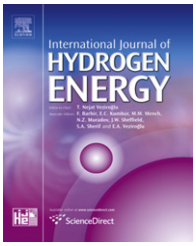
INTERNATIONAL JOURNAL OF HYDROGEN ENERGY 36 (2011) 319–325

Available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he



Study on a compact methanol reformer for a miniature fuel cell

Liwei Pan, Changjun Ni, Xuebin Zhang, Zhongshan Yuan, Chunxi Zhang, Shudong Wang[*]

Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian 116023, PR China

ARTICLE INFO

Article history:
Received 19 July 2010
Received in revised form
28 August 2010
Accepted 29 August 2010
Available online 8 October 2010

Keywords:
Methanol reforming
Reformer
Hydrogen production
Miniature fuel cell

ABSTRACT

A compact methanol reformer for hydrogen production has been successfully fabricated, which integrated one reforming chamber, one water gas shift reaction chamber, two preheating chambers and two combustion chambers. It can be started-up at room temperature by the combustion of liquid methanol in the combustion chamber within 7 min without any external heating. The cold start response of the methanol reformer has been investigated using different parameters including methanol and air supply rate, and the experiments revealed that the optimum methanol and air flow rate were 0.55 mL/min and 3 L/min respectively. The results indicated that this methanol reformer can provide a high concentration of hydrogen (more than 73%) and the system efficiency is always maintained above 74%. It is further demonstrated in more than 1600 h continuous performance that the reformer could be operated autothermally and exhibited good test stability.

1. Introduction

Fuel cells are electrochemical systems converting chemical energy directly into electrical energy. Heat and water are by-products. These systems work very efficiently and produce low emissions. In the first stage of the research about hydrogen and fuel cell, more attention has been focus on Fuel Cell Vehicles. But these technologies are too difficult to meet the demand for onboard use and seemingly not to be into practice in the near future. Currently, the ever-increasing use of portable electric and electronic devices such as laptop computers, cellular phones, personal digital assistants increases the need for efficient man-portable power supplies [1–3].

The miniature fuel cell has much drawn attention as a primary candidate for an alternative power source because the energy density is higher than that of the existing batteries [4]. Because of the size, portability and low operating temperature, direct methanol fuel cells (DMFCs) and proton-exchange membrane fuel cells (PEMFCs) have been envisaged as suitable power sources for the small portable applications [5,6].

Nevertheless, DMFC devices presently suffer from methanol crossover across polymer electrolyte membranes [5–9] and poor methanol electro-oxidation kinetics [5]. Though PEMFC is not suffered from the fuel crossover, the storage of hydrogen is a technical bottleneck in the successful development of PEMFC systems. Due to the difficulty in transporting and storing hydrogen, on-site generation of hydrogen by reforming hydrocarbons and alcohols seems to be more realistic. Specially, methanol is an attractive fuel because its energy density is much higher than that of hydrogen, and it is an inexpensive liquid that is easy to handle, store and transport.

However, even parts per million level of CO can cause serious poisoning for PEMFC. So immediately after reforming,

---

[*] *Corresponding author*. Fax: +86 411 8466 2365.
E-mail address: wangsd@dicp.ac.cn (S. Wang).

0360-3199/$ – see front matter © 2010 Professor T. Nejat Veziroglu. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijhydene.2010.08.142

