Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2017

Evaluation of Fuel Burnup Effects on LOCA PCT Using MARS/FRAPTRAN Coupled Code

Hyong Chol Kim, Young Jin Lee, and Sam Hee Han

NSE TECHNOLOGY

■ Introduction (1)

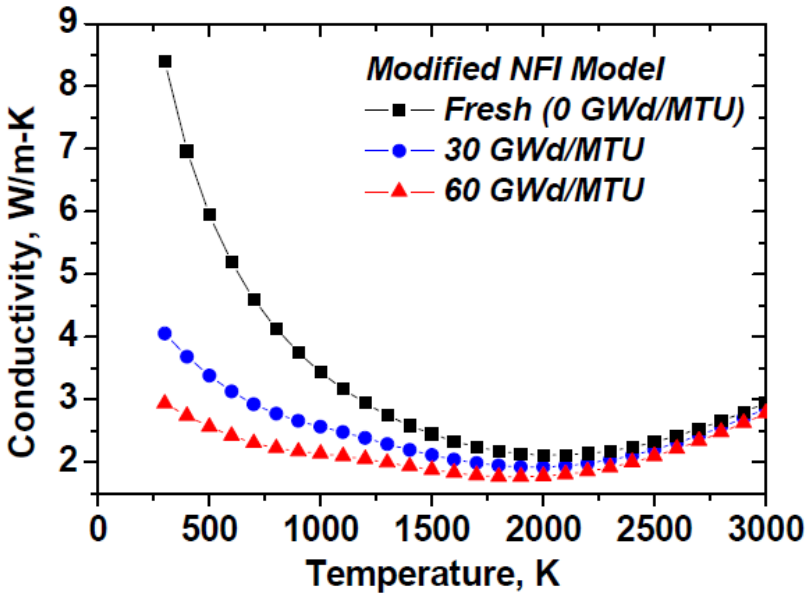
- **Previous Works**
  - **MARS code has been coupled with the FRAPTRAN code.**
  - **A LOCA was analyzed for OPR-1000 using the MARS-FRAPTRAN coupled code.**
  - **Effects of cladding failure on PCT during a LOCA was assessed using the MARS-FRAPTRAN coupled code**

- **Focus of the Present Study**
  - **The effect of fuel burnup on PCT during LOCA are evaluated using the MARS/FRAPTRAN coupled code.**

■ Introduction (2)

- **Safety concern has been raised regarding fuel thermal conductivity degradation.**

※ U. S. NRC Information Notice 2009-23 Supplement 1, "Nuclear Fuel Thermal Conductivity Degradation," October 2012.

