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

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Fluid on Reynolds and temperature

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One of the main drawbacks of ACPEMFC’s is the relatively low maximum current density around 0.4 A/cm².

It is highly desirable to operate at higher current densities 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)

Where \( \bar{u} \) and \( \bar{u}^' \) are the mean and fluctuation velocity respectively. Likewise, for pressure and other quantities it is:

\[
\overline{p} = \bar{p} + p^' \]

Where \( p \) denotes a scalar such as pressure, energy or species concentration.

Substituting the expressions into the instantaneous continuity and momentum equations and taking the time average (dropping the overbar on the mean velocity) yields the following RANS equations for continuity and momentum [ANSYS, 2018c]:

\[
\frac{\partial \rho \bar{u}}{\partial t} = \frac{\partial}{\partial x} \left( \rho \bar{u} \frac{\partial \bar{u}}{\partial x} \right) + \bar{p} \frac{\partial \bar{u}}{\partial x} - \rho g + \frac{\partial}{\partial x} \left( -\rho u' \bar{u} \right) \tag{4}
\]

where the term \( (-\rho u' \bar{u}) \) is the Reynolds stresses and are modelled with the turbulence model SST-\( k-\omega \), \( u \) is velocity, \( \rho \) is density, \( g \) is the gravitational constant and \( \mu \) is the viscosity.

Energy Equations

The energy equation the fluid is given as:

\[
\frac{\partial \rho \bar{u} T}{\partial t} = \frac{\partial}{\partial x} \left( \rho \bar{u} \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial x} \left( -\rho u' \bar{T} \right) \tag{6}
\]

Where \( \overline{T} \) is the fluid heat capacity, \( T \) is the temperature of the fluid and \( \kappa \) is the thermal conductivity of the fluid. The energy equation for the solid region is given as:

\[
\frac{\partial}{\partial x} \left( \rho_s c_s \frac{\partial T_s}{\partial x} \right) + \left( \rho_s c_s \bar{T}_s + \rho_s c_s T_s \right) \frac{\partial \bar{u}}{\partial x} = 0 \tag{6}
\]

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.

The honeycomb grid has the increased 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.