COMPLETE MODELING OF kW-RANGE SOFC STACKS

Andreas Gubner, Dieter Froning, Bert de Haart and Detlef Stolten
Forschungszentrum Jülich GmbH
Institute for Materials and Processes in Engineering
IWV 3: Energy Process Engineering
D-52425 Jülich, Germany

The development of the planar SOFC technology has been progressing over the last years worldwide. The aim of development becomes more and more to scale up the technology from the laboratory-type Watt to the commercially much more relevant kW-range. At the Forschungszentrum Jülich, an anode substrate supported planar concept is under development featuring 20 cm by 20 cm (7.9" by 7.9") cells with a metallic interconnector made of ferritic steel. It was possible to assemble and operate stacks as tall as 40 cells yielding 9.2 kW on hydrogen fuel and 5.4 kW on methane fuel, respectively. This progress causes an increased need for modeling capabilities for large stacks so that their behavior can be studied and subsequent stack design improvements and SOFC plant operation optimization can be introduced more efficiently. Since modeling is a service contributing to the overall system engineering efforts, modeling must be able to follow the way to larger stacks so it will remain able to deliver the required solutions. Within the scope of modeling must be both the stack and the power plant. Here the difficulty arises that it seems necessary to have a 3D model of the stack which requires so much CPU-time that using this 3D model as a component in the flowchart of the overall power plant does not seem feasible. The present investigation proposes a strategy for looping a CFD (Fluent) based concept for kW-range stacks and a corresponding 1D spin-off to be used as a component for more rapid flow chart simulation of the entire SOFC system.

Fig. 1 shows a comparison of a temperature profile for a 5 cell short stack running on H_2. The circles and boxes are experimental values obtained by inserting thermocouples in two different planes of a test stack and the solid line represents the calculated profile.

Fig. 2 shows a result of the 1D behavior model which is based on the same equations for the electrochemical and chemical reactions as the full 3D CFD model. The operating conditions are typical for an SOFC power plant featuring internal reforming of methane. A terminal voltage of 0.71 V is calculated at 300 mA/cm² and a fuel utilization of 80 %. The model is implemented in Matlab and took approx. 30 seconds (AMD Athlon 1 GHz).

Fig. 3 shows the corresponding species distribution in terms of molar fractions along the gas channel. All models are based on the Jülich counter flow design where the fuel flows from the left to the right and the air in the opposite direction. The absolute pressure was 100 kPa.

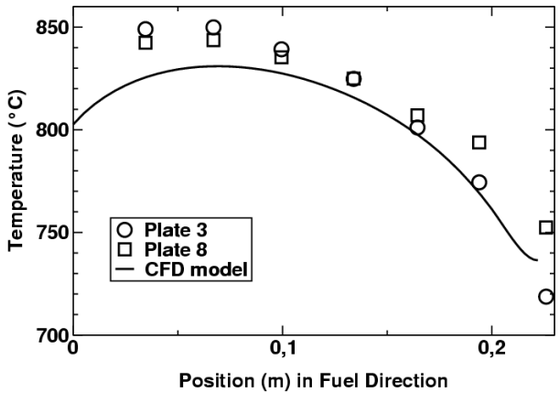

Fig. 1. Comparison New And Old Model

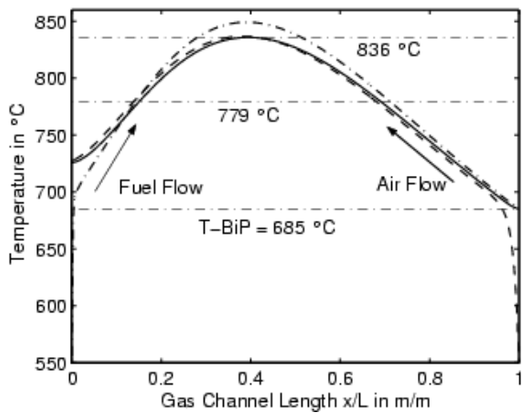

Fig. 2. Stationary Behavior Model Run

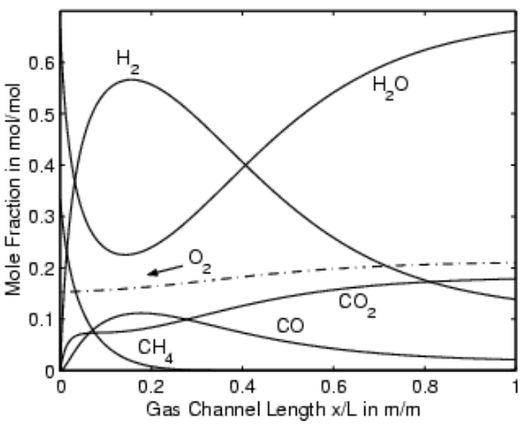

Fig. 3. Behavior Model: Species Distribution