

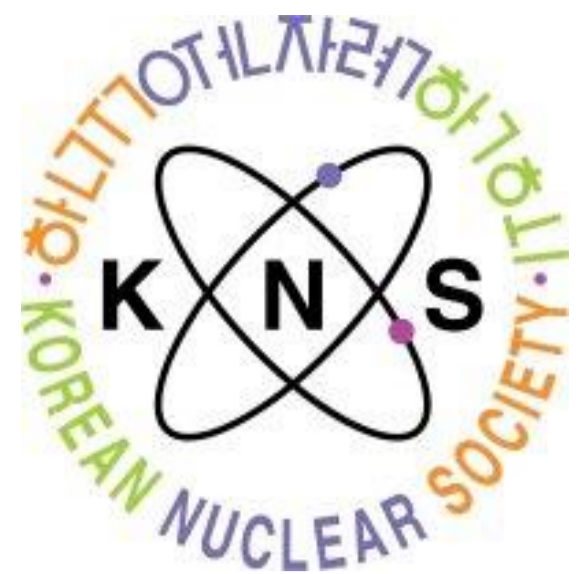
Sensitivity and Uncertainty Analysis on TMI-1 PWR Pin Cell with STREAM

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INTRODUCTION

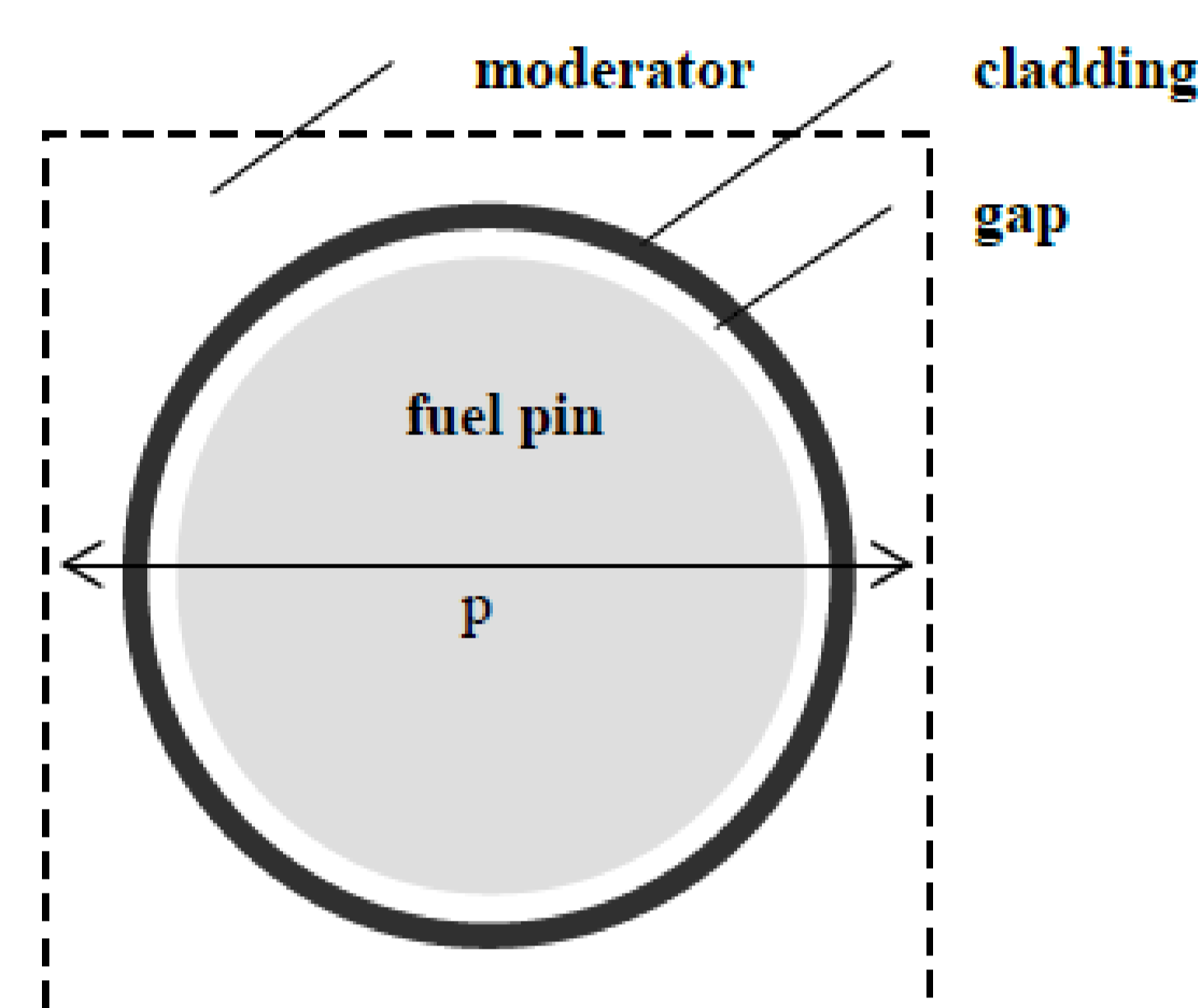
- The eigenvalue and nuclear data uncertainty analysis capability based on the generalized perturbation theory (GPT) has been implemented in the deterministic code STREAM developed at UNIST.
- In this paper, we present the sensitivity and uncertainty calculation of TMI-1 PWR pin cell in LWR UAM benchmark in STREAM.
- The results of STREAM calculation are compared to NEWT/TSUNAMI-2D calculation results in SCALE6.2.

