Effect of Flow Configuration on the Performance of One-Dimensional Solid Oxide Electrolysis Cell

Ju Ho Lee*, Tae-Hoon Lee, Chang Keun Jo, Min-Hwan Kim
Korea Atomic Energy Research Institute, 111, Daedeok-daero 989 beon-gil, Yuseong-gu, Daejeon, Republic of Korea
*jhlee835@kaeri.re.kr

1. Introduction

High Temperature Solid Oxide Electrolysis(HTSE) is considered as promising technology for hydrogen production without carbon dioxide release for various heat sources. Mixture of steam and hydrogen is supplied to cathode of electrolyzer in which water dissociation reaction occurs and air or steam is fed to anode of electrolyzer. These streams are related to the heat removal from or heat supply to electrolyzer cell and thus its flow configuration considerably affect the cell performance and operation. In this study, we evaluate the effect of flow configuration, counter-flow and co-flow, on the performance and operation of HTSE using one-dimensional electrolyzer model

2. SOEC model

A planar cell type is considered and its geometry is given in the literature [1]. In cathode side, a mixture of steam and hydrogen is fed and only air is considered as anode sweep gas. Two flow configuration, co-flow of which both streams flow in the same direction and counter-flow in the opposite flow, are considered and corresponding governing equations including mass, energy balance, initial and boundary conditions and physical parameters required for simulation are given in [1] and [2]. Simulation conditions are listed in Table 1 and calculation results are obtained using differential equation solver embedded in MATLAB

Table. 1: Specification for flow configuration simulation

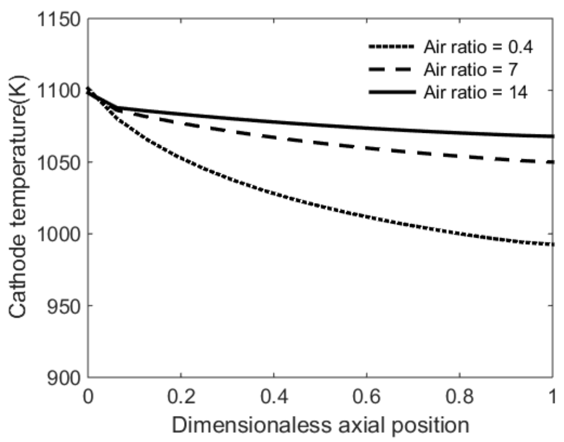
Stack temperature	1123 K
Inlet H_2O concentration at cathode side	90 %
Steam utilization	80%
Air ratio	0.4, 7, 14
Average current	4500 A/m^2
Cell operating pressure	0.1 Mpa

3. Results and Discussion

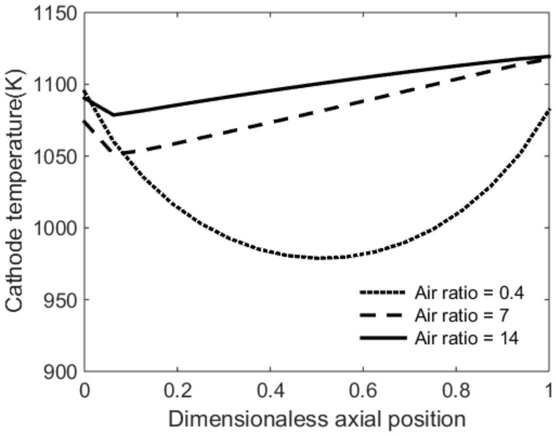
As revealed in Fig.1(a), in co-flow configuration, average current of 4500 A/m^2 corresponds to endothermic condition consistent with the decreased temperature of cathode stream towards the outlet. The higher air ratio yields to the increased cathode stream temperature along the stack implying that the increased anode gas provides enhanced heat during endothermic operation. However, in counter-flow configuration as shown in Fig.1(b), a complex behavior is observed.

At low air ratio of 0.4, the cathode temperature distributions are concave downwards related to the fact that cathode outlet is adjacent to anode inlet at which the fresh air heated to stack temperature is supplied and thus cathode outlet temperature is increased. This temperature distribution is not desirable in cell temperature management and the maximum temperature difference of 130 K larger than 110 K of co-flow configuration also is found at the center of reactor length.

At high air ratio of 7 and 14, the cathode temperature distribution also shows concave downwards, however, its magnitude is slightly weak and the cathode stream outlet temperature is increased and become slightly higher than cathode inlet temperature indicating exothermic operation. This behavior is partially related to the above–mentioned fact that cathode outlet stream is partially heated by the anode inlet stream. Concerning this behavior, however, Fig.2(b) reveals important aspect that local current density in counter-flow shows relatively more uniformly distribution than that of co-flow configuration since the steam dissociation reaction more easily occurs along stack due to the slightly lowered oxygen content in anode-fed stream. These temperature and local current density distribution of counter-flow configuration is considered as desirable in cell temperature and operation compared to co-flow configuration.

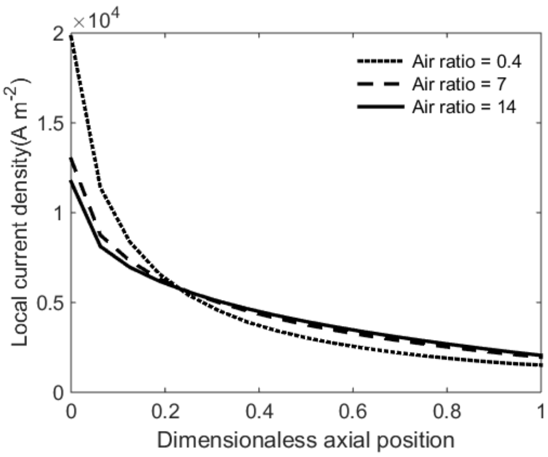


(a)

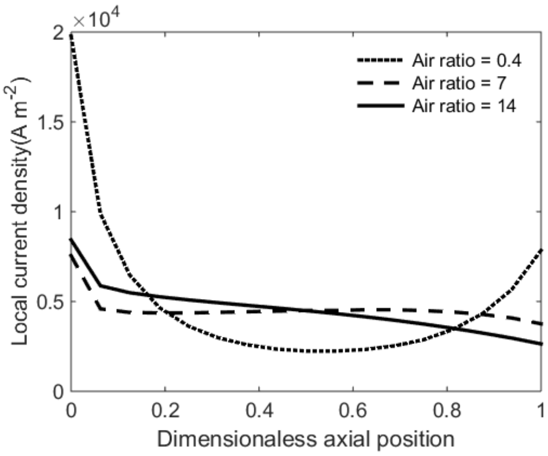


(b)

Fig. 1.Cathode stream temperature along the stack for an average current density of 4500 Am^{-2}, an inlet temperature of 1123K and air ratios of 0.4, 7 and 14 (a) co-flow and (b) counter-flow



(a)



(b)

Fig. 2. Local current density distribution along the stack for an average current density of 4500 Am^{-2}, an inlet temperature of 1123K and air ratios of 0.4, 7 and 14 (a) co-flow and (b) counter-flow

4. Conclusions

Counter-flow configuration is more advantageous than co-flow configuration at air ratio above 7 in that cathode stream temperature and local current density are more uniformly distributed along the stack. The effect of both flow configuration will be more evaluated through dynamic simulation.

Acknowledgement

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