Ammonia Electrolysis to Power a Hydrogen Fuel Cell: Case Study of an Integrated System

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An integrated fuel cell power system is presented, which includes an ammonia electrolytic cell for *in-situ* hydrogen production combined to a proton exchange membrane fuel cell (PEMFC). Ammonia electrolysis in alkaline media as a source of hydrogen was selected because of low energy consumption during electrolysis in alkaline media,[1] high faradaic efficiency of the electrolytic process,[2] high specific energy (in kWh/kg),[3] simplicity of storage,[4] and absence of production of poisoning, toxic, or greenhouse gases.[4]

Figure 1 describes a selected design for the integrated system. After exiting the PEMFC, unconsumed hydrogen stream flows either through a re-circulation loop or through a combustion chamber (Burner). Heat released during combustion is transferred to the inflow of the electrolytic cell in order to maintain a temperature of 65°C both in the electrolytic cell (EC) and the fuel cell (FC). Two condensers (C1 and C2) are used before and after the fuel cell to prevent its flooding by condensing water vapor from EC and from the re-circulation loop, respectively. In this paper, one also investigates the possibility of powering EC with electrical current γI produced by FC providing autonomy of the integrated system.

Mass and energy balances corresponding to the system described in Figure 1 can be solved using either simulation software ASPEN[5] or computational mathematics software MAPLE.[6] The objective of the simulation is to determine or optimize, with respect to applied current, the following parameters:

- Realistic molar flow rates of ammonia feed for the integrated system
- Optimum re-circulation flow rate
- Optimum utilization of current produced by FC to power EC
- Overall efficiency of the process

The overall electrolysis reaction is given by:

$$2NH_3 \Leftrightarrow N_2 + 3H_2 \qquad (1)$$

Corresponding efficiency $\eta_1$as a function of the applied current density was determined in our laboratories. The efficiency η_2 of FC is taken from the literature.[7]

The corresponding overall reaction is:

$$H_2 + \frac{1}{2}O_2 \Leftrightarrow H_2O \qquad (2)$$

The amount of hydrogen fed to FC is R times the stoichiometric amount as determined by Equation (2). The parameter R can be modified for the purpose of higher efficiency of FC. Additional parameters considered are the efficiency η_3 of burning hydrogen gas for heat production, the heat exchange efficiency η_4 between hot gases and EC feed stream.

REFERENCES

1. F. Vitse, M. Cooper, G. G. Botte, *"Electroxidation of ammonia for the production of hydrogen", Proceedings of the ECS symposium Advanced Materials for Fuel Cells and Batteries*, Orlando, 2003.

2. T. Katan, R. J Galiotto, J. *Electrochem. Soc.*, **110** (9), 1022 (1963).

3. R. Metkemeijer, P. Achard, *J. Power Sources*, **49**, 271 (1994)

4. R. A. Wynveen, *Fuel Cells*, **2**, 153 (1963).

5. Online support at http://support.aspentech.com/

6. M. L. Abell, J. P. Braselton, *"The Maple V Handbook"*, AP Professional, Cambridge, Massachusetts (1994).

7. F. Babir, T. Gomez, Int. *J. Hydrogen Energy*, **22**, 1027 (1997).

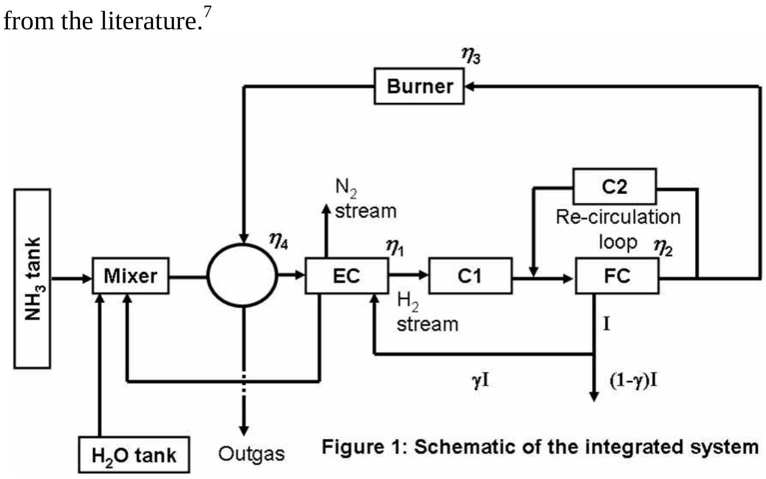

Figure 1: Schematic of the integrated system