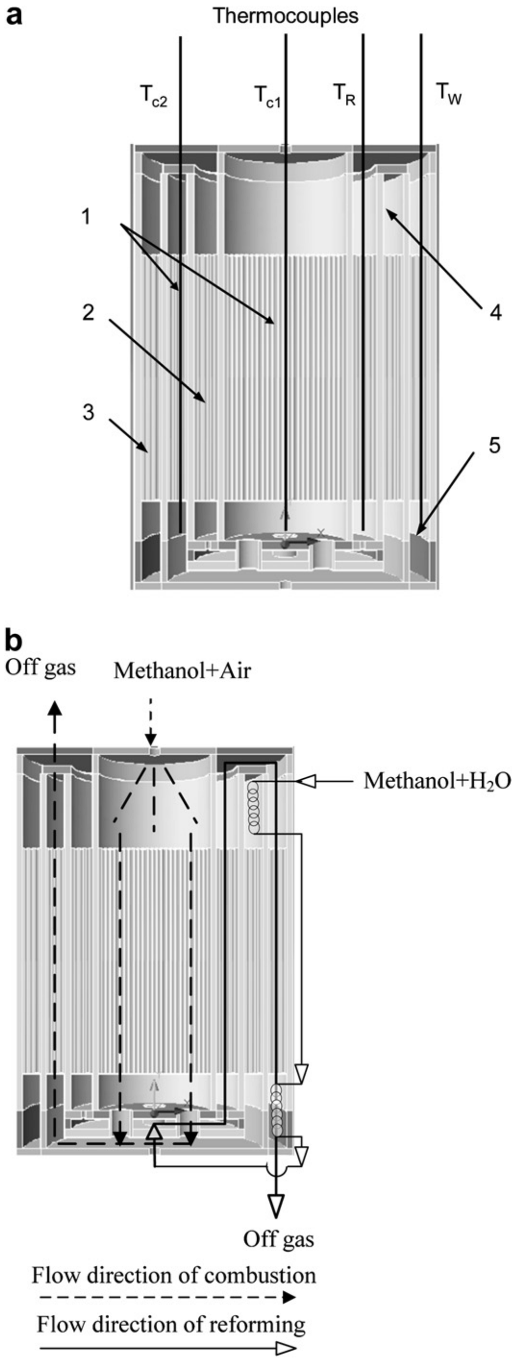


Fig. 1 – Cutaway drawing of the methanol reformer (1. Combustion chamber; 2. Reforming chamber; 3. Water gas shift reaction chamber; 4. Preheating chamber I; 5. Preheating chamber II).

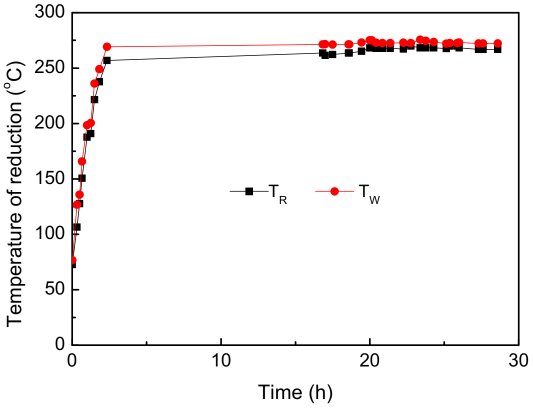


Fig. 2 – The reduction temperature variation in reforming and water gas shift chambers during the reduction process.

a few CO cleaning steps such as high and low temperature water–gas shift reactions and CO preferential oxidation are needed to reduce the concentration of CO in the reformate, but this series of steps results in a complex fuel processor system. Consequently, recent efforts using fuel processors in portable power systems have taken an alternative approach to the CO problem. In these cases, a promising solution to this problem is to use an innovative small power system integrating the reformer with a miniature fuel cell [10,11], and in this fuel cell technology usually utilizes the phosphoric acid imbibed polybenzimidazole (PBI) membranes originally developed by Case Western University [12], and now Motorola and UltraCell have developed series of portable power by this concept. The PBI cell operating at above 150 °C, relative to the well-developed PEMFC technology typically operating at 80 °C, can tolerate up to 1% CO and 10 ppm SO_2 in the fuel stream, allowing for simplification of the fuel processing system and possible integration of the fuel cell stack with fuel processing units [13].

In the recent years, numerous groups using multiple methods have developed microreactors for hydrogen production [14–20]. Compared with large industrial units, heat losses are also substantially greater for portable systems. Substantial extra sources of heat are then required for portable and microreformers. Electrical heating is typically used, but is viable only for research purposes, as supplying sufficient electrical power severely decreases the efficiency of a complete system [21–24]. In addition, simplicity is one of the primary system features or improvements needed to realize effective portable fuel processor/fuel cell systems. It minimizes the balance-of-plant inherently improves reliability and efficiency as well as lowers weight and cost.

In this study, a compact methanol reformer was developed based on our own design and fabrication. Vaporization

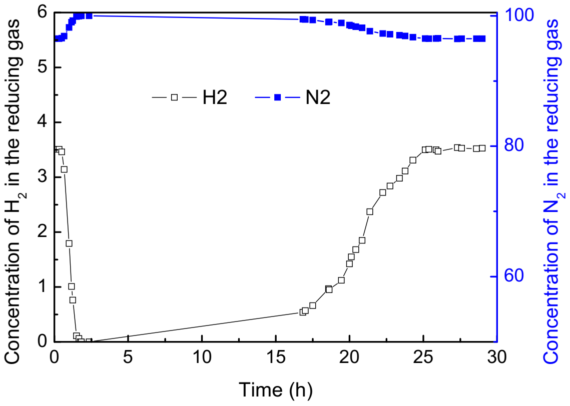


Fig. 3 – The variation of reducing gas during the reduction process.