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Numerical analysis of modified parallel flow field designs for fuel cells

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ABSTRACT

Bipolar plates engraved with flow fields are key components in proton exchange membrane fuel cells (PEMFCs). These flow fields are important because they isolate and enhance the diffusion of the reactant for the electrochemical reaction. The flow fields on these plates are pathways that both supply reactant and remove reaction products from the anode and cathode of a PEMFC. Fluid flow in these flow fields can greatly affect the performance and life span of the device. In this study, conventional and modified parallel flow field designs were analyzed using computational fluid dynamic modeling. The designs split flow into variant channel widths to facilitate even reactant distribution. Flow characteristics are presented, including the pressure and velocity variations in the flow channels across the flow field and comparison of the pressure-drop characteristics of different flow fields. The results show that multiple stages of flow distribution can achieve an evenly distributed pressure drop with an ideal distribution of reactant among channels.

Introduction

Nationally, concern has grown about the depletion of fossil fuels and climate changes caused by their burning. The proton exchange membrane fuel cell (PEMFC) has been identified as one of the most effective power systems to substitute for conventional ones in automotive industries [1]. PEMFCs have low emission and high efficiency and appear to be the most promising option to build a future low-carbon environment [2]. Only current, water and heat are produced by PEMFCs through their electrochemical reactions between hydrogen and oxygen.

A bipolar plate in the PEMFC stack acts as its mechanical structure; it holds the membrane electrode assembly for efficient collection and transmission of current and separates the hydrogen and oxygen reactants on the anode and cathode sides [3]. The flow field on the bipolar plate is the path for the reactant to flow and diffuse into the membrane electrode assembly to cause an electrochemical reaction. Uneven flow distribution and a high pressure drop in the flow field design is the most significant design challenge for fuel cells [4]. To achieve maximum power output of a fuel cell, a uniform distribution of the reactant is crucial. Uneven flow distribution in the flow field leads to uneven production of water, heat and current. This, in turn, leads to localized hotspots or flooding within the cell and directly reduces its performance

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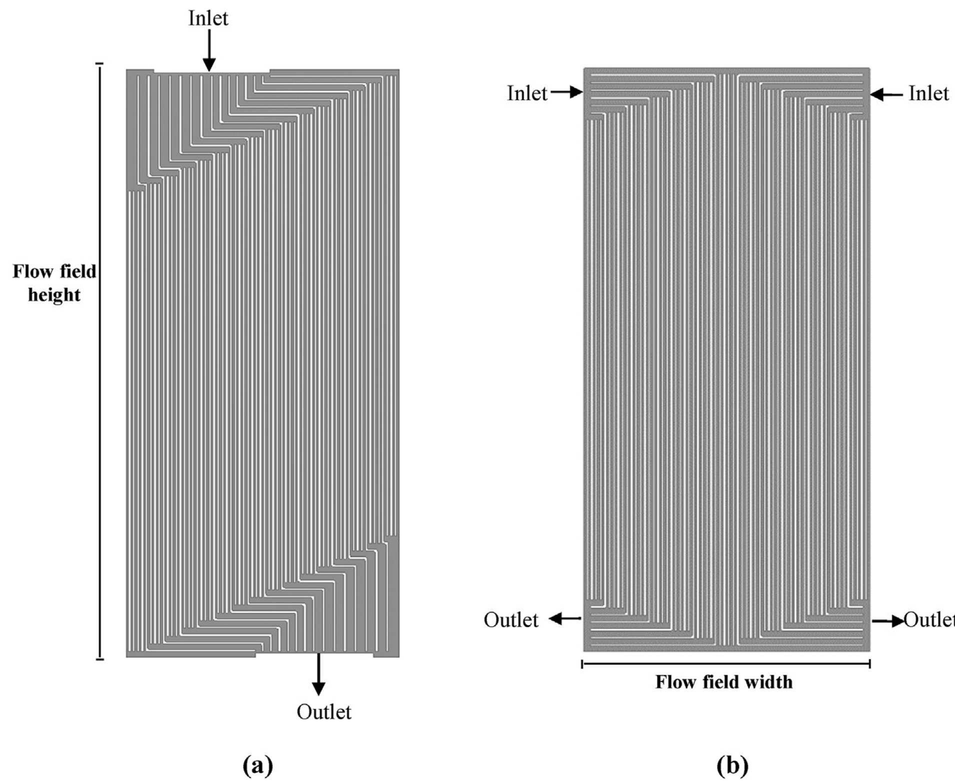

Fig. 1 – Modified flow field design with three sections of channels: inlet, mid-section and outlet. (a) modified parallel flow field with single inlet/outlet, (b) modified parallel flow field with double inlet/outlet.

and durability. The flow field also plays an important role in removing the water and heat byproducts produced by the electrochemical reaction. Water remaining in the flow field causes uneven reactant distribution; water in the channels blocks the reactant pathway [5]. A high pressure drop in the flow field design can reduce the flooding effect; however, it also leads to high parasitic power, which reduces the overall efficiency of the cell. Moreover, a high pressure drop also causes cross-leakage of reactant and incurs additional mechanical stresses that damage the cell. Numerous researchers have investigated the effects of various flow field designs to increase PEMFC performance, such as a parallel flow field, a serpentine flow field, an interdigitated flow field and a pin-type flow field [6–9]. Among the different types of flow fields, serpentine and interdigitated fields have received the most attention from researchers. A serpentine flow field with multiple turns in a single path helps force the reactant into the gas diffusion layer to react and also creates a larger pressure drop that enhances the reactant flow from inlet to outlet [10–14]. On the other hand, an interdigitated flow field with a dead-end channel increases the reaction rate by forcing the reactant to diffuse into the gas diffusion layer [15–17]. However, large initial pressures are required for serpentine and interdigitated flow fields to force the reactant into the gas diffusion layer. Historically, it has been known that a parallel flow field has a simple and cost-saving design; however, researchers have not given it much attention. This is because of the poor distribution of reactant of the conventional parallel flow field [18]. More recently, research has been conducted to improve PEMFC performance with parallel flow fields. Bi et al. [19] have experimentally enhanced parallel flow field design by adding a gas flow restrictor channel near the flow field inlet. This improved the flow distribution so that the pressure drop in the flow field channel increased compared to the conventional parallel flow field. Research was also performed numerically on multiple design modifications to the conventional parallel flow field to improve the flow distribution [20]. Among eight design changes that have been reported, it was concluded that the increase in collector area widths, the top and bottom areas of the flow field, can enhance uniform flow distribution. Wang and Wang [21] modified the conventional parallel flow-field design and reported that reducing the ratio of channel area to intake header improves the uniformity of the flow. Reduction of this ratio is achieved by separating the active area into two areas; two inlets and outlets were used.

The objective of this paper is to establish a modified parallel flow-field design for fuel cells for application in automobiles. A large active area is required to achieve the high power output cars need. To ensure a uniform flow distribution in a conventional parallel flow field, multiple inlets are required for a large active area. This is not economical because adding inlets increases the total area of the bipolar plate. Thus, improvement of the modified parallel flow field was

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