**ME 370B**
**Energy Systems II:**
**Modeling and Advanced Concepts**

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Projects 10: SOFC with Channels

**Due as a PDF file via Canvas (along with any rework of Project 9),**
**Noon, Wednesday, March 22**

You already have the major task of this assignment—developing the channel code—as described at the end of the Project 9 handout. It turns out that we cannot do what I would really like (a micro-GT wrap-around) without solving the multicomponent diffusion problem (which would take more time than we have), so you are not far from finished. In fact all we have listed here is what to do with your model (the Deliverables) and maybe a little more work on how to extract understanding from the results (i.e., making an exergy distribution). Our basic objective is to both make sure that your channel code works and to have you spend a little time exercising it and looking at what it can tell you about SOFCs.

Before you get started, be sure to exercise you code from last week at elevated pressures. Since all of your work last week was at one bar, your base code may have issues when operating at higher pressures. See if you can shake those out before you get going too far on the assignment.

<u>The Deliverables for Project 10</u>

Configure your channel-cell code to model our base-case operating conditions: 1000°C, 3 bar reactants (supply pressure for both channels), 1 m/s inlet velocity at the anode channel entrance, and 100% excess air at the cathode entrance (i.e., $\lambda = 2$).

(1) Make a plot showing the following as a function of cell output current (A) for the base-case configuration:
   - output terminal electrical potential difference (V),
   - output electrical power (W),
   - heat transfer from the cell (W), and
   - fuel utilization (fraction of fuel consumed, %).

   Make a plot showing the following as a function of cell output current (A) for the base-case configuration:
   - output terminal electrical potential difference (V)—just for reference this time,
   - LHV of the hydrogen exiting the cell unused (W),
   - first-law efficiency based on LHV of hydrogen input to the cell, and
   - first-law efficiency based on LHV of hydrogen consumed within the cell.

   Make a plot showing the following as a function of cell output current (A) for the base-case configuration:
   - rate of exergy input to the cell (W),
   - rate of exergy exiting at the end of the channels (W),

- rate of exergy leaving as electricity (W)
- rate of exergy leaving as heat transfer (W), and
- rate of exergy destruction within the cell (W).

Make a plot showing the following as a function of cell output current (A) for the base-case configuration:
- rate of exergy destruction in the gas diffusion layers (W),
- rate of exergy destruction due to activation (W),
- rate of exergy destruction due to ohmic resistance (W),
- total rate of exergy destruction (W).

Considering the previous two plots, is the overall exergy balance closed?
(No response required. Your figures will show the answer.)

Make a plot showing how the following quantities vary as a function of distance from the channel entrance (m) for the base-case configuration operating at the output potential corresponding to peak electrical power:
- current density ($kA/m^2$),
- electrical power density ($kW/m^2$), and
- heat flux ($kW/m^2$).

Make a plot showing how the following quantities vary as a function of distance from the channel entrance (m) for the base-case configuration operating at the output potential corresponding to peak electrical power:
- hydrogen, water, and oxygen mole fractions,
- equilibrium electrical potential corresponding to the local channel composition (V), and
- the actual electrical potential imposed on the channel (V, a constant, for reference).

(2) Make the same set of plots listed above, but with the cell temperature reduced from the base case value to 800°C. (All else should remain unchanged from the base case.)

(3) Make the same set of plots listed above, but with the electrolyte thickness increased from the base case value to 0.5 mm.

(4) Make the same set of plots listed above, but with the anode inlet velocity (and therefore reactant flow rate) decreased from the base case value to 0.5 m/s. (Note that the cathode flow rate will change too, in order to maintain the excess air coefficient constant.) For the channel plots, choose an output potential of 0.5 V (instead of the potential at peak power) since this will allow you to see what happens when the cell is heavily loaded, but starved for reactants.

Please make sure that every member of the group has a copy of your code up and running on their machine. We are not going to insist that each of you make one of the four plots above—that just seems silly—but we really do want each one of you to play with the code to see what it can tell you.

Some things you might want to look at include: electrolyte thickness below 50 microns, the effect of the excess air coefficient, the effect of thinning down the cathode-side GDL to improve oxygen diffusion, how well the heat flux values match up with the endothermic heat requirement of the SMR reaction (requires some separate calculations), how the cell operates if you give it steam at the anode channel inlet and impose a voltage from the outside (i.e., turn it into a high-temperature electrolyzer of the kind advocated by proponents of nuclear power), etc. Enough said—you probably already got the point...

Cheers!

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