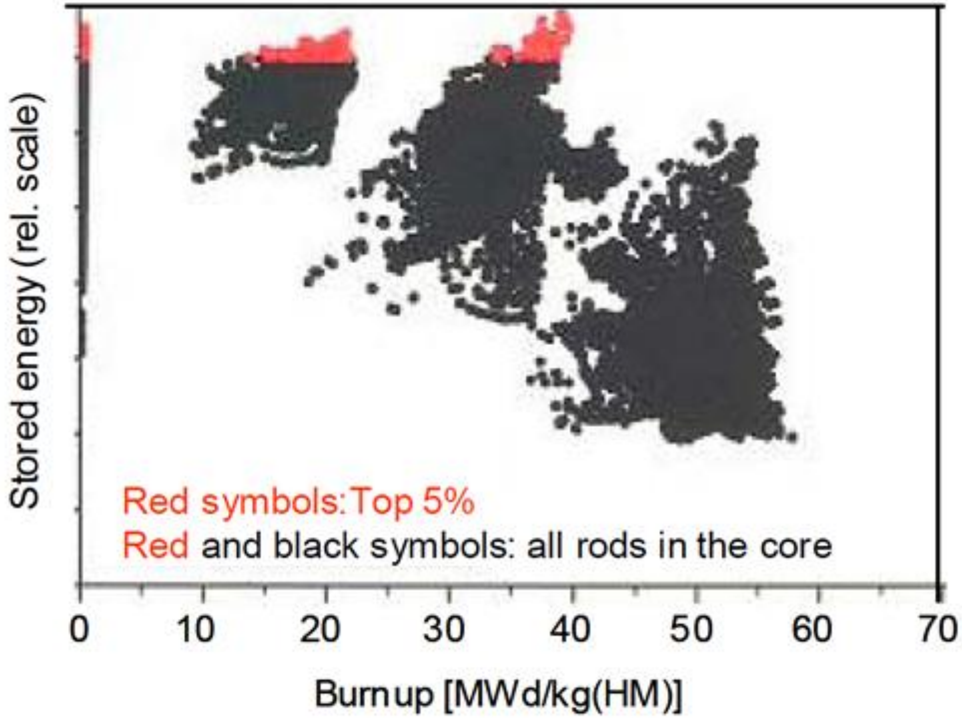


UO_2 thermal conductivity model used in FRAPCON

■ Introduction (3)

- **Stored energy is one of the major factors affecting LOCA results.**

※ A. Wensauer, LOCA: AN OPERATOR'S VIEW ON GERMAN LICENSING PRACTICE, IAEA-TECDOC-CD-1709, Proceedings of a Technical Meeting Held in Mito, Japan, 18-21 October 2011, International atomic energy agency, Vienna, 2013, p.167.



