Progress in Energy and Combustion Science 000 (2017) 1–33

Contents lists available at ScienceDirect

Progress in Energy and Combustion Science

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

Cold start of proton exchange membrane fuel cell

Yueqi Luo, Kui Jiao*

State Key Laboratory of Engines, Tianjin University, 135 Yaguan Road, Tianjin 300350, China

A R T I C L E I N F O

Article History:
Received 20 January 2017
Accepted 9 October 2017
Available online xxx

Keywords:
PEM fuel cell
Cold start
Transport phenomena
Performance optimization

A B S T R A C T

In this review, "cold start" is defined as the startup of proton exchange membrane (PEM) fuel cells from subfreezing temperatures. Problems occurring during the cold start pose some of the remaining barriers to commercial applications of PEM fuel cells in transportation, stationary, auxiliary and portable systems. Fundamental studies of transport phenomena are critical to a better understanding of the mechanisms of cold start and offer ultimate solutions to resolving cold-start issues. In this review, experimental studies are discussed, focusing on output performance degradation, water and ice visualization, and component damages during a cold start. Analytical, numerical, and microscopic models and their results are also discussed. One of the emphases is on transport phenomena relevant to cold starts, including supercooling, phase change and transport of water in the membrane, catalyst layer, microporous layer, and gas diffusion layer. Another emphasis is placed on the strategies utilized to optimize cold-start processes for improved performance. The strategies include material designs of the components, cell/stack structures, and startup mode/load controls. It is shown that all of the effective strategies to mitigating cold-start problems derive from a basic understanding of the transport mechanisms during a cold start. It is also suggested that future models for this problem should place a great deal of attention in supercooling phenomena and water phase-change and transport in multilayer porous media. Lastly, more advanced experimental methods, such as real-time water/ice visualization and cryogenic microscopy, are needed to validate emerging theories and models.

Contents

* Corresponding author.
E-mail address: kjiao@tju.edu.cn (K. Jiao).

http://dx.doi.org/10.1016/j.pecs.2017.10.003

1. Introduction

Proton exchange membrane fuel cells (PEMFCs) are a promising energy conversion device that has the potential for applications in automotive, stationary, portable, auxiliary power systems, and even submarines and space shuttles [1]. A PEM fuel cell consumes hydrogen and oxygen in the anode and cathode electrodes, respectively. It converts chemical energy directly into electrical energy. PEM fuel cells have unique advantages over traditional combustion engines. As a power source, it is clean, since the only exhaust is water. It works quietly and gently, as there are no moving components inside. It can have high power density and operate at low temperatures [2].

1.1. Origin and importance of cold start

One of the most exciting prospects of PEM fuel cells is in automotive applications. In 2017, three major automakers (Toyota, Hyundai, and Honda) will release their latest fuel cell vehicles (FCVs) to the market [3]. FCVs are expected to survive in a variety of environments and especially under extreme conditions, such as subfreezing temperatures. The normal operation of PEM fuel cells requires a constant supply of fuel and oxidants from the flow channel to the catalyst layer, as well as the drainage of produced water. In subfreezing temperatures, the water produced can freeze in porous layers and even in flow channels. Ice then accumulates, blocking gas transport

Please cite this article as: Y. Luo and K. Jiao, Cold start of proton exchange membrane fuel cell, Progress in Energy and Combustion Science (2017), http://dx.doi.org/10.1016/j.pecs.2017.10.003