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Evaluation of Gap Conductance Approach for Mid-Burnup Fuel LOCA Analysis

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1. Introduction

There are many uncertainty parameters of fuel rod that can change the PCT during LOCA analysis, and these have been identified by the authors' previous work already[1]. But, for the 'best-estimate' LOCA safety analysis the methodology that does not use the overall uncertainty parameters altogether but uses the gap conductance uncertainty alone has been developed to simulate the overall fuel rod uncertainty, because it can represent many uncertainty parameters. Based on this approach, uncertainty range of gap conductance was prescribed as 0.67~1.5 in audit calculation methodology on LBLOCA analysis[2]. This uncertainty was derived from experimental data of fresh or low burnup fuel. Meanwhile, recent research work identify that the currently utilized uncertainty range seems to be not enough to encompass the uncertainty of mid-burnup fuel[3]. Instead it has to be changed to 0.5~2.4 for the mid-burnup fuel(30 MWd/kgU).

In this study, therefore, the applicability of gap conductance approach on the mid-burnup fuel in LOCA analysis was estimated in terms of the comparison of PCT distribution between the gap conductance approach and the direct combination method. Here direct combination method means the fuel rod uncertainty is taken into account by the combination of overall uncertainty parameters of fuel rod altogether by use of a simple random sampling(SRS) technique.

2. Analysis Details

For the evaluation of impacts of gap conductance uncertainty to the PCT distribution, the probabilistic approach, so called a non-parametric order statistics approach, was utilized. Detailed information is as follows.

- Considered gap conductance uncertainty at low burnup fuel(0.5MWd/kgU) was 0.67~1.5 and 0.67~3.1. And at mid-burnup fuel(30MWd/kgU) it was set as 0.67~1.5 and 0.5~2.4.
- Sampling probability of the gap conductance uncertainty was assumed as a uniform distribution for conservative analysis.
- For the validation of gap conductance approach, the PCT evaluation by direct combination of each uncertainty parameter, here we considered total 34 different parameters, was also performed.
- To obtain more reliable data, five sets of 124 FRAPTRAN input for each analysis condition were prepared by use of the SRS technique.

3. Results and Discussion

3.1 Effect of Gap Conductance Uncertainty

Fig. 1 shows the frequency counts of blowdown PCT. In low burnup(0.5 MWd/kgU) case, as the uncertainty range of gap conductance was set as 0.67~3.1, the third highest PCT among 124 runs was 1130.9K(five sets averaged). When it was set as 0.67~1.5, the PCT distribution moved to higher temperature and the third highest PCT was 1138.2K, showing that these were very similar to results obtained by direct combination of 34 different parameters.

Meanwhile, when the fuel burnup was changed to mid-burnup(30 MWd/kgU), the PCT distribution and the third highest PCT was very similar even though the considered gap conductance uncertainty was changed. However, these were different to the results obtained by direct combination of each uncertainty parameter. The dirrerence of the third highest PCT between two methods was about 50K. These results imply that contrary to the low burnup case, the impacts of gap conductance uncertainty to the PCT distribution is relatively small at mid-burnup fuel conditions, and within currently considered uncertainty ranges, gap conductance approach seems to be ineffective to simulate the PCT distribution successfully.

3.2 Validation of Gap Conductance Approach

In this study we noticed that if the gap conductance was set as 0.67~1.5 with the uniform sampling probability, frequency count as well as cumulative count of PCT were very similar to the results, obtained by the direct combination of 34 uncertainty parameters. This means that if the uncertainty is chosen properly, the gap conductance approach seems to be effective to simulate overall fuel rod uncertainty in the low burnup fuel. However, as the fuel burnup for LOCA analysis increases to mid-burnup(30MWd/kgU), the gap conductance approach seems to be insufficient to simulate the PCT distribution. Fig. 2 shows the relationship between stored energy(ΔSE) and gap conductance(ΔGC) changes as well as PCT change and ΔGC. From the figure, the relationship between ΔGC and ΔSE as well as the ΔPCT and ΔGC on each