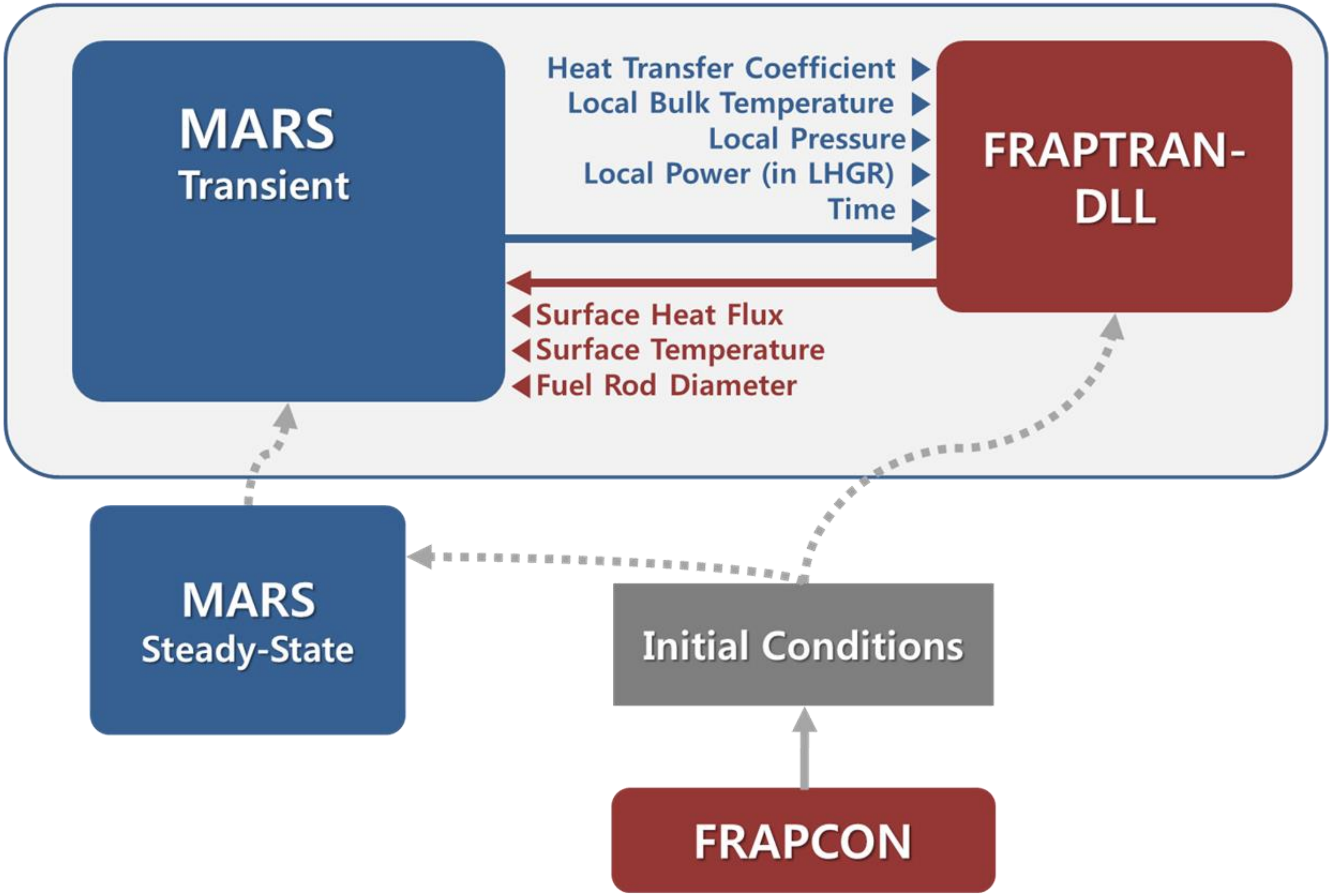
Stored Energy for Rods in the Core

■ Introduction (4)

- **The steady-state temperature distribution and stored energy in the fuel before the hypothetical accident shall be calculated for the burn-up that yields the highest calculated cladding temperature.**
- **Thermal conductivity of the UO2 shall be evaluated as a function of burn-up and temperature.**
- **The thermal conductance of the gap between the UO2 and the cladding shall be evaluated as a function of the burn-up.**

※ U.S. Nuclear Regulatory Commission, (2012). Title 10, Code of Federal Regulations, “Appendix K to Part 50-ECCS Evaluation Models,“ p.513.

■ Methods of Coupled calculation



❖Steady-state Depletion Calc.

※ Code Versions : MARS-KS subversion-77, FRAPTRAN-1.5, and FRAPCON-3.5

■ Input Preparations for Analysis

- Reference scenario
  - A large-break LOCA for an OPR-1000 PWR
- Core Modeling
  - Two flow channels: hot and average with crossflow junction
  - Three heat structures: hottest rod, hot assembly, core average rod
- Power Data
  - OPR-1000 equilibrium cycle core
  - Radial peaking factor and the axial power distribution
  - Adverse conditions allowed for the normal plant operation
- FRAPCON depletion
  - Generation of restart file for FRAPTRAN
  - Constant linear power rate of fuel rod is assumed with cycle-average axial power profile
- MARS steady-state adjustment
  - Thermal conductivities of the coupled fuel rods were adjusted
  - Resulting average fuel temperatures are made close to the FRAPCON results at the given burnups

■ Formulation of Analysis-State Points

- For a conservative PCT determination, the analysis-state points should be selected on the envelope line.
- For the state points on the slope line, MARS and FRAPCON inputs were modified to accommodate the reduced linear power rate.

