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Benchmark Analysis of the MIX-COMP-THERM-02 Experiments Using the SCALE/CENTRM Sequence

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INTRODUCTION

This paper examines a set of lattice problems to evaluate the differences between the NITAWL resonance processor and the CENTRM/PMC resonance processor. NITAWL uses the Nordheim Integral Treatment to process resolved resonances while CENTRM/PMC produces point-wise fluxes, which are then used to collapse point cross-sections.[1,2] The purpose of this report is to determine the effect of resonance overlap on Mixed-Oxide systems. NITAWL processes resonances individually, not taking into account the change in the background cross-section. CENTRM/PMC does not contain this potential problem since it calculates a point-flux using all resonances from all materials simultaneously.

DESCRIPTION

A set of six critical benchmarks was analyzed, each consisting of a square-pitched array of mixed plutonium-uranium fuel rods submerged in water surrounded by a water reflector.[3] The fuel rods sit on a support plate above the bottom of the tank. The tank is wide and deep

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enough to assume an infinite moderator on the sides and bottom. The reactor is brought to critical by raising the water level in the tank.

The primary differences between the six benchmarks are lattice pitch, number of rods in the lattice, water level, and boron concentrations. All other benchmark characteristics are constant. To simplify the accumulation of power densities, advantage was taken in the symmetry of the problem whenever possible. The entire problem was explicitly modeled, but instead of having a separate unit for each pin, 1/8th symmetry was used in placing fuel rods in the arrays when possible.

ANALYSIS

All six computational benchmarks were processed twice using SCALE 5.0 and ENDF/B-V cross-section data, first with NITAWL and then with CENTRM. Table 1 contains the k_{eff} and energy of the average lethargy causing fission (EALF). The k_{eff} values for all the benchmark cases are close to 1.0: the worst NITAWL benchmark is 0.90% high, and the worst CENTRM case is 0.68% high. A small negative bias of 0.25% does appear between NITAWL and CENTRM. However, both produce excellent and consistent results for the k_{eff} and fission energy.

Additional calculated parameters include pin-power distributions, absorption, $\nu\Sigma_f$, reaction-rates, and total fluxes in the pin cell. Data was then collapsed to four-group fluxes and cross sections for selected nuclides. In most cases the CENTRM and NITAWL results fall within two standard deviations. The peak-to-low power changes with change in pitch and boron concentration, ranging from a low of 1.86 for the smallest pitch with no boron to a high of 4.19 at the largest pitch with boron. The addition of boron significantly shifts the flux profile to the center of the assembly by depressing the thermal flux in the moderator.

The reaction rates, total fluxes, and flux ratios are also in good agreement, seldom varying by more than 1%. The reaction rates and fluxes increase as the pins approach the center of the assemblies, excluding the outer two layers of the arrays. The lowest power pin occurs in one of the two outer layers of the array.

Finally, four-group fluxes and cross sections are calculated for selected nuclides in the fuel region of the same corner and center pins. The macroscopic cross-sections calculated include the radiative capture, fission, and $\nu\Sigma_f$ cross-sections for U-235, U-238, and Pu-239. The four groups are collapsed from the 238-group cross-section set using the flux profile calculated in KENO V.a as follows: group 1 (MeV to 9.5 keV), group 2 (9.5 keV to 3.0 eV), group 3 (3 eV to 0.4 eV), and group 4 (0.4 eV to 10^{-5} eV). The 0.4 eV was chosen as a boundary because it is the cadmium cutoff energy. Groups 2 and 3 contain the resolved resonance regions for most of the nuclides used in these cases. Most of the cross-section data for the CENTRM and NITAWL cases of a given benchmark case agree within 1%.

CONCLUSIONS

Either cross-section processor produces acceptable results. For all cases, the k_{eff}*'s* produced using CENTRM are slightly lower, ~0.25%, than those produced using NITAWL. The pin-power distributions, fluxes, reactions rates, and macroscopic cross sections all agree to approximately 1% between CENTRM and NITAWL.

The presence of boron in the moderator depresses the fraction of the flux in the moderator, thus creating a larger difference between the highest- and lowest-power pins but does not seem to affect the quality of the results. No significant differences were identified between the results produced by NITAWL and CENTRM.

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Table 1. Comparison of k_{eff} and EALF from CENTRM and NITAWL

CASE MIX-COMP-THERM-2	NITAWL k_{eff} (± σ)	CENTRM k_{eff} (± σ)	% Difference	EALF (eV)
PNL-30	1.0000 (0.0005)[a]	0.9966 (0.0004)	−0.34	0.575[b]
PNL-31	1.0026 (0.0004)	0.9987 (0.0003)	−0.39	0.768
PNL-32	1.0021 (0.0004)	1.0000 (0.0004)	−0.21	0.193
PNL-33	1.0090 (0.0003)	1.0064 (0.0004)	−0.26	0.282
PNL-34	1.0046 (0.0004)	1.0020 (0.0005)	−0.26	0.138
PNL-35	1.0079 (0.0004)	1.0068 (0.0004)	−0.11	0.182

[a] Values in parentheses are the standard deviations.
[b] Value from CENTRM calculation, Differences between CENTRM and NITAWL is less than 0.1 %