Numerical Modeling of Power Reactors' Fuel Bundles

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Introduction: CANDU (CANada Deuterium Uraniam) reactors are currently using heavy water as its pressurized coolant. The purpose of this study was to create a valid COMSOL model for one configuration of fuel rod bundles. The thermal behavior of the model for different Reynolds numbers has been investigated and the average heat transfer coefficient for each case has been plotted. Figures 1 and 2 show different configurations of CANDU Fuel rod bundles.

Figure 1:
Example of Bruce 37 Element

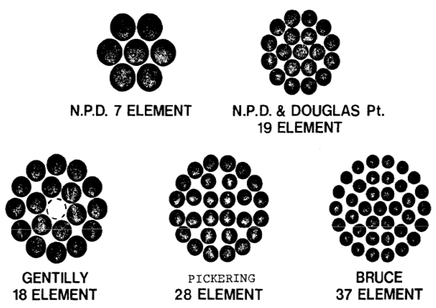

Figure 2:
Different Configurations of CANDU Fuel Bundles

Computational Methods: Using the heat transfer module in COMSOL Multiphysics, the governing equations include continuity, momentum, and energy equations. Their appropriate boundary conditions are

$$\nabla \cdot \mathbf{v} = 0$$

$$\rho \frac{D\mathbf{v}}{Dt} = \rho \mathbf{g} - \nabla p + \mu \Delta \mathbf{v},$$

$$\rho \, Cp \, V . \nabla T = k \nabla^2 T + \mu \phi + \dot{q}$$

The geometry of the model is based off of the specifications provided by CANDU 6 Technical Summary [1]. The specific material of the rods as well as the fluid were chosen off of this source as well.

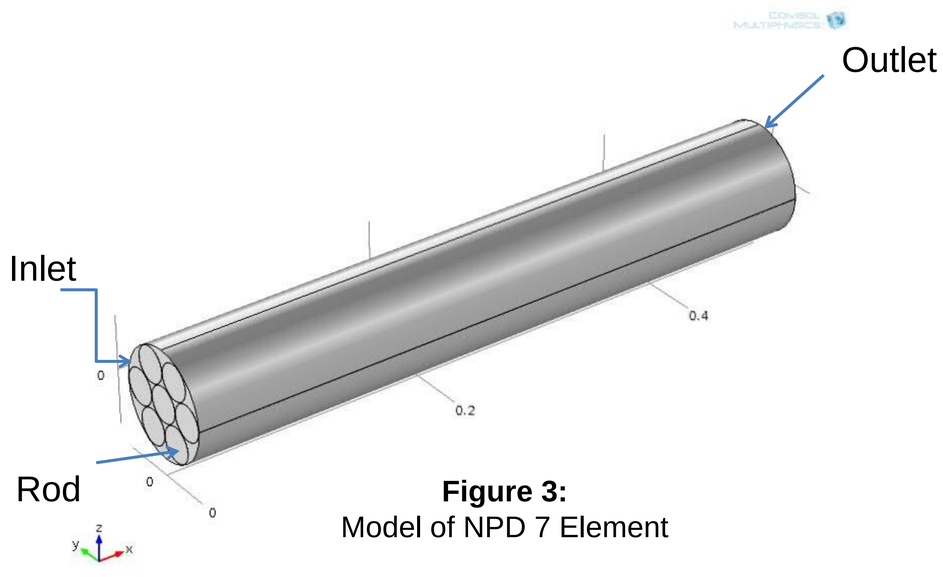

Figure 3:
Model of NPD 7 Element

Results: Basing the model on the correct geometry and boundary conditions, Figure 4 shows the expected results of the convective coefficient. Figure 5 shows the expected gradual increase in fluid temperature

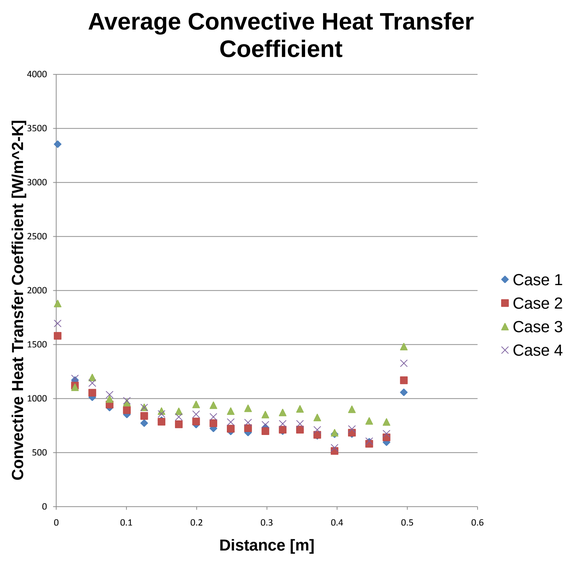

Figure 4:
Expected Behavior of Convective Coefficient

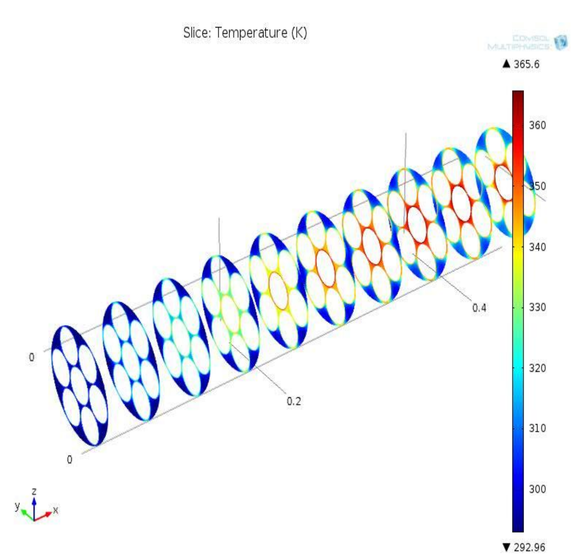

Figure 5:
Temperature Slice of Case 1

Material [Rods]	Zircaloy-2			
Material [Fluid]	Heavy Water			
	Case 1	**Case 2**	**Case 3**	**Case 4**
Inlet Velocity [m/s]	0.0196	0.0222	0.02461	0.03004
Outlet Velocity [m/s]	0.0196	0.0222	0.02461	0.03004
Inlet Temperature [K]	293	293	293	293
Boundary Heat Source [kW/m^2]	15.536	15.536	15.536	15.536

Table 1:
Model Properties and Boundary Conditions of Model

Conclusions: With the validation of the model by observing the behavior of the convection coefficient, different materials can now be used to try and optimize the heat transfer from the rods. This ultimately improves efficiency of energy production.

References:

1. CANDU 6 Technical Summary, prepared by CANDU 6 Program Team, Reactor Development Business Unit, May 2005.

Excerpt from the Proceedings of the 2013 COMSOL Conference in Boston