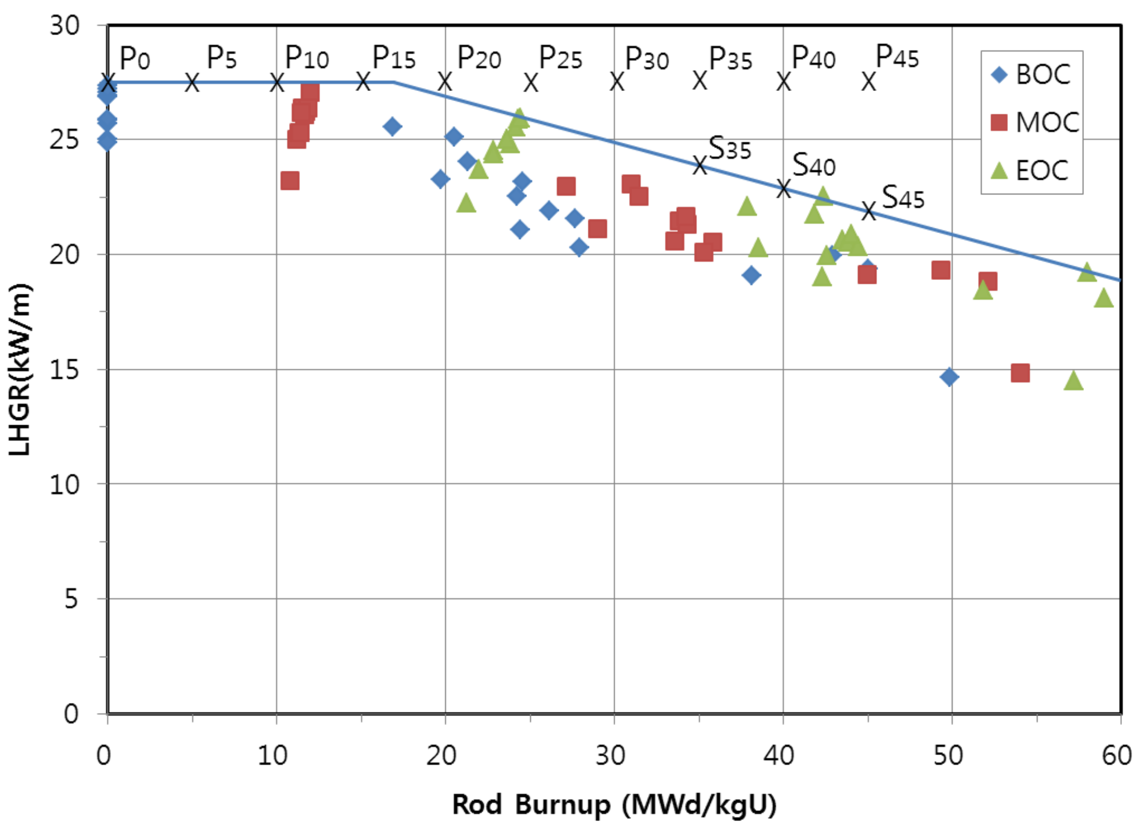


Fig. 1. Fuel rod survey data and analysis-state points

■ Results of FRAPCON Calculation

- **FRAPCON calculation was carried out with constant linear power rate corresponding to BOC radial peaking.**

