Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2011

Study on Quantification Method of the Uncertainties of Ageing Elements for Evaluation of the effects of Ageing on Safety Margins during LBLOCA for CANDU reactors

Yong Won Choi[a*], In Young Kim[a], Un Chul Lee[a], Kab Kim[b]
[a] *Dept. Nuclear Engr. Seoul Nat'l Univ., Shillim-dong, Kwanak-gu, Seoul, 151-744*
[b] *Korea Institute of Nuclear Safety, Goosong-dong, Yusong-gu, Daejeon, 19*

[*] *Corresponding author: goldsky7@snu.ac.kr*

1. Introduction

As a part of development of a valid method to evaluate the effects of ageing on safety margins during LBLOCA (Large Break Loss of Coolant Accident) for CANDU reactors [1][4], it is required the verification of effectiveness of the methodology. In this study, order to verify the validity of developed methodology, quantification of the uncertainty was attempted through various methods. And through these results, the effectiveness of the developed method was verified.

2. The method to evaluate the effects of ageing on safety margins during LBLOCA

The assessment methodology consisted of six steps, and a brief explanation on each step is given as follows. The first step was the establishment of code applicability. This step was divided into three parts by selecting the power plant, accident scenario, and thermal-hydraulic code for the assessment. In the second step, ageing elements that affect the main safety variables were selected. The ageing elements can comprehensively consider the thermal hydraulic effects of NPPs due to ageing. In addition, it allows for immediate consideration of the code input without adjusting the preexisting thermal hydraulic system code. After identifying the ageing elements [2], it was necessary to predict the variation in these elements properly over time. Unfortunately, it was not easy to form an explicit relationship between the ageing elements and ageing mechanism because of insufficient data and lack of applicable models. Thus, a third step was to develop a degradation model. A degradation model is a model that predicts the change in the level of the ageing elements over time. At this step, the range of the ageing elements was also determined by the degradation model. The degradation model used measured data and statistical analysis methods. In addition, it is an open model so improvement is possible. The fourth step was a newly introduced method in this study which conservatively selected optimized combinations of ageing elements and their effects. This means that optimized combinations of ageing elements were selected that caused the highest PCT during the transient state based on the sensitivity analysis taking into consideration all possible combinations. In the fifth step of this proposed method, statistical analysis methods (Wilks' Formula) were used to combine the uncertainty. The 3rd highest value of PCT during an accident, which guarantees a 95% probabilistic upper limit at a 95% confidence level, was calculated. The third Wilks' formula used in this step was utilized to widely combine each individual uncertainty. The sixth step was for the assessment of safety margins [3], and the concept of safety margins was introduced to propose a criterion for the assessment of thermal hydraulic influence on CANDU reactors related to ageing. Figure 1 shows the flow chart for the assessment of the safety margin for this method.

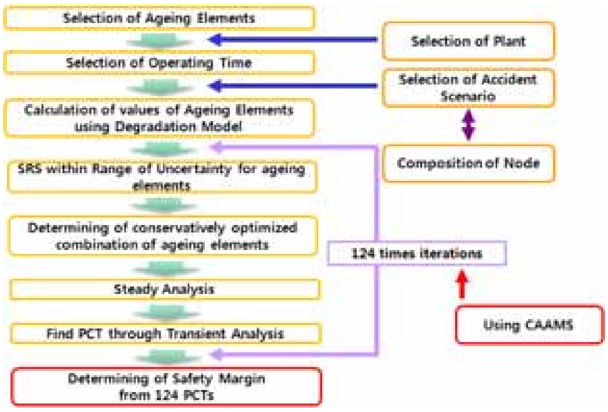

Fig. 1. Diagram of the safety margin assessment methodology for the ageing

3. Quantification of the uncertainty through various methods.

The following table shows the quantification of the uncertainty through the various methods. The three major elements mean the roughness, the loss coefficient and the flow area of fuel channel according to the results of PIRT.

The 8 maximum PCTs compared in Table 1 are as follows.

