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

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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 a very big challenge for validation at this point

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Are there any questions?