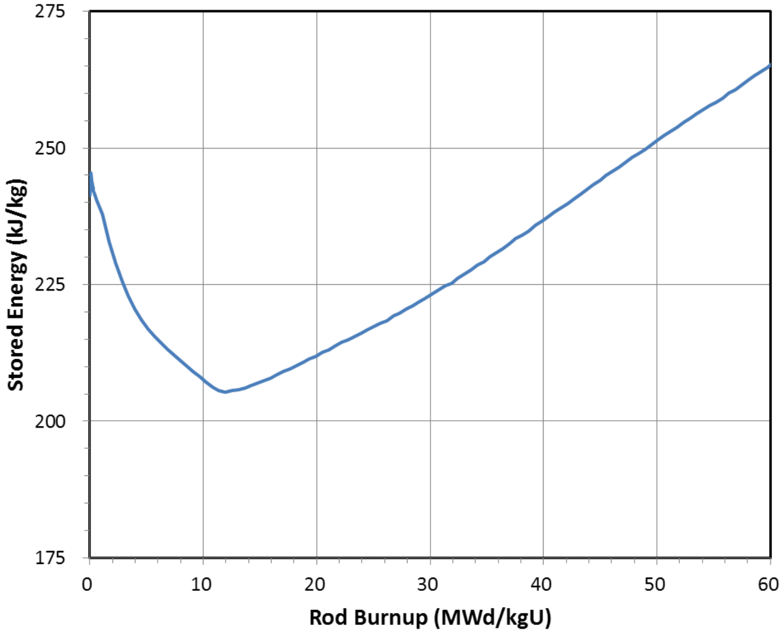


Fig. 2. Stored energy for rod with fixed linear power rate

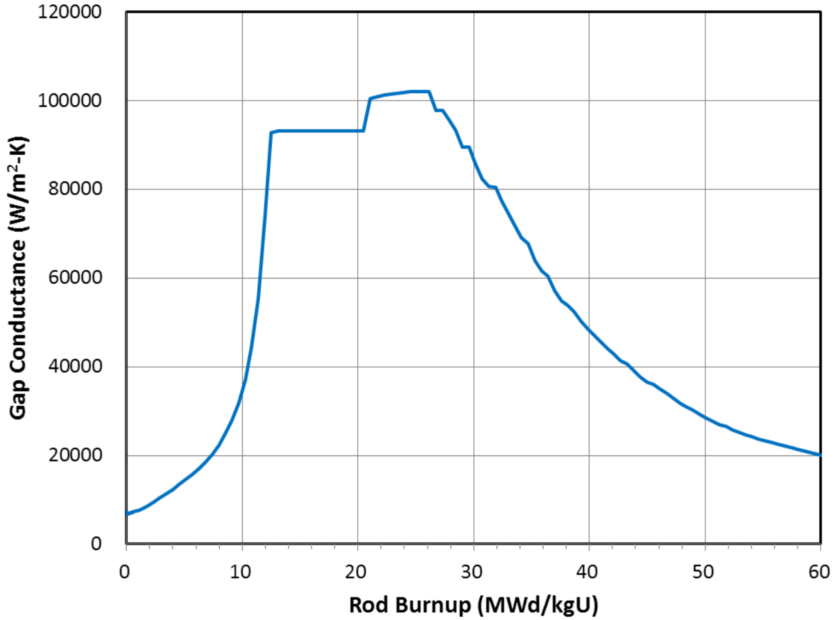


Fig. 3. Fuel rod gap conductance variation.

■ Calculation Results with Fixed Linear Power Rate (1)

- **The blowdown PCT decreases while the reflood PCT increases.**
- **Cladding rupture occurred around 150 seconds and 180 seconds respectively and the reflood PCT occurred after the rupture.**
- **Rupture model of FRAPTRAN escalates the PCT.**

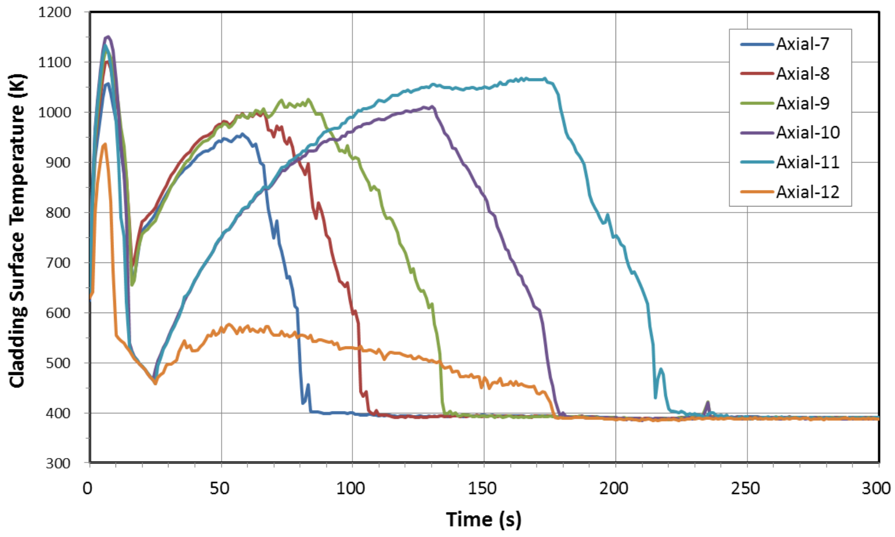


Fig. 4. One-way calculation results at 0 MWd/KgU.

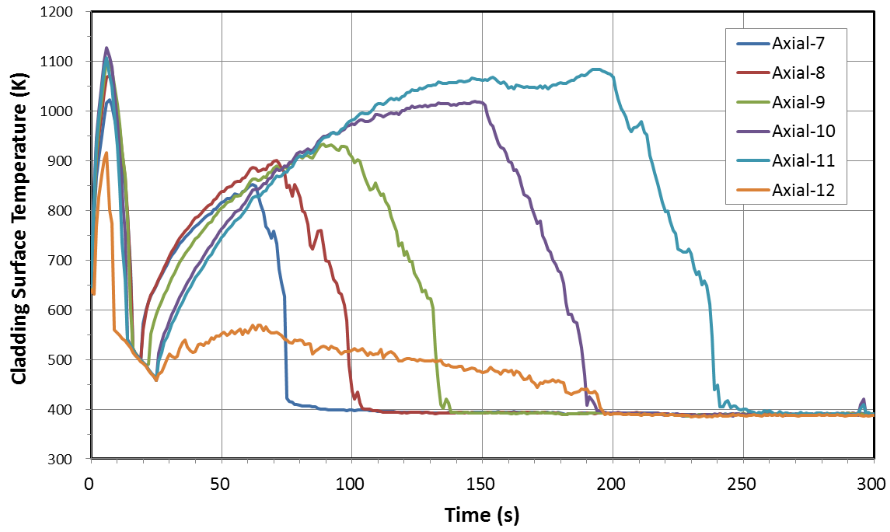


Fig. 5. Feedback calculation results at 35 MWd/KgU.