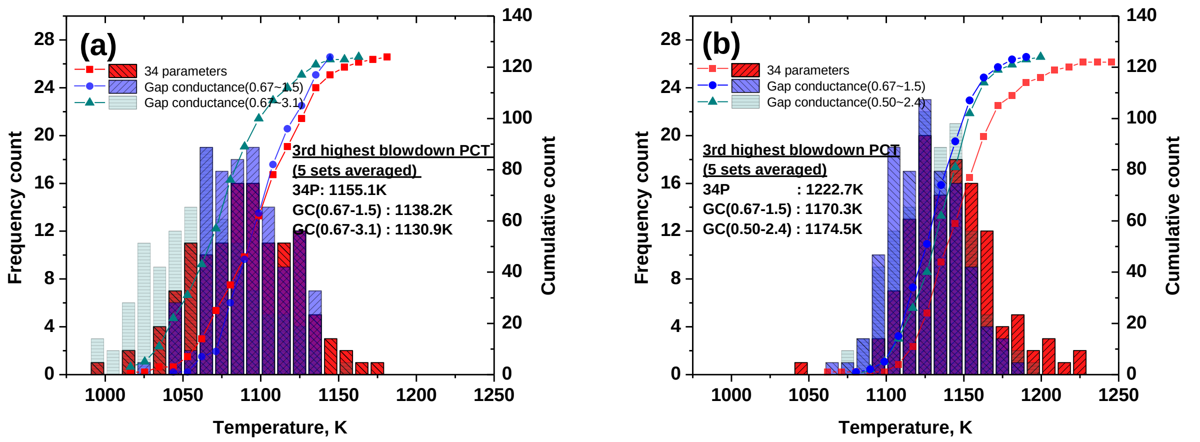

Fig. 1. PCT distribution with gap conductance uncertainty change in (a) 0.5MWd/kgU and (b) 30MWd/kgU fuel burnup. The third highest PCT in the figure is five sets averaged value.

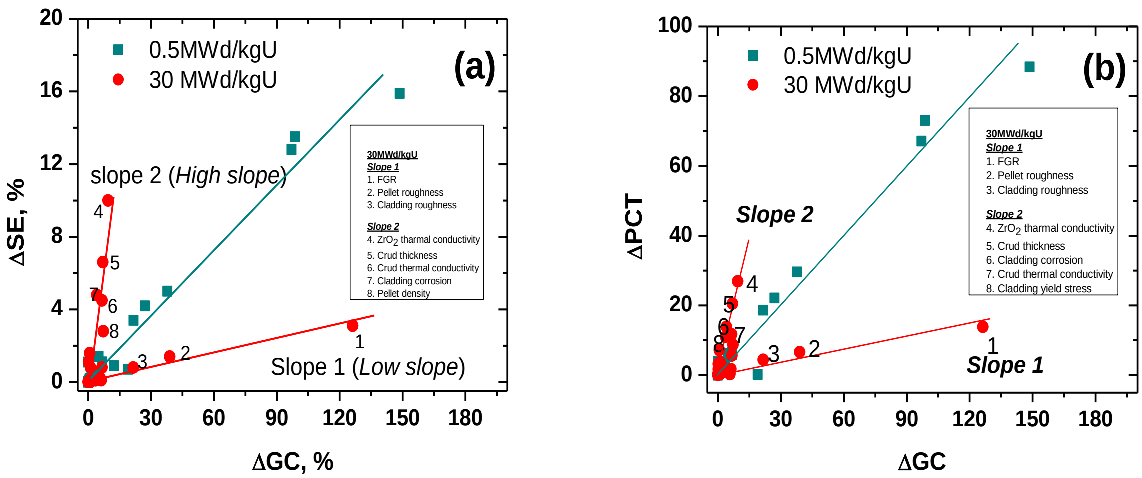

Fig. 2. Relationship between (a) stored energy(ΔSE) and gap conductance change(ΔGC) as well as (b) the ΔPCT and the ΔGC, obtained by sensitivity analysis results (FRAPCON-3.4a calculation) [1, 3]

uncertainty parameter can be represented as a single line in the low burnup fuel condition. Therefore if we adjust the gap conductance uncertainty properly, the distribution of the stored energy and the PCT can be controlled successfully. But, at the fuel burnup of 30MWd/kgU, the relationship is divided into two lines, high and low slope. Low slope(slope 1) is composed of the uncertainty parameters such as FGR, roughness of pellet/cladding. Meanwhile, high slope(slope 2) is composed of thermal conductivity and thickness of crud and oxide, pellet density and so on. This means that, if a contact condition between pellet and cladding has been developed, the uncertainty parameters, which can affect the gap conductance by changing the gap temperature, can induce much higher ΔSE than the parameters which constitute the gap conductance model itself. For this reason, currently considred gap conductance uncertainty cannot induce sufficenent stored energy chagnge, and finally it also cannot simulate PCT distribution succefully. This result suggest that when the contact between fuel pellet and cladding happen at mid-burnup fuel condition, the gap conductance approach seems to be ineffective to represent the overall rod uncertainties.

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