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Sensitivity Study for Uncertainty Range of Fuel and Safety Injection Parameters in KINS-REM

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1. Introduction

In KINS Realistic Evaluation Methodology (KINS-REM), the uncertainty parameters could be classified into 4 categories, e.g. parameters related the fuel stored energy, the heat transfer model, the plant system and the safety injection. The initial stored energy in the fuel was related to the steady-state temperature distribution and was an initial condition at the onset of a postulated LOCA. The core power, the decay heat, the gap conductance and the fuel thermal conductivity were an influencing parameters in the fuel stored energy in KINS-REM. The related parameters with a safety injection could change the thermal behaviors in a core in the refill and reflood phases. The parameters of the safety injection tank (SIT) and the refueling water storage tank (RWST) were considered in KINS-REM.

In general, the uncertainty range of these parameters could influence the overall calculation uncertainty for the large break LOCA (LBLOCA) and the effect of uncertainty range was different for the parameters. Therefore, the uncertainty range should be selected carefully through the relevant procedures such as the comparison with experiments and/or the expert judgment. In this study, the effect of uncertainty parameters related the fuel stored energy and the safety injection was evaluated for the LBLOCA analysis for OPR1000.

2. Uncertainty Parameters

Table 1 show the uncertainty range and distribution for the parameters related the fuel stored energy and the safety injection. In a MARS-KS code [1], the gap conductance was calculated using the mole fraction of gases, width of fuel-cladding gap, surface roughness of the cladding and temperature jump distance. In KINS-REM, the uncertainty of gap conductance was determined as 0.4 ~ 1.5 to fit the results of the fuel performance code. The uncertainty ranges for the fuel thermal conductivity and the decay heat were determined by reviewing the experimental documents. The uncertainty range of core power was considered by the conservative technical guidance. In KINS-REM, the actuation pressure, the water temperature and the water inventory of SIT and the water temperature of RWST were used as the uncertainty parameters. The uncertainty ranges related safety injection were determined by the FSAR [2] of OPR1000.

Table 1. Uncertainty Range and Distribution

Parameters	**Range/Distribution**
Related Fuel Stored Energy	
Gap conductance (Clad roughness)	0.4~1.5 (U)
Fuel thermal conductivity	0.847~1.153 (U)
Core power	0.98~1.02 (N)
Decay heat	0.934~1.066 (N)
Related Safety Injection	
SIT actuation pressure (psi x 10^2)	5.846~6.467 (U)
SIT water inventory (ft^3 x 10^3)	1.7901~1.9271 (U)
SIT water temp. (°F)	50.1~120.0 (U)
RWST water temp. (°F)	40.0~120.0 (U)

* Distribution (L : Log-Normal, N : Normal)

3. Analysis Results

For OPR1000, the calculated initial conditions showed a good agreement to the plant actual values for the major operating parameters.

Fig. 1, Fig. 2 and Fig. 3 show the variation of the blowdown PCT, the reflood PCT (Peak Cladding Temperature) and final quenching time for the fuel parameters respectively. The minimum and maximum uncertainty values were applied to compare the reference base calculation. In general, the blowdown temperature could be affected by the internal stored energy of the fuel and the blowdown temperature increased as the internal stored energy increased. For the core power and decay heat, the blowdown/reflood PCT increase and the quenching time delay occurred at the maximum uncertainty value. Also, the initial stored energy and the blowdown PCT increased at the maximum uncertainty value of the cladding roughness since the gap conductance decreases with the cladding roughness. On the contrary, the initial stored energy decreased as the heat transfer rate increased due to the high fuel thermal conductivity. Therefore, the blowdown/reflood PCT increase was shown at the minimum uncertainty value. Among these parameters, the gap conductance and the fuel thermal conductivity had a large impact on the blowdown PCT. The reflood PCT and the quenching time showed the similar trend with the blowdown PCT.

