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Similarity Evaluation of LBLOCA Calculation Results Applying Different Important Uncertainty Variables

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1. Introduction

In best estimate plus uncertainty (BEPU) method, an identification of important uncertainty variables to an accident consequence and a quantification of their uncertainties are crucial tasks. Several works for identification of important uncertainty variables have been conducted, and the most of them used statistical methods. However, those results were mostly drawn from data with small sample sizes. On the other hand, the consideration of important uncertainty variables to an accident influences the distribution and the value of the figures of merit (FOMs) such as peak cladding temperature (PCT), the 95-percentile PCT with 95% confidence level (PCT95/95).

Among the previous studies, Kang [1] identified important uncertainty variables influential to APR1400 large break loss of coolant accident (LBLOCA) by applying comprehensive correlation and multiple linear regression analysis with hypothesis testing. In his study, the correlation analysis and multiple linear regression analysis provided different identification results. Therefore, in this study, direct Monte Carlo (MC) calculations were conducted by applying important uncertainty variables derived from each correlation analysis and multiple linear regression analysis [1]. Then, the similarity of PCT distribution was evaluated. In addition, the PCT95 with 95% tolerance limit (PCT95/95 TL) by Wilks' method was also compared to validate previous work obtained by statistical methods.

2. APR1400 LBLOCA Calculations

In the previous work [1] in which important variables were identified by statistical methods among 18 uncertainty variables, the correlation analysis showed that 7 variables are important, while the multiple linear regression analysis found that 11 variables have the influence on the PCT. Considering 7 (correlation analysis, noted as 7 UPs), 11 (multiple linear regression analysis, noted as 11 UPs), 18 (all, noted as 18 UPs) uncertainty variables, corresponding direct MC calculations with different samples were performed. In the previous work [2], it was shown that the MC method using 1000 samples could provide reliable enough results with narrow confidence interval (CI) and high convergence. Therefore, in this study, 1000 samples were used in the MC calculations, and the latin hypercube sampling was used.

3. Results and Discussions

Fig. 1 shows the empirical cumulative distribution function (ECDF) of PCT according to the number of considered uncertainty variables. For blowdown PCT and Max PCT, there were little differences between the results. For reflood PCT, there was also little difference between the result of 11 UPs and 18 UPs, while the result of 7 UPs and 18 UPs showed a difference.

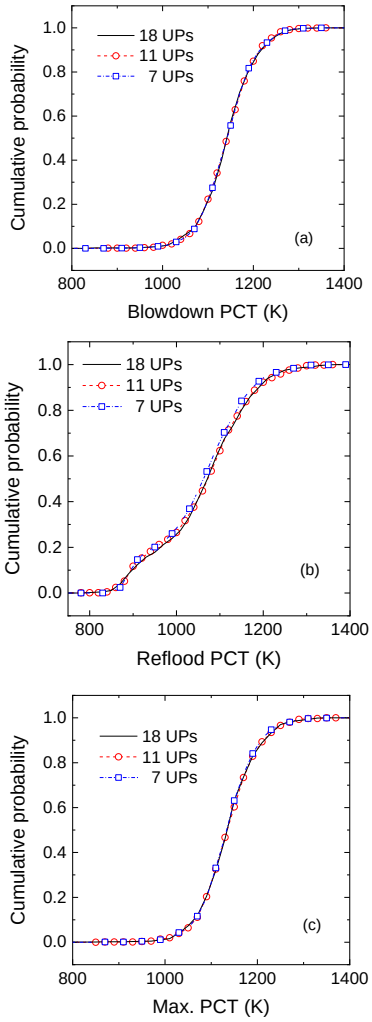

Fig. 1. Cumulative distribution function of PCT: (a) blowdown PCT, (b) reflood PCT, (c) Max PCT.

