Uncertainty Quantification using Polynomial Chaos Expansion in Numerical Simulations of Spent Nuclear Fuel Assemblies

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Abstract

A two-dimensional computational model of a Spent Nuclear Fuel (SNF) 9x9 boiling water reactor (BWR) assembly in a horizontal support basket was developed with the use of the FLUENT computational fluid dynamics package. Heat transfer simulations were performed to predict the maximum cladding temperature for different assembly heat generation rates, different uniform basket wall temperatures, and with helium backfill gas. The heat is transferred through conduction within the fuel rods, convection and radiation across the gas-filled region between the rods and the enclosure. Package designers must accurately predict the temperature of the cladding that surrounds the pellets to assure that it does not exceed 400°C to preserve the integrity of the zircalloy cladding tubes containing the nuclear fuel.

Current researchers in this field use different computer codes in their studies and have presented numerical results for models of SNF assemblies but the current inability to benchmark the regional material property models for the full range of applicable conditions increases the uncertainty of the resulting temperature predictions. In order to deal with this uncertainty, our research incorporate Uncertainty Quantification (UQ) method into the numerical simulations and the heat transfer and fluid flow modeling techniques. UQ method used in this research is based on a unique approach that uses the Polynomial Chaos Expansion (PCE) to characterize the solution of stochastic differential equations and is a transformative way of applying uncertainty analysis in model-assisted design optimization.

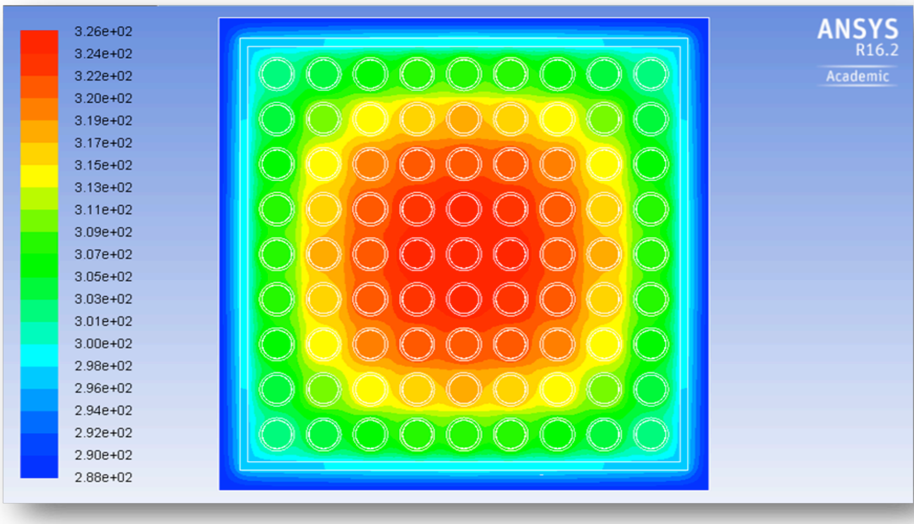

Fig1. Temperature Distrubition Results.

References

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Presentation Method: Invited Oral (30 min presentation)
* A full paper should be submitted separately if authors intend to submit one.
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