Characteristic Analysis of Fine Mesh Calculation Using VIPRE/BOA code System

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1. Introduction

VIPRE/BOA code system is currently used by KHNP to evaluate the risk of AOA(Axial Offset Anomaly) by the CRUD(Chalk River Unidentified Deposits), or CIPS (CRUD-Induced Power Shift), for domestic nuclear power plants. CIPS determines the degree of power shift by total boron deposition in CRUD deposited throughout a reactor core, so detailed analysis in pin-wise is not required. In CILC(Crud Induced Localized Corrosion) analysis, however, the possibility of a fuel damage due to localized deposition of the CRUD and maximum temperature of fuel cladding at a specific location should be evaluated. Therefore, a finer basis model than the normal calculation is necessary. For this reason, a fine mesh analysis methodology was suggested recently for CILC analysis. In this study, the preliminary analysis using fine mesh methodology was conducted and the results are used to characterize the fine mesh calculation.

2. Methods and Results

2.1 Analysis Tool

VIPRE-01 is a subchannel analysis code. It receives power distribution from nuclear design code and generates the thermal-hydraulic data needed to run BOA code[1]. And it has an option to reproduce the output in format that the BOA needs and can read.

BOA is a computer code to evaluate the AOA risk due to the CRUD and boron deposition using loading patterns, water chemistry conditions such as critical boron concentration by burnup[2] and the T-H data of the reactor core produced by VIPRE code.

VIPRE and BOA code have been developed by EPRI and the utility with EPRI membership is easy to access the codes. Therefore, VIPRE/BOA code system is conducted to analyze the water chemistry by KHNP.

2.2 VIPRE-01 Lumped Channel Model

In normal analysis, the lumped channel model is applied. The 1/4 symmetric core geometry and the 1/4 assembly as one channel are modeled on the case of nuclear design. Based on a OPR1000, the core geometry consists of 177 channels and gaps connecting the channels. The core structure and channel numbers of the general model are shown in figure 1.

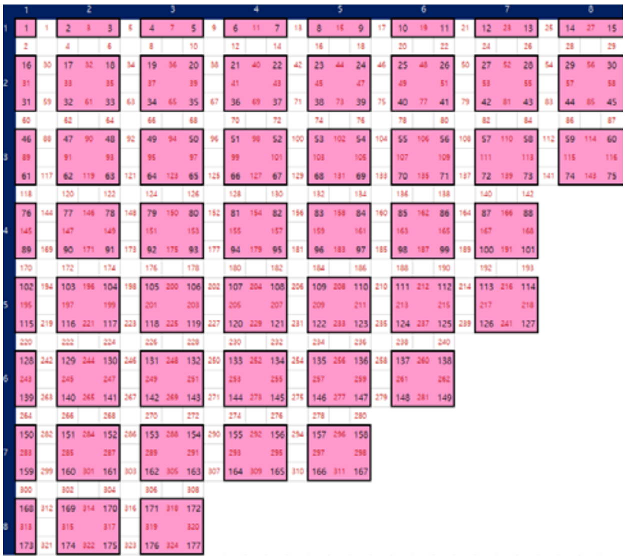

Fig. 1. 1/4 Core Geometry Designed by VIPRE-01

2.3 BOA Normal Model Result

To select target assembly for the fine mesh calculation, the BOA calculation was performed in advance so that CRUD thickness distribution is obtained(see fig. 2). The thickest channel is 109 and the channel was selected as a target assembly. And channel 81 was also selected to compare with channel 109 to find out what effects of selecting the wrong channel as a target. And the fine mesh results were compared with the normal model results.

