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Flow distribution analyzing for the solid oxide fuel cell short stacks with rectangular and discrete cylindrical rib configurations

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ABSTRACT

The commercial software Ansys is utilized to simulate and compare the fuel and air flow distribution characteristics within the specific 10-cell solid oxide fuel cell (SOFC) stacks with different rib configurations, such as the rectangular, discrete symmetric cylindrical and staggered cylindrical rib configurations, respectively. The stack flow uniformity index and the standard flow deviation index are used to properly represent the flow distribution qualities among the piled cell units at stack level and among the rib channels within each cell unit, respectively. Part of the result shows that for a 10-cell short stack, the influences of different rib configurations on the flow uniformity at stack level are negligible, which further approves that a short modular stack as 10-cells is a proper choice in establishing the large power supplied SOFC system. A typical 10-cell modular SOFC using the rectangular rib configuration to establish the fuel rib channels and using the discrete symmetric cylindrical rib configuration to construct the air rib channels is concluded to be proper designing in achieving a good stack performance, while carefully considers the produced current collecting, flow distribution over the electrode surface and the reaction species transporting within the composite electrode.

Introduction

Solid oxide fuel cell (SOFC) has been considered to be the promising electric power generating devices on account of its several advantages, such as, fuel flexibility, high power density, compactness and so on [1–7]. Furthermore, the planar SOFC stack is widely utilized because it is easy to be manufactured. However, to be of high cost as well as many technology problems unresolved, such as non-uniform flow rate, fuel leakage and cell degradation, full commercialization of the planar SOFC technology, still faces great challenges

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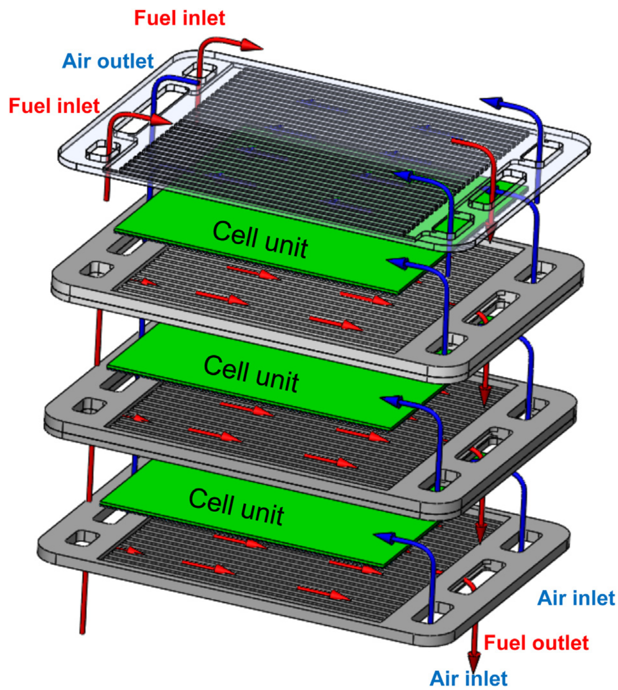

Fig. 1 – A typical planar SOFC stack structure using traditional rectangular ribs configuration, designed by Jülich [28].

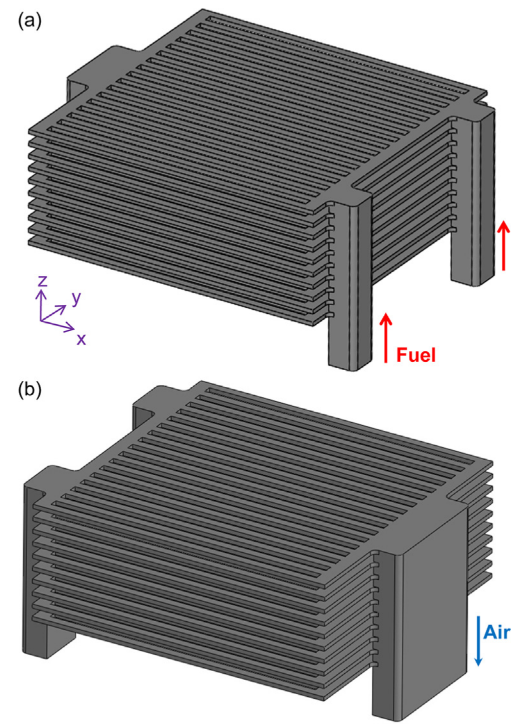

Fig. 2 – The relevant flow paths within the typical 10-cell planar SOFC stack, a) for fuel flow path, b) for air flow path.

[8–13]. Generally, non-uniform flow rate is the root cause of no sufficient reaction and decreasing power density. Thus, it is an important parameter to evaluate the performance of the SOFC system. As the experimental equipment and supplies are very expensive and the measurement results may be affected by the working environment, the numerical simulation method is generally agreed to be a proper method to study the flow characteristics within the SOFC stack.

In recent years, many model examples have been introduced in the literature to investigate the flow distribution characteristics and many studies have devoted themselves into researching this technology through analytical and numerical approaches [14–22]. In 1997, an analytical method has been proposed by R. J. Boersma and N. M. Sammes to figure out the pressure and flow distribution within a fuel cell stack [23]. A 2D calculated fluid dynamics (CFD) model has been developed to study the effects of the rib thickness on the pressure and flow distributions within a Molten carbonate fuel cell stack [24]. After that, a more detail CFD calculation has been further focused on the T-type junction within the inlet and outlet manifolds. The result showed that the flow pressure will increase, while the fluid flows through the T-type junction in the inlet manifold side, and the opposite conclusion can be obtained on the outlet manifold side. R. J. Kee et al. have used the Twopnt software to establish a 2D CFD model for the Z-type flow path in a specific SOFC stack, and proposed that the ratio between the inlet manifold and the outlet manifold is a key factor to attain uniform flow rate [25]. Koh. et al., have simulated a 2D SOFC stack model piled by 100 unit cells to investigate the pressure drop between the inlet and outlet manifolds [16], and verified that these pressure losses would have great relation with the flow distribution quality among the piled cell units. Winkler et al., have compared the flow distributions of the tubular, planar and ring tubular fuel cell stack through the theoretical analysis approach [17]. Xia et al., have coupled the momentum, energy, continuity and charge conservation equations to study the flow characteristics within the SOFC stack [19], and concluded that co-flow arrangement design may attain more uniform temperature and current distribution contrast to the count-flow arrangement design in a specific structure.

Generally, in a typical planar SOFC stack piled by several unit cells, the rib configuration within each unit cell will play an important role in determining the SOFC performance. Taking the traditional rectangular rib configuration in cathode side for example, i) one of its important functions is collecting the produce electric current from the reaction sites with low voltage loss. Apparently, adopting of different rib configuration and geometric parameters will lead to different electric current conducting path and characteristics, while the electric currents are produced at the cathode electrochemical reaction sites. ii) another important function of the solid ribs is constructing the flow rib channels to distribute the fluid over the fuel cell unit surface uniformly, and providing convenience for the reactant to diffuse within the porous composite cathode. The air rib channels over each single cell are split and constructed by the solid rectangular ribs. Thus the solid rib configuration will determine the flow distribution quality over