Applied Thermal Engineering 41 (2012) 104–110

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

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

A combined capillary cooling system for fuel cells

Ana Paula Silva, Renan M. Galante, Pablo R. Pelizza, Edson Bazzo*

Federal University of Santa Catarina, Mechanical Engineering Department, Laboratory of Combustion and Thermal Systems Engineering, Campus Universitário, 88040-900 Florianópolis, SC, Brazil

A R T I C L E I N F O

Article history:
Received 12 April 2011
Accepted 4 January 2012
Available online 24 January 2012

Keywords:
Cooling capillary system
PEMFC
PEM fuel cells
CPL
Heat pipes

A B S T R A C T

Control of the operation temperature has an important influence over the performance of a Proton Exchange Membrane Fuel Cell (PEMFC). In this study a two-phase heat transfer system is proposed as an alternative for the cooling and thermal control of a PEMFC. The proposed system consists of a Capillary Pumped Loop (CPL) connected to a set of constant conductance heat pipes. Ceramic and stainless steel mesh wicks were used as the capillary structures of the CPL and heat pipes, respectively. Experimental results are reported herein for the separate components, i.e. three ¼-inch diameter stainless steel heat pipes, one CPL and for the assembled cooling system. Different tests were performed for power inputs up to 50 W. Acetone was used as the working fluid for the CPL and deionized water for the heat pipes. All tests were considered successful, with the proposed system providing the required heat dissipation and maintaining the required temperature operation range for PEM fuel cells.

1. Introduction

The fuel cell is an electrochemical device designed to convert chemical energy into electrical energy. It is composed of an electrolyte which transports ions between two electrodes. Hydrogen enters the anode while oxygen or air enters the cathode. In the Proton Exchange Membrane Fuel Cell (PEMFC) the electrolyte is a proton conducting membrane that transports the H^+ from the anode to the cathode. In the cathode $2H^+$ and ½O_2 react exothermically producing water. Electrons flow through an external circuit generating a continuous current (Fig. 1).

The PEMFC has been proposed as an alternative approach to portable energy generation systems and vehicles [4] due to its low operation temperature, compact size, light weight, quick startup, long useful life and the capacity to work in a discontinuous regime. However, designing an efficient system for the thermal control of the PEMFC remains an important technological challenge to be overcome.

The temperature control plays an important role in the overall PEMFC performance. High temperatures can dry out the membrane and interrupt the proton conduction and electricity generation. On the other hand, high temperatures are favorable for the chemical reaction. There is a narrow optimal temperature range at around 70–90 °C considering the contrasting temperature effects in terms of performance. Currently, the operation temperature is controlled by inefficient single-phase heat transfer using water or air. In order for the PEMFC technology to become competitive in the market, an efficient cooling system with low energy consumption is required.

A joint project has been carried out by CETHIL – Centre de Thermique de Lyon to develop a two-phase heat spreader (TPHS) as a proposed cooling system for application in the PEMFC [6]. In the design, the cooling system was not integrated into the fuel cell. A TPHS resembles a mini flat heat pipe with a single vapor channel. Different capillary structures and combinations of materials and working fluids were successfully tested. The best result was obtained for a TPHS made of longitudinal grooves in a thermosyphon orientation, using methanol as the working fluid. The maximum temperature did not exceed 75 °C and the difference between the evaporator and the condenser was 3.5 °C. An experimental validation was also reported to show the ability of a proposed numerical model to predict the meniscus curvature radii related to the maximum heat transfer capability of the TPHS [7].

Faghri (2005a and 2005b) [2,3] filled two patents for different two-phase systems for fuel cell cooling. However, no results were presented to validate the proposed mechanisms. These cooling systems are heat pipes in two different configurations for the PEMFC. The first design proposes micro heat pipes integrated into a fuel cell bipolar plate and the second design uses flat heat pipes integrated into a bipolar plate.

Vasiliev and Vasiliev (2008) [8] proposed different heat pipe designs for thermal fuel cells: micro/mini heat pipes, a loop heat pipe (LHP), a loop thermosyphon, a LHP with non-inverted

* Corresponding author. Tel.: +55 48 3721 9390.
E-mail address: ebazzo@emc.ufsc.br (E. Bazzo).

1359-4311/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.applthermaleng.2012.01.008