The Anderson-Darling (AD) test which is non-parametric and distribution-free, was performed to statistically compare distributions of PCTs with respect to the number of considered uncertainty variables [3]. The AD test is known to be sensitive towards to differences at the tails of distributions and to be better capable of detecting very small differences even between large samples sizes than well-known Kolmogorov-Smirnov (KS) test [4]. The null hypothesis is that two data come from the same continuous distribution, and the alternative hypothesis is that there is evidence that the data don't come from the same distribution. Table I shows the p-values of AD tests. As a result of the AD test, the p-value of the reflood PCT between 18 UPs and 7 UPs was less than the level of significance of 0.05, therefore it was found that the reflood PCT distribution of 18 UPs and that of 7 UPs were statistically different. In all other cases, the null hypothesis that PCT distributions are the statistically same, could not be rejected.

Table I: Summary of AD test (p-value)

	7 UPs vs. 18 UPs	11 UPs vs. 18 UPs
Blowdown PCT	0.933	0.924
Reflood PCT	0.038	0.921
Max PCT	0.819	0.962

To compare the PCT95 with 95% tolerance limit (PCT95/95 TL) according to the number of considered uncertainty variables, the 3rd order Wilks' method was used. In this study, 30 uncertainty parameter data sets were newly sampled using simple random sampling. Then, 30 PCT95/95 TLs were calculated for each case. When the 3rd order Wilks' method is employed, the minimum number of required samples is 124, which was used in this study. Fig. 2 shows the Box-Whisker plot of PCT95/95 TLs with respect to the number of considered uncertainty variables. The 11 UPs showed similar results to the 18 UPs. In particular, the mean of 11 UPs was ~ 2.74 K higher than 18 UPs. However, the 7 UPs showed significant differences with 18 UPs. All statistics except minimum were smaller than those of 18 UPs, showing non-conservative results.

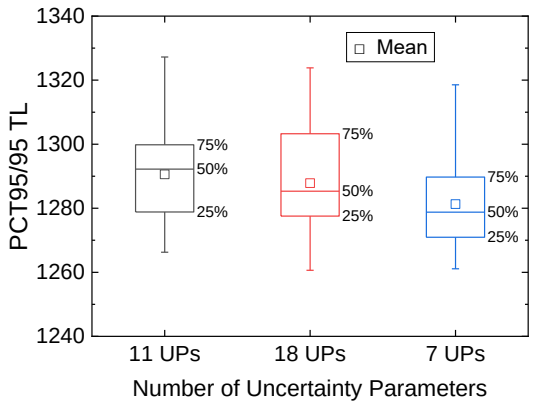

Fig. 2. Box-Whisker plot of PCT95/95 TLs using Wilks' method.

4. Conclusions

In this study, direct MC calculations were performed by applying influential uncertainty parameters previously derived from correlation analysis and multiple linear regression analysis [1]. Considering 7 (correlation analysis), 11 (multiple linear regression analysis), 18 (all) uncertainty parameters, corresponding MC calculations using 1000 samples were conducted. Then, the similarity of PCT distribution, and PCT95/95 TL was evaluated to verify previous work [1] obtained by statistical methods.

There were little differences in distributions for blowdown PCT among the 7 UPs, the 11 UPs, and the 18 UPs. However, for reflood PCT, the distribution of 7 UPs was found to be statistically different to that of 18 UPs by the AD test. Meanwhile, there was no statistical evidence that the distributions between 11 UPs and 18 UPs were different. The difference in reflood PCT prediction between 7 UPs and 11 UPs have an effect on the prediction of PCT95/95 TL. The PCT95/95 TL of 7 UPs were estimated to be smaller than those of 18 UPs, showing non-conservative results. On the other hand, the PCT95/95 TL of 11 UPs were higher or similar to those of 18 UPs; it means that the change in PCT can be sufficiently predicted only by considering 11 UPs, but not by considering 7 UPs. These results showed that the multiple linear regression analysis could provide sufficiently reasonable assessment result in identifying important uncertainty variables, while the correlation analysis showed a limitation.

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