Numerical simulation and performance optimization of solid oxide fuel cells

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Abstract

Fuel cells are electrochemical devices that convert the energy from a chemical reaction directly into electrical energy. With advantages of high energy-conversion efficiency and reduced emissions, including greenhouse gases, fuel cell technology has emerged as a critical components in future clean power generation and hydrogen economy [1-4]. The fundamental thermodynamic advantage of fuel cells over the conventional combustion is the small exergy losses associated with the fuel oxidation process. Fuel cells can work with high efficiency at relatively lower temperatures than heat engines; for example, a proton exchange membrane fuel cell works at temperatures ranging from room temperature to 100^oC. On the other hand, when a fuel cell works at a higher temperature, around 1000^oC, the waste gases can be introduced to a heat engine, such as a gas turbine, to produce even more power and a higher efficiency [9-13]. Among the various types of fuel cells, solid oxide fuel cells (SOFC) must be operated at high temperatures, ranging from 600^oC to 1000^oC, and are feasible to combine with gas turbines to form hybrid systems. This paper describes a comprehensive numerical analysis that is capable of simulating the complete energy conversion process in SOFC, including fuel reforming and water shift. The analysis uses a custom-developed finite-volume numerical procedure based on strong coupling of electrochemistry, electricity, material properties and transport phenomena. Efficacy of this analysis is demonstrated by simulating the cell performance and detailed transport phenomena of two important types of solid oxide fuel cells (SOFC), i.e. tubular-type and planar-type SOFCs. This simulation effort is followed by an optimization study to further enhance the power density of anode-supported planar SOFC. The optimization procedure is to identify optimal combination of the size of current collector and its domain of influence.

Keywords: Keywords: Energy, Fuel Cells, Solid Oxide Fuel Cells, Numerical Simulation.

References

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