① Quantification of the uncertainty with the proposed methodology (conservatively optimized combinations assessment method)

- 59 iterations of calculations (3 major elements)
- Simple Random Sampling
- 1277.8K

② Quantification of the uncertainty not through the conservatively optimized combinations assessment method

- 59 iterations of calculations (3 major elements)
- Simple Random Sampling
- 1266.9K

③ Quantification of the uncertainty for which the uncertainty range of each of the ageing elements is extended

- Performing random sampling at -∞ ~ +2σ by extending the minimum range (-∞ means that ageing rate is 0)
- 59 iterations of calculations (3 major elements)
- Simple Random Sampling
- 1277.6K

④ Quantification of the uncertainty through the response surface method (3 major elements)

- 1267.2K

⑤ 125 calculations with various combinations for the 3 major elements

- 125 iterations of calculations (3 major elements)
- Using 5 points for each ageing element
- 1269.3K

⑥ Summation of the independent effects, which are exerted on the PCT of each of the ageing elements (3 major elements)

- 1288.1K

⑦ Quantification of the uncertainty through the deterministic method (3 major elements)

- 1264.2K

⑧ Quantification of the uncertainty through the Mote Carlo Method

- 3000 iterations of calculations
- Simple Random Sampling
- 1284.1K

According to the results, quantification of the uncertainty through the conservatively optimized combinations assessment method presented in the proposed methodology has a PCT which is lower than the summation of the independent effects and lower than the results calculated with the Monte Carlo method; however, it has a PCT value which is larger than any of the quantification methods for the uncertainty even if there are not any big differences.

In addition, the result, calculated through 3000 iterations with the Monte Carlo method, has a limit of errors of 0.58 K with a confidence level of 99%. Additionally, its maximum value was 1284.1K when considering the 3 major elements while the maximum PCT calculated through the proposed methodology was 1277.8K. From these results, the difference between the two PCTs is just 6.3K and the difference between the standard deviations of the results is 0.8K. Thus, there is no great difference in reliability between the two results. However, considering the time efficiency, there is a great difference. Thus, the time of calculation to get the results using the Monte Carlo method was about 10 times longer than the proposed methodology. Hence, the proposed methodology is considered to have an advantage with respect to efficiency.

Table 1. The results of quantification of the uncertainty through various methods

No	Content	Maximum PCT(K)	Rank	Note
1	Quantification of uncertainty through the developed methodology (conservatively optimized combinations assessment method)	1277.8	3	- Calculation of 59 times - Simple Random Sampling - 3 major elements
2	Quantification of uncertainty not through conservatively optimized combinations assessment method	1266.9	7	- Calculation of 59 times - Simple Random Sampling - 3 major elements
3	Quantification of uncertainty for which the uncertainty range of each of the ageing element is extended	1277.6	4	-Performing random sampling at -∞(ageing rate =0) ~ +2σ by extending the minimum range - Calculation of 59 times - Simple Random Sampling - 3 major elements
4	Quantification of uncertainty through the response surface method	1267.2	6	- 3 major elements
5	Calculations of 125 times through various combinations for the 3 major elements	1269.3	5	- Calculation of 125 times - Using 5 points for each ageing element - 3 major elements
6	Summation of independent effect which is exerted to PCT of each of the ageing element	1288.1	1	- 3 major elements
7	Quantification of uncertainty through deterministic method	1264.2	8	- 3 major elements
8	Quantification of uncertainty through Mote Carlo Method	1284.1	2	- Calculation of 3000 times - Simple Random Sampling - 3 major elements

4. Conclusions

In this study, order to verify the validity of developed methodology, quantification of the uncertainty was attempted through various methods. Although this result of the assessment does not represent all of the ageing elements used in this study, when considering that the assessment was done for the upper 3 elements for the results from the PIRT, a considerable degree of validity has been shown here for the conservatively optimized combinations of the ageing element assessment method.

REFERENCES

[1] Choi, Y. W. et al., "A statistically-engineered approach for assessing ageing effects on thermal-hydraulic elements for CANDU reactors" , Annals of Nuclear Energy 38 1527–1544, April 2011.

[2] IAEA, "Assessment and management of ageing of major nuclear power plant components important to safety: CANDU Reactors assemblies" IAEA-TECDOC-1197, April 2001.

[3] IAEA, "Safety margins of operating reactors-Analysis of uncertainties and implications for decision making", IAEA-TECDOC-1332, January 2003.

[4] Choi, Y.W., Kim, M.W., et al., "Development of Evaluation System of Safety Margin Effects for Degradation of CANDU Reactors Using RELAP-CANDU", ICAPP 2008, Jun 2008