Preliminary TSUNAMI Assessment of the Impact of Accident Tolerant Fuel Concepts on Reactor Physics Validation

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SCALE Users' Group Workshop
Oak Ridge, TN
August 19-21, 2019

Outline

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Purpose

- Accident tolerant fuels (ATF) will introduce new cladding and fuel materials into commercial reactors that have not been present before
- There is some concern about the validation of these materials
  - Do they increase the data-induced uncertainty in reactivity?
  - Are there available critical experiments to support validation?
  - Ultimately, do these materials impact fabricability, shipping, and storage?
- These questions can be addressed with sensitivity/uncertainty methods

Systems considered

PWR ATF systems

- Westinghouse 17x17 standard
- Base case: UO_2 with Zircaloy
- Cr_2O_3 and Al_2O_3 doped UO_2 fuel and Cr-coated Zircaloy cladding
- Cr_2O_3 doped UO_2 fuel and Cr-coated M5 cladding
- Cr_2O_3 doped UO_2 fuel and SiC cladding
- U_3Si_2 fuel with coated Zircaloy cladding
- U_3Si_2 fuel with SiC cladding

BWR ATF systems

- GE14 dominant lattice
- Base case: UO_2 with Zircaloy
- UO_2 fuel and Cr-coated Zircaloy cladding
- UO_2 fuel and FeCrAl cladding
- UO_2 fuel and FeCrAl cladding with enrichment and dimension changes
- Generic ATRIUM 11 lattice
- Base case: UO_2 with Zircaloy
- Cr_2O_3 doped UO_2 fuel with Zircaloy cladding

Nuclear data-induced uncertainty: Overview

- Sensitivity data generated in TSUNAMI-3D for each of the applications
- 56-group covariance data based on ENDF/B-VII.1 from SCALE 6.2.3 propagated with sensitivities to determine uncertainty in k_{eff} due to uncertainties in nuclear data
- Uncertainty compared to base case for each system
- Top individual contributors also identified for each system

Nuclear data-induced uncertainty: PWR results

- Uncertainties slightly above 0.5% Δk
- Small differences among UO_2 systems
- Slight increase in U_3Si_2 systems
- Top contributors are ^{235}U, ^{238}U, and ^{1}H in all cases
- Harder spectrum in U_3Si_2 systems increases contribution from ^{238}U

PWR Model	Data Induced Uncertainty (pcm)
Base (UO_2/Zircaloy)	544
Cr_2O_3 and Al_2O_3 doped UO_2/Cr-coated M5	551
Cr_2O_3 doped UO_2/M5	548
Cr_2O_3 doped UO_2/SiC	545
U_3Si_2/coated Zircaloy	571
U_3Si_2/SiC	571

Nuclear data-induced uncertainty: BWR results (1)

- Uncertainties above 0.6% Δk for GE14 systems and just over 0.5% for ATRIUM11 cases
  - No Gd_2O_3 in ATRIUM cases
- Small differences among UO_2 systems
- Increase in FeCrAl system, mitigated with optimization
- Top contributors are ^{235}U, ^{238}U, and ^{56}Fe or ^{157}Gd in GE14 cases
  - Optimization reduces impact of ^{56}Fe
- Top contributors are ^{235}U, ^{238}U, and ^{1}H in ATRIUM cases

Nuclear data-induced uncertainty: BWR results (2)

BWR Model	Data Induced Uncertainty (pcm)
GE14 Base (UO_2/Zircaloy)	614
GE 14 UO_2/Cr-Coated Zircaloy	616
GE14 UO_2/FeCrAl	661
GE14 UO_2/FeCrAl, enr. & dim. Optimization	632
ATRIUM11 Base (UO_2/Zircaloy)	526
ATRIUM11 Cr_2O_3 Doped UO_2/Zircaloy	524

Potentially applicable experiments

- Set of 1,643 critical experiments used for BWR BUC validation used here as well to assess the number of applicable critical benchmarks for validation
  - Over 1100 LEU and over 475 MIX experiments
- c_k greater than or equal to 0.8 viewed as applicable
- PWR:
  - Base case: 48 experiments, max c_k 0.959
  - UO_2 cases: 40 experiments, max also over 0.95
  - U_3Si_2 cases: 25 experiments, max around 0.93

Potentially applicable experiments (continued)

- BWR:
  - GE14 base case: 14 experiments, max c_k 0.828
  - GE14 Cr_2O_3-coated Zircaloy: 14 experiments, max c_k 0.828
  - GE14 FeCrAl: 1 experiment (2 for optimized) max c_k under 0.81
  - GE14 models contain Gd_2O_3 which hardens spectrum and reduces applicability of many benchmarks
  - ATRIUM base case: 50 experiments, max c_k 0.949
  - ATRIUM Cr_2O_3-doped UO_2: 52 experiments, max c_k 0.95
  - ATRIUM11 lattice has no Gd_2O_3 and softer spectrum

Conclusions

- Assessment of impact of ATF on PWR and BWR systems
- Many systems have little impact on data-induced uncertainty
  - U_3Si_2 fuel increases uncertainty because of harder spectrum (PWR)
  - FeCrAl increases uncertainty because of ^{56}Fe (BWR)
- Many systems have little impact on benchmark applicability
  - PWR cases have small impact
  - BWR FeCrAl is very big challenge for validation at this point

Thanks to the NRC Office of Nuclear Regulatory Research for supporting this work and to the DOE NCSP for sponsoring this presentation.

Are there any questions?