Improving the Performance of an Air-Cooled Fuel Cell Stack by a Turbulence Inducing Grid

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Air-cooled proton exchange membrane fuel cells (ACPMEFC’s) are gaining more popularity due to their:
- Simplicity (run on dry H2), and
- Quick start-up.
ACPMEFC’s are commercialized and designed for applications in the range of up to few kWs such as telecom-backup systems and portable power.
The stoichiometric ratios at the supplied Air into the cathode open channel is typically 40-60, because it is used for cooling the stack besides providing O2 for the reaction,
- while at the supplied dry H2 into anode channels it should be as low as possible to not waste hydrogen.
- One of the main drawbacks of ACPMEFC’s is the relatively low maximum current density and thereby increase the power density.
- This might be achieved by more efficient cooling.
- Thus, Turbulence grids are utilized to increase the mixing effect and thereby enhance the heat transfer in the cathode channels.
- In this work, the effect of the turbulence grid is demonstrated experimentally and numerically using CFD.

**Computational Fluid Dynamics (CFD):**

**Reynolds Average Navier Stokes Equations (RANS)**
\[
\overline{\rho u_i u_j} = \frac{\partial}{\partial x_j} \left( \mu \left( \frac{\partial \overline{u_i}}{\partial x_j} + \frac{\partial \overline{u_j}}{\partial x_i} \right) - \rho \frac{\partial \overline{u_i}}{\partial x_i} \right) + \frac{\partial}{\partial x_j} \left( \rho \overline{u_i u_j} \right) + \rho g_j + \overline{\rho \sigma_{ij}}
\]

Temperature along the channel. On the left figure the distance between the grid and channel is constant at 10 mm. On the figure in the right side this distance is varied.

**Energy Equations**

The energy equation the fluid is given as:
\[
\frac{\partial T}{\partial t} + \frac{\partial}{\partial x_j} \left( \rho c_p \overline{u_j} T \right) = \frac{\partial}{\partial x_j} \left( \chi \frac{\partial T}{\partial x_j} \right)
\]

Where \( \chi \) is the fluid heat capacity, \( T \) is the temperature of the fluid and \( c_p \) is the thermal conductivity of the fluid. The energy equation for the solid region is given as:
\[
\frac{\partial}{\partial t} \left( \rho c_v \overline{u_j} T \right) + \frac{\partial}{\partial x_j} \left( \chi \frac{\partial T}{\partial x_j} \right) = 0
\]

**Velocity distribution along the channel.**

**Turbulence intensity distribution along the channel.**

- There is a slight decrease in temperature when the two grids are implemented.
- The square grid effect on the temperature is larger.
- The effect of the grid is seen right after the grid and before the channel, and the velocity distribution is almost identical along the channel.
- The increase in turbulence intensity is highest for the case with the square grid.

**Experimental Set-up**

**Polarization curve of the experiment with honeycomb grid and no grid.**

**Temperature at the cathode inlet channel with honeycomb grid and no grid.**

**Polarization curve of the experiment with square grid and no grid.**

**Temperature at the cathode inlet channel with square grid and no grid.**

- The honeycomb grid has increased the performance by 2.75 %, and the square grid has increased the performance by 10.42%.
- The temperature of the air at the channel inlet is generally lower with the grid.
- The square grid indeed results in more effective cooling and higher performances.
- The experiment assisted the model by showing an improved performance of the air-cooled fuel cell stack by placing grids before the cathode inlet and furthermore resulted in decreasing temperatures.