# Peak Cladding Temperature Analysis of a Spent Fuel Assembly According to Heat Transfer Modes

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## 1. Introduction

Thermal evaluation of a cask using three-dimensional models is especially difficult if the spent fuel assemblies are modeled explicitly and included in the analysis. The method, which explicitly models spent fuel assemblies, is costly in time of setup and computational time and does not lend itself to parametric evaluation of cask design. Therefore, these assembly elements are modeled as solids with homogenous "smeared" or "effective properties". This solid method can predict the peak cladding temperatures of casks with reasonable accuracy [1, 2]. One of the solid methods is CFD simulation on transverse cross-section of a spent fuel assembly [3]. The CFD simulation has used the convection and radiation for heat transfer.

In this work, the temperatures of a spent fuel assembly were calculated by using the conduction, convection and radiation in heat transfer. 3D CFD simulation is used for this calculation.

## 2. Modeling and method

*2.1 Modeling for peak cladding temperature*

14x14 PWR spent fuel type is selected to calculate the peak cladding temperature. The assembly heat load is 796.2W. Fig. 1 shows the three-dimensional CFD mesh model of the assembly which includes the gap between fuel rods and cladding. The result of mesh work has over 2 million elements.

Thermal properties of helium, claddings, guide tubes, fuel rods are used with a temperature-dependent value [4]. The emissivity is 0.8 for zircaloy and 0.36 for stainless steel (basket wall).

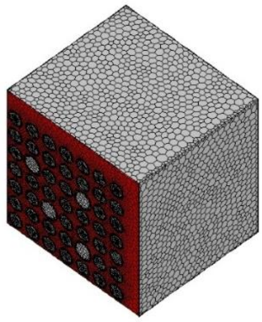

Fig. 1. CFD model for 14x14 assembly.

*2.2 Physics model and solution method*

The discrete ordinates (DO) radiation model was selected to solve the radiation of spent fuel assembly. The DO radiation model solves the radiative transfer equation (RTE) for a finite number of discrete solid angles, each associated with a vector direction fixed in the global Cartesian system. The value of angular discretization and pixelation available in the discrete ordinates radiation model significantly affects the behavior of temperature. The constants were determined to solve the spent fuel assembly: 3x3 for pixelation, 5x5 for discretization.

The convergence of a natural convection problem is not good with the normal steady-state calculation. So, the pseudo-time progression method has been used to obtain a converged solution. This method works by using a steady calculation and introducing a pseudo-time term to relax the equation. The settings for this method were: PRESTO! spatial discretization for pressure, second order space discretization for momentum and energy, 0.5 relaxation coefficients for momentum and pressure, 10 for timescale factor, 1 for verbosity. For turbulent flow, the first cell height around wall is calculated from y+ (<10).

## 3. Results and discussion

Fig. 2 shows the Pseudo transient method converged. In Fig. 3, temperature distribution of a 14x14 assembly is shown for 300K of basket wall temperature. The maximum temperature is 317K. The temperature difference between 2D and 3D simulation is above 30K [3]. The lower temperature would result from convection in heat transfer mode. Effective thermal conductivity of solid method will increase in comparison with the 2D simulation.

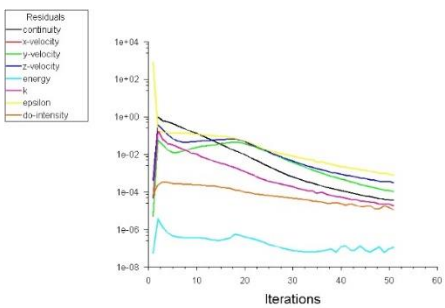


Fig. 2. Residuals graph for pseudo transient coupled solver.

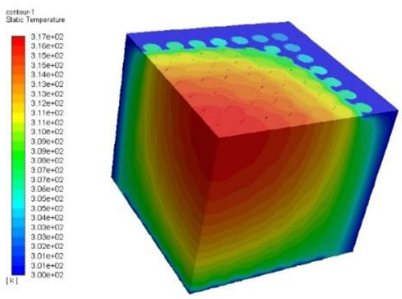

Fig. 3. Temperature distribution of 14x14 fuel assembly.

## 4. Conclusions

3D CFD simulation was performed to predict the peak cladding temperature of a spent fuel assembly. The maximum temperature of 3D simulation is lower than that of 2D. This result would come from the difference of heat transfer modes used for simulation.

The axial length of the assembly modeling would be not enough to study the trend of the temperature. But, one knows that the temperature change requires engineers to perform 3D simulation on spent fuel assemblies. This work will be expanded with larger domain and other fuel types.

## ACKNOWLEDGEMENT

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