walls of the wash coated reactor tubes. Membrane hydrogen permeate was obtained from a variety of feeds, including isooctane, naphtha and methane, at reaction temperatures of 600-700ºC. The experimental results were in close agreement with the modeling predictions. Our modeling suggested that our steam reforming approach could have thermodynamic efficiencies of up to 40%.

4. Conclusions

While considerable research and development would be required to advance this technology, these results demonstrate the potential of the heat integrated steam reforming membrane reactor system onboard a fuel cell vehicle – a most challenging example of process intensification.

Keywords

Reactors; process intensification; steam reforming; membrane reactor

References

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