CONFIGURATION OF TMI-1 PIN CELL

Design parameters

Parameter	Value
Unit cell pitch, [mm]	14.427
Fuel pellet diameter, [mm]	9.391
Fuel pellet material	UO ₂
Fuel density, [g/cm ³]	10.283
Fuel enrichment, w/o	4.85
Cladding outside diameter, [mm]	10.928
Cladding thickness, [mm]	0.673
Cladding material	Zircaloy-4
Cladding density, [g/cm ³]	6.55
Gap material	He
Moderator material	H ₂ O

Geometry



Parameters for reactor condition

Parameter	HZP	HFP
Fuel temperature, [K]	551	900
Cladding temperature, [K]	551	600
Moderator temperature, [K]	551	562
Moderator density, [kg/cm ³]	766	748.4

RESULTS

- There are two covariance data library for STREAM calculation:
 - Covariance data from ENDF/B-VII.1
 - Covariance data from SCALE6.2 (56-group)
- Implicit sensitivity analysis is omitted in both STREAM and SCALE calculation.
- Cross-section values and their uncertainties are calculated for the fuel region only (gap, cladding and moderator are excluded).

k-effective uncertainties of TMI-1 pin cell (HZP)

Code	SCALE6.2	STREAM	STREAM
Covariance data library	SCALE(56g)	SCALE(56g)	ENDF/B-VII.1
k-effective	1.43089	1.43216	1.43216
Isotope – reaction pair	Uncertainty (%Δk/k)		
U-235 (nu-bar)	0.3411	0.3414	0.6078
U-235 (nu-bar)			
U-238 (n,gamma)	0.2755	0.3703	0.2905
U-238 (n,gamma)			
U-235 (n,gamma)	0.1963	0.1967	0.1962
U-235 (n,gamma)			
U-235 (chi)	0.1525	0.1492	0.1516
U-235 (chi)			
U-238 (inelastic)	0.1157	0.1148	0.1158
U-238 (inelastic)			
Total uncertainty	0.5429	0.5902	0.7467

k-effective uncertainties of TMI-1 pin cell (HFP)

Code	SCALE6.2	STREAM	STREAM
Covariance data library	SCALE(56g)	SCALE(56g)	ENDF/B-VII.1
k-effective	1.41761	1.41890	1.41890
Isotope – reaction pair	Uncertainty (%Δk/k)		
U-235 (nu-bar)	0.3407	0.3410	0.6060
U-235 (nu-bar)			
U-238 (n,gamma)	0.2821	0.3817	0.2999
U-238 (n,gamma)			
U-235 (n,gamma)	0.1961	0.1964	0.1959
U-235 (n,gamma)			
U-235 (chi)	0.1553	0.1520	0.1544
U-235 (chi)			
U-238 (inelastic)	0.1184	0.1174	0.1184
U-238 (inelastic)			
Total uncertainty	0.5477	0.5984	0.7509

Cross-section uncertainties of TMI-1 pin cell (HZP)

Code	SCALE6.2	STREAM	STREAM
Covariance data library	SCALE(56g)	SCALE(56g)	ENDF/B-VII.1
Cross-section	Value [uncertainty, %ΔR/R]		
Σ _a	6.89560E-02 [1.0312]	6.91418E-02 [0.9751]	6.91418E-02 [0.9769]
σ _{a,U-235}	4.34470E+01 [1.2458]	4.36130E+01 [1.1961]	4.36130E+01 [1.1871]
σ _{a,U-238}	9.16461E-01 [1.0000]	9.16401E-01 [1.2234]	9.16401E-01 [1.0122]
Σ _f	4.18714E-02 [0.9545]	4.19982E-02 [0.9082]	4.19982E-02 [0.8965]
σ _{f,U-235}	3.52045E+01 [1.2572]	3.53259E+01 [1.2043]	3.53259E+01 [1.1952]
σ _{f,U-238}	1.01792E-01 [4.9335]	1.01338E-01 [4.8677]	1.01338E-01 [4.8717]

Correlation coefficient matrix of TMI-1 pin cell (HZP)

- Code : STREAM
- Covariance data library: SCALE6.2 (56-group)

$$\text{Corr}(A, B) = \frac{\text{Cov}(A, B)}{\sqrt{\text{Var}(A) * \text{Var}(B)}}$$

Value	k _{eff}	σ _{a,U-235}	σ _{a,U-238}	σ _{f,U-235}	σ _{f,U-238}	Σ _a	Σ _f
k _{eff}	-	-	-	-	-	-	-
σ _{a,U-235}	-0.162	-	-	-	-	-	-
σ _{a,U-238}	-0.674	0.171	-	-	-	-	-
σ _{f,U-235}	-0.072	0.978	0.168	-	-	-	-
σ _{f,U-238}	0.304	-0.937	-0.348	-0.927	-	-	-
Σ _a	-0.386	0.934	0.512	0.910	-0.945	-	-
Σ _f	-0.005	0.963	0.113	0.994	-0.883	0.881	-

DISCUSSION AND SUMMARY

- STREAM gives quite reasonable uncertainties compared to the SCALE6.2 for TMI-1 pin cell calculation result.
- For future work, it is necessary to calculate implicit sensitivities of general response with advanced resonance treatment methods.