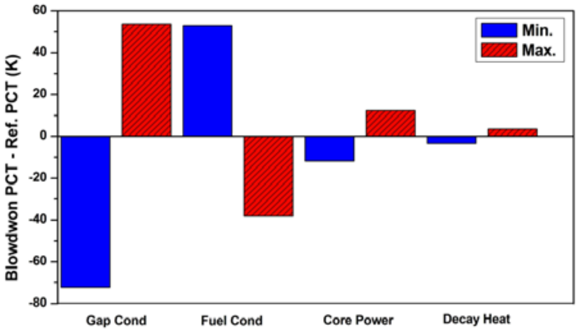

Fig. 1 Blowdown PCT difference for fuel parameters

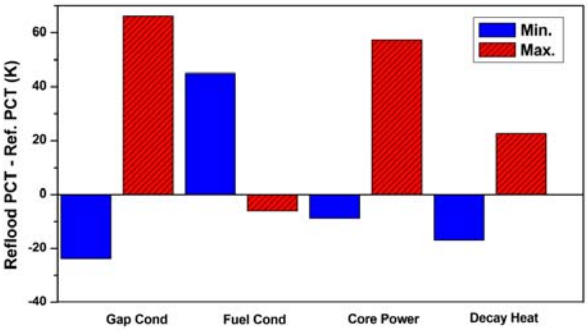

Fig. 2 Reflood PCT difference for fuel parameters

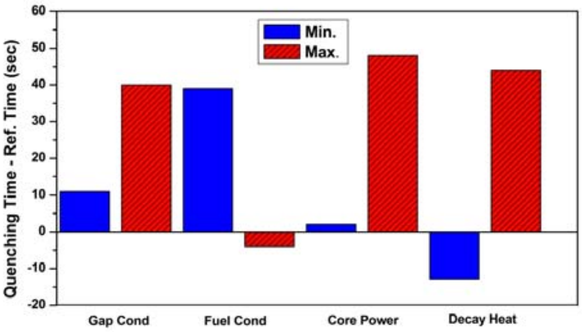

Fig. 3 Quenching Time difference for fuel parameters

Fig. 4 and Fig. 5 show the variation of reflood PCT and final quenching time for safety injection parameters. In this calculation, the loss of off-site power and the worst single failure were assumed simultaneously with the break and the minimum safety injection flowed into the core. The injected flow rate of SIT was adjusted according to the pressure of the downcomer and the injecting time is determined by the actuating pressure of SIT. In general, the delay time (~30 sec) of SI injection was assumed and the SIT injection started about 15 sec after a break in the LOCA analysis. Therefore, the safety injection parameters could not influence the blowdown phase. As shown in Fig. 4 and Fig. 5, the consistent results were not shown for the reflood PCT and the quenching time. For the water temperature of SIT, the reflood PCT decreased largely at the minimum temperature since the SIT flow was injected earlier and much more than the SI flow as we expected. The effects of the actuation pressure and the water inventory of SIT were not significant because the injection and the empty of SIT for the maximum and minimum cases were occurred at roughly the same time due to the high depressurization of a reactor coolant system in LOCA. And, the difference of reflood PCT for SI water temperatures was insignificant because of a low safety injection rate compared to SIT. The quenching time was reflected in the trend of the reflood PCT.

