Applied Thermal Engineering 40 (2012) 161–173

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

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

Tools for designing the cooling system of a proton exchange membrane fuel cell

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A R T I C L E I N F O

Article history:
Received 10 April 2011
Accepted 4 February 2012
Available online 14 February 2012

Keywords:
Cooling
Channel geometry
Boiling
PEMFC
Pressure drop
Dryout

A B S T R A C T

Proton exchange membrane fuel cell (PEMFC) requires a careful management of the heat distribution inside the stack. The proton exchange membrane is the most sensitive element of this thermal management and it must operate under specific conditions in order to increase the lifetime and also the output power of the fuel cell. These last decades, the enhancement of the output power of the PEMFC has led the manufacturers to greatly improve the heat transfer effectiveness for cooling such systems. In addition, homogenizing the bipolar plate temperature increases the lifetime of the system by limiting the occurrence of strong thermal gradients. In this context, using a fluid in boiling conditions to cool down the PEMFC seems to be very suitable for this purpose. In order to compare the thermal performances between a coolant used in single-phase flow or in boiling flow conditions, we have built an experimental set-up allowing the investigation of cooling flows for these two conditions. Moreover, the geometry of the cooling channels is one of the key parameters which allows the improvement of the thermal performances. Indeed, the size or the aspect ratio of these channels could be designed in order to decrease the thermal system response. The sizing of the fuel cell cooling system is of paramount importance in boiling flow conditions because it can modify, not only the pressure losses along the channel and the heat transfer coefficient like in a single-phase flow but also, the onset of nucleate boiling (ONB) and the dryout point or critical heat flux (CHF). Thus, in order to understand some heat transfer mechanisms, which are geometry-dependent, a parametric study was completed by considering flows in four different rectangular channels. Finally, this study allows a better insight on the optimization of the geometrical parameters which improve the thermal performances of a PEMFC, from a cooling strategy aspect point of view.

1. Introduction

For about thirty years, fuel cells have been at the center of many industrial concerns due to their higher performance and their lower environmental impact compared to thermal engines. Moreover, the increase in legal constraints relative to environmental protection and specifically the limitation of greenhouse gases has led the manufacturers to consider low polluting strategies. One of the strategies is to use fuel cells which could allow for the broadening of energy production.

One of the main advantages of operating PEM fuel cells is related to their low running temperature which allows a quick start up, in comparison with other types of fuel cells. However, several drawbacks due to this low running temperature, such as the poisoning of the electrodes by carbon monoxide (CO) or problems of water management have already been reported in the literature [1,2]. There is a very close relationship between thermal management in the stack and operating performances of a PEMFC. Thus to ensure the good operation of a PEMFC each cell should be carefully cooled. This is due to the substantial amount of heat that is generated in each cell by entropy changes and irreversibility during operation. If too much heat is removed, the kinetic of the reaction is adversely affected, resulting in lower stack performance. Conversely, if the stack is allowed to heat up beyond its optimal operation temperature, the membrane dries out and its proton conductivity drops. The control of the membrane water content is therefore also a vital part of the stack management strategy. Intuitively, placing a cooling plate between the successive adjacent cells should allow for a good control of the thermal envelope and ensure nearly identical operational conditions throughout the stack; this, however, would increase the cost, weight, volume, and complexity of the system. In light of this, a careful balance has to be made in designing such a cooling system.

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doi:10.1016/j.applthermaleng.2012.02.008