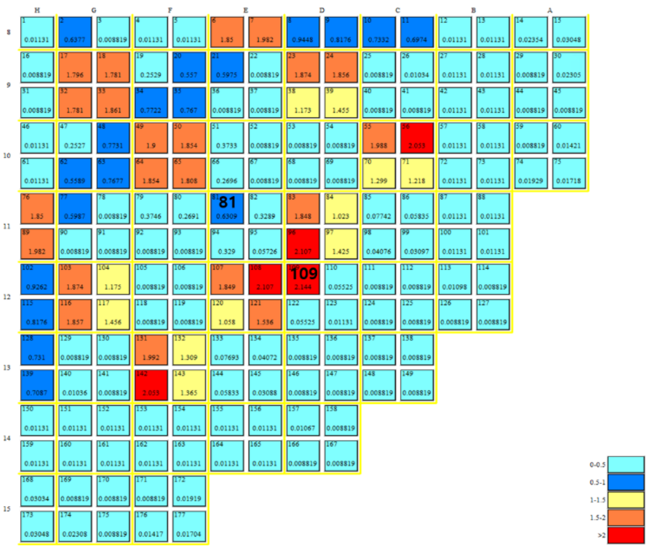

Fig. 2. CRUD Thickness Distribution map

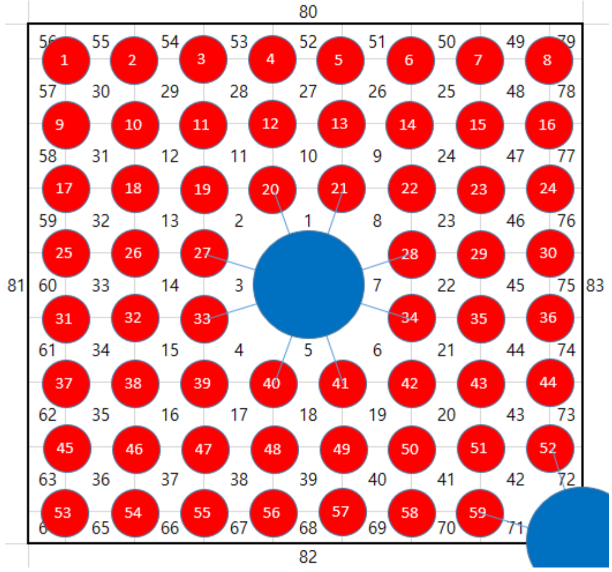

Fig. 3. VIPRE-01 Subchannel Model of the Second Quadrant of PLUS7 for Ch109 and Ch81 Fine Mesh Calculation

2.4 VIPRE-01 Subchannel Model for Fine Mesh

The fine mesh structure of PLUS7 fuel of a OPR1000 is shown in figure 3.

There are 59 fuel rods and 79 subchannels within a quarter assembly. Channels from 80 to 83 are lumped channels for boundary surface calculations. Each fuel rod surface is divided by subchannels in contact with the fuel rod so that there are four surfaces per one fuel rod. The fine mesh calculation produces detailed results such as the maximum temperature of a fuel cladding, maximum thickness of the CRUD, fuel rod position and surface number with them.

2.5 BOA Fine Mesh Calculation Results

The calculation results of the fine mesh model were compared with the normal model. As shown in figure 4, the fine mesh calculation has a very small effect on the total boron deposition mass at the core that can determine the degree of CIPS. This results means that the fine mesh model contributes very little to improving the accuracy of the CIPS predictions.

On the other hand, there is a big difference in the thickness of the CRUD. When the fine mesh target channel was selected properly, that was evaluated to be 10% thicker than the normal model result(see table 1). In case of the fine mesh modeling of channel 109, the thickness of the CRUD on the cladding surface 1 of the rod 19 increased by about 8μm. At the same location, the cladding surface temperature increased by 3℃.

And the location with maximum value of Mass evaporation rate(MER) moved from 96 to 109 channel. This means that the channel selection should be different depending on the purpose of fine mesh modeling(e.g., DNB analysis).

In case of channel 81 that the inappropriate channel is selected as a fine mesh target, these values are almost same with normal analysis results or very slightly smaller than them. This is because a small amount of CRUD moves to that channel. Improper selection of a target channel with a small impact of the CRUD for fine mesh can get non-conservative results.

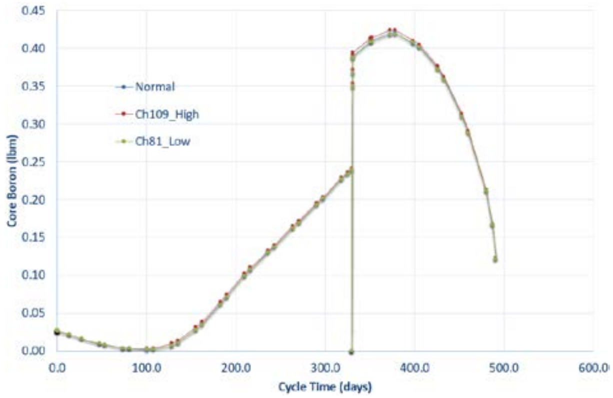

Fig. 4. Total core boron deposition mass by cases

Table 1. Comparison of Results by cases

Case	Normal	Ch.109 (proper)	Ch.81 (improper)
Core Boron Depo.[lbm]	0.402	0.405	0.401
Max. CRUD Thick. [μm]	60.24 (109)	68.23 (109,19,1)	60.16 (109)
Max. Clad Temp. [℃]	357.40 (109)	360.42 (109,19,1)	357.39 (109)
Max. MER [lbm/hr-ft^2]	521.39 (96)	564.99 (109,19,1)	521.39 (96)

3. Conclusions

The fine mesh method has no effect on the improvement of CIPS prediction. However, some parameters such as local CRUD thickness, cladding surface temperature and MER, which are very important information for the fuel performance analysis can be obtained by fine mesh analysis with proper target channel selection. Therefore, the fine mesh method will be used as a main tool for the AOA risk with pin-wise fuel performance.

REFERENCES

[1] C. W. Stewart, et al., VIPRE-01 : A Thermal-Hydraulic Code for Reactor Cores Volume 2: User's Manual(rev3), EPRI, Palo Alto, 1989

[2] J. L. Westacott, et al., Boron-induced Offset Anomaly (BOA) Risk Assessment Tool version 4.0, EPRI technical report 3002012131, 2017.