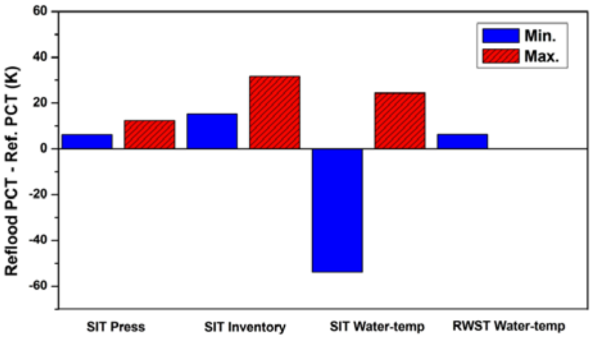

Fig. 4 Reflood PCT difference for safety injection parameters

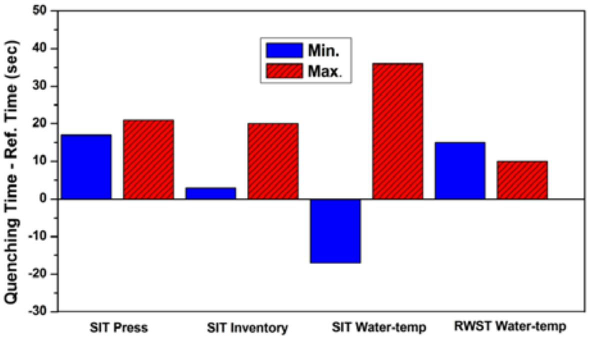

Fig. 5 Quenching time difference for safety injection parameters

Fig. 6 and Fig. 7 show the PCT behaviors for the combinations of fuel parameters and safety injection parameters respectively. The separate parameter in Table 1 was selected to make the combination to increase or decrease the PCT. In the case to increase PCT of Fig. 6, the increase of blowdown PCT was very significant and the increase of PCT was about 230 K compared to the case to decrease PCT. Therefore, the selection of uncertainty range for the fuel parameters, especially including the gap conductance and the fuel thermal conductivity, was very important to quantify the overall uncertainty for LBLOCA. In the case to increase PCT of Fig. 7, the reflood PCT increased slightly but the quenching time delayed significantly because of the water inventory and the water temperature of SIT.

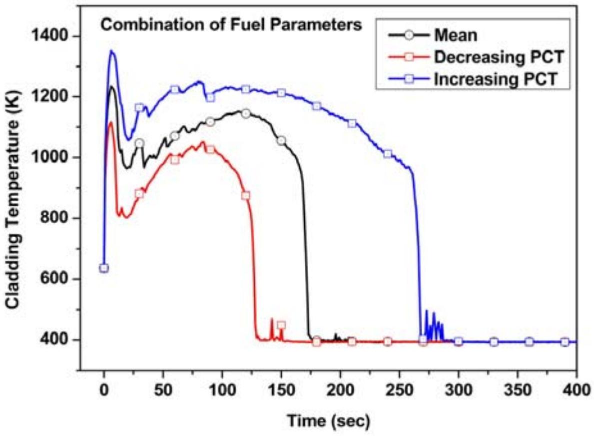

Fig. 6 PCT behaviors for fuel parameters

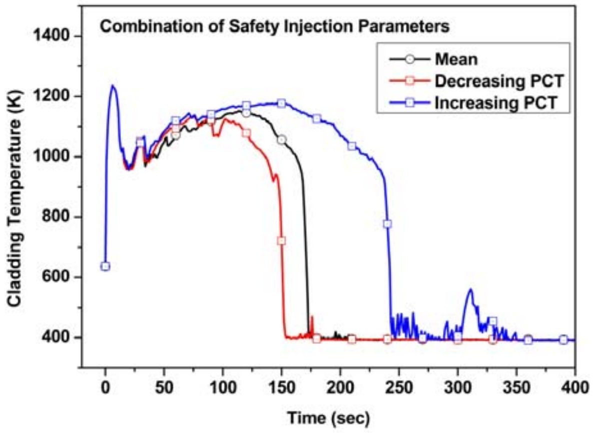

Fig. 7 PCT behaviors for safety injection parameters

4. Conclusion

The LBLOCA calculation for OPR1000 was performed to evaluate the effect of uncertainty parameters related the fuel stored energy and the safety injection. For the fuel parameters, the blowdown PCT increased when the stored energy increased as expected. The effects of the gap conductance and the fuel thermal conductivity was significant. For the safety injection parameters, the water temperature of SIT had a big effect on the reflood PCT because of the high injection rate. Therefore, in order to obtain the more robust uncertainty range, the generic tool would be needed for quantifying model uncertainties.

REFERENCES

[1] KAERI, MARS Code Manual, Volume V: Models and Correlations, KAERI/TR-3872, 2009.
[2] KHNP, Hanbit 5&6 Final Safety Analysis Report, 2013.