■ Calculation Results with Fixed Linear Power Rate (2)

- **PCT has similar trend as the stored energy of Fig. 2.**
- **The blowdown PCT reaches a minimum at around 20 MWd/KgU and exceeds that of BOC near 42 MWd/KgU.**

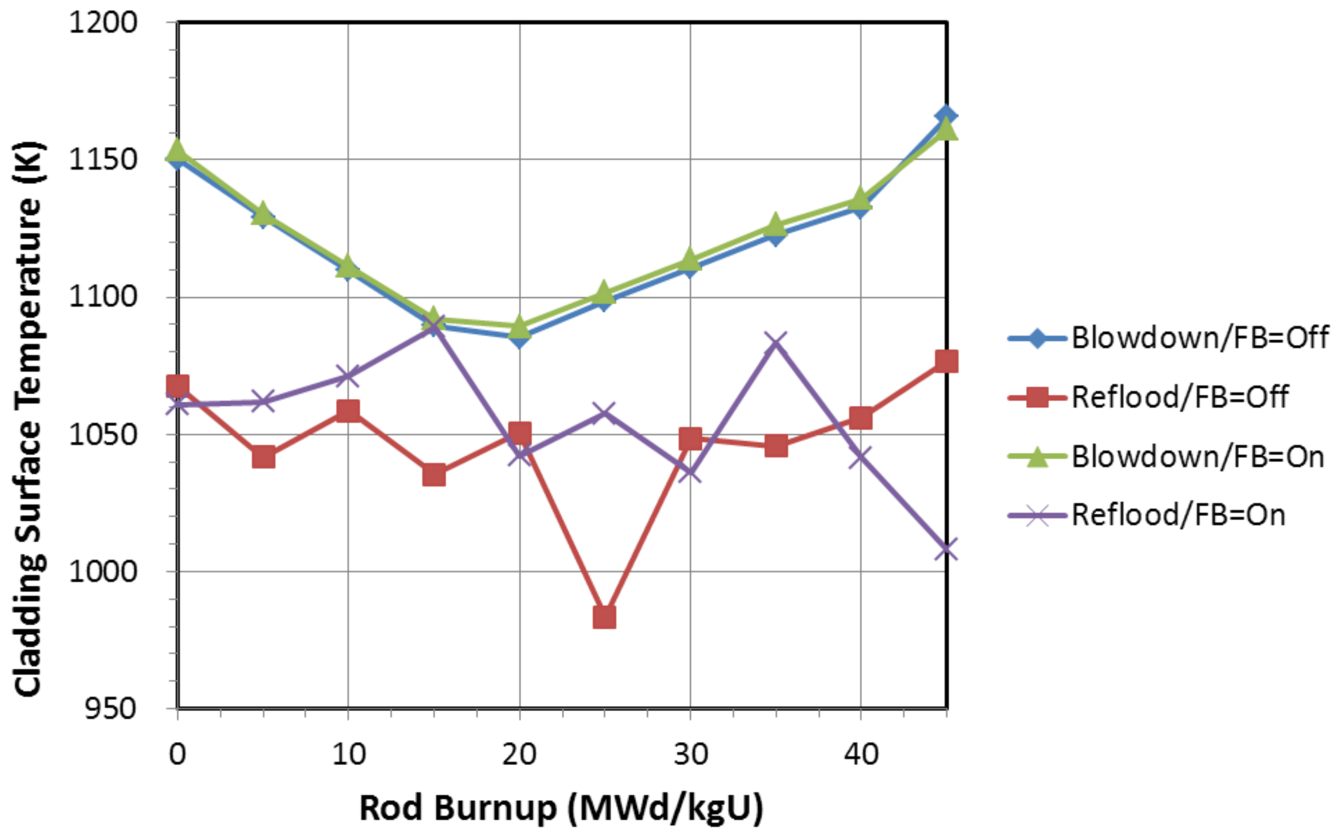


Fig. 6. PCT variation as function of fuel burnup.

