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Thermal Management Optimization of a Thermoelectric-Integrated Methanol Evaporator Using a Compact CFD Modeling Approach

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To better manage the magnitude and direction of the heat flux in an exchanger-based methanol evaporator of a fuel cell system, thermoelectric (TE) modules can be deployed as TE heat flux regulators (TERs). The performance of the TE-integrated evaporator is strongly influenced by its heat exchange structure. The structure transfers the fuel cell exhaust heat to the evaporation chamber to evaporate the methanol, where TE modules are installed in between to facilitate the heat regulation. In this work, firstly, a numerical study is conducted to determine the working currents and working modes of the TERs under the system working condition fluctuations and during the system cold start. A three-dimensional evaporator model is generated in ANSYS FLUENT® by combining a compact TE model with various heat exchange structure geometries. The compact TE model can dramatically improve the computational efficiency, and uses a different material property acquisition method based on module manufacturers' datasheets. Secondly, a simulation study is carried out on the novel evaporator to minimize its thermal resistance and to assess the evaporator pressure drop. The factors studied include the type of fins in the heat exchange structure, the thickness of the fins, the axial conduction penalty, etc. Results show that the TE-integrated evaporator can work more efficiently and smoothly during both load fluctuations and system cold start, offering superior performance.

Key words: Thermoelectric heat regulator, TE-integrated methanol evaporator, heat regulation, heat loss, compact TE model

INTRODUCTION

High-temperature polymer electrolyte membrane fuel cell (HTPEMFC) power systems with onboard methanol reformers offer a great market opportunity, because they are more efficient, more environmentally friendly, and practical as compared with other available technologies.[1,2] One typical configuration of this kind of HTPEMFC power system is illustrated in Fig. 1.

The evaporator inside this system is exchanger based with cartridge heaters mounted in the two base plates, as shown in Fig. 2a. It is designed to evaporate a methanol–water mixture ("Methanol" in Fig. 1) pumped into the evaporation chamber using the system waste heat from the exhaust gas ("Cathode Exhaust" in Fig. 1) recovered by the fins. In case heat imbalance happens, e.g., due to lack of waste heat during the system cold start, cartridge heaters are driven electrically to supplement the heat shortage. However, as analyzed in Ref. 3, a significant amount of electric heat can be lost to the fuel cell exhaust air, which would lower the overall system efficiency, and the heat shortage may still

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