■ Calculation Results with Reduced Linear Power Rate

- **In actual power reactors, the linear power rates of fuel rods will decrease as burnup increases in the high burnup range.**
- **If the reduced linear power rate of the high fuel burnup range is considered, the PCTs decrease significantly, and they are lower than those at BOC.**

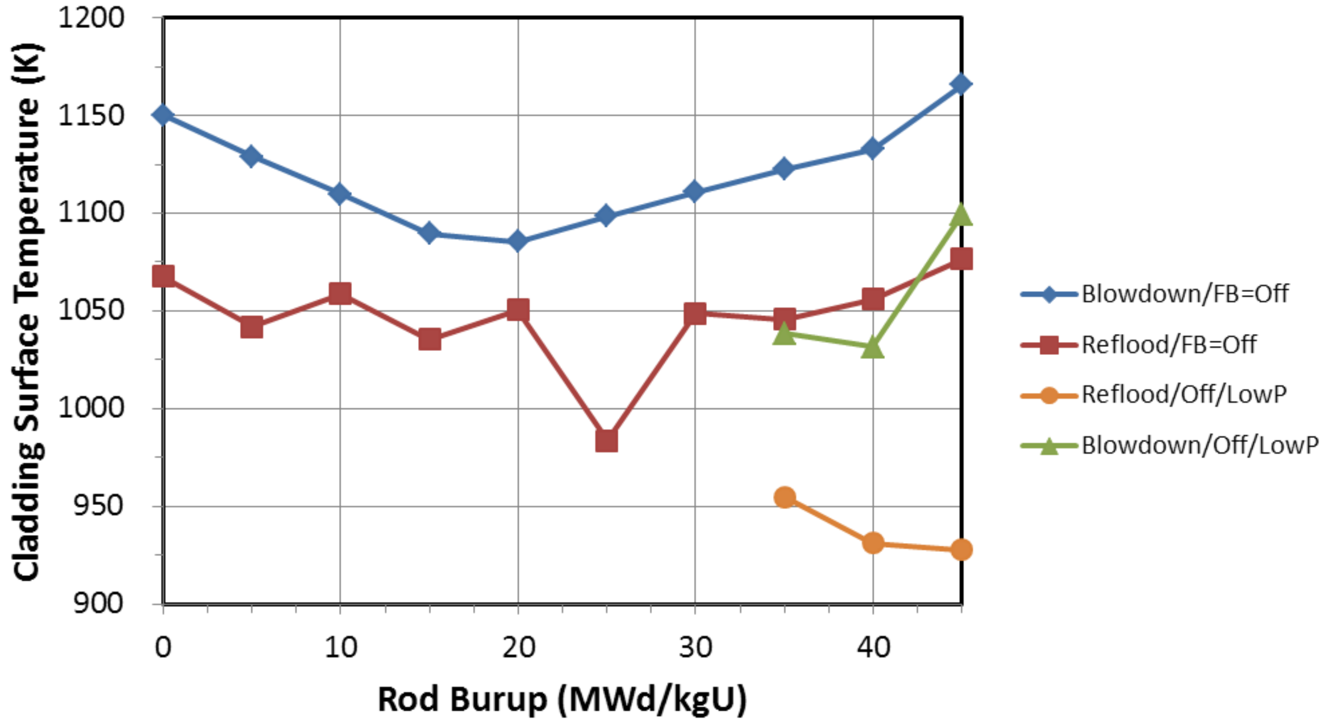


Fig. 6. PCT variation as function of fuel burnup.

■ Conclusions

- PCT during LOCA is speculated to increase due to fuel thermal conductivity degradation as fuel burnup proceeds.
- The MARS/FRAPTRAN coupled code was applied to assess the effect of burnup on PCT in LOCA analysis.
- PCTs decrease until the fuel burnup reaches around 20 MWd/KgU and then increase afterwards, when the initial linear power rate is fixed.
- When the linear power rate of the fuel rod is reduced in the high burnup range, the PCT decreases eventually.
- Although the fuel burnup tends to increase the PCT, the results show that the effect of reduced linear power rate on PCT can exceed that of burnup.
- The results suggest that the PCT of LOCA analysis at BOC remains effective for the whole burnup range of the cycle.
- Further systematic studies are needed to draw more comprehensive conclusions on this issue.

감사합니다

NSE
TECHNOLOGY