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Analysis of Fission Rate Distribution on BFS-75-1 Assembly

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1. Introduction

As the second stage of critical experiment plan for developing the KALIMER core design, following the first stage critical experiment, BFS-73-1, an experimental program named BFS-75-1 was carried out and the comparison between calculation and experiment was performed[1]. In case of BFS-75-1 critical experiment core, there exists actually a lot of heterogeneity because the core is composed of a lot of plate type pellet to simulate the reactor core instead of fuel pin used in the actual core. The core design is commonly performed on the homogenous model and differences with the actual core calculations scheme happen, so that the heterogeneity corrections are needed to correct these differences.

In this paper, the calculation results on the fission reaction rate distribution which shows a lot of heterogeneity effect are shown. The calculated results with heterogeneity correction were compared with experiment data of BFS-75-1 critical assembly.

2. Analysis Method

2.1 BFS-75-1 Critical Assembly Description

The BFS-75-1 critical assembly was constructed at the BFS-1 facility in 1998 for investigating basic neutronics characteristics of a simple, two-zone configuration with a typical neutron spectrum in a uranium metal fueled fast reactor. The core has a simple and homogeneous configuration fueled with LEZ(Low Enrichment Zone) of 15.11 % enrichment as inner core and HEZ(High Enrichment Zone) of 19.96 % enrichment as outer core.

The LEZ, as shown in Figure 1, consists of 91 fuel elements with 1.604 round stainless steel stick per fuel element between the tubes. The HEZ consists of 162 fuel elements with 1.855 round stainless steel per fuel element between the tubes. The radial blanket surrounding the core is assembled by RB-1(Radial Blanket-1) with 144 tubes assembled by ^{238}U pellets and RB-2(Radial Blanket-2) with 522 tubes made by depleted ^{238}U pellets. All of the gap of tube in the blanket region were inserted by 2 round stick in average per tube. In all zones, stainless steel sticks are placed between tubes to make a lattice pitch of 51 mm. The fuel elements in the LEZ region and the HEZ region were composed by 8 unit cell and 2 axial blanket unit cells. The unit cell of the fuel element in LEZ region was composed by 1 uranium metal pellet of 90 % enrichment, 2 uranium metal pellets of 36% enrichment, 4 ^{238}U metal pellets, 5 sodium pellets and 2 zirconium pellets. The unit cell of the fuel element in the HEZ region was composed by 2 uranium metal pellets of 90 % enrichment, 1 uranium metal pellet of 36% enrichment , 4 ^{238}U metal pellets, 5 sodium pellets and 2 zirconium pellets.

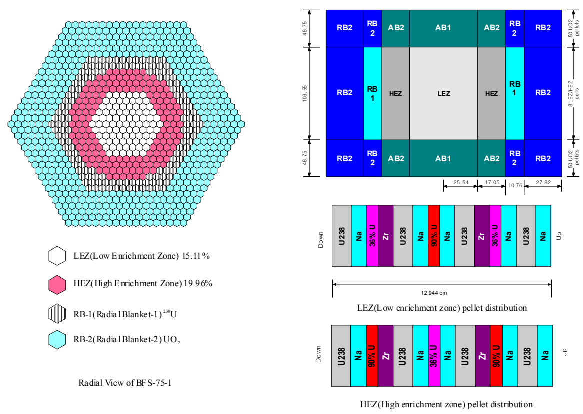

Figure 1. Layout of BFS-75-1 critical assembly

2.2 Nuclear Design and Analysis Methodology

The microscopic cross sections were generated by utilizing the effective cross section generation module composed of the TRANSX[2] and TWODANT[3] codes. The neutron spectra for collapsing the cross section data to fewer group libraries was obtained from the S_N approximation flux solution calculations for a two-dimensional reactor model as desired. To get the flux distribution inside a unit cell, the TWODANT code was used after the generation of 80 group effective cross section through cell calculation of the LEZ region and the HEX region. Flux calculations were carried out with the DIF3D code.

3. Analysis Result

The previous calculated ^{238}U fission rate distributions in the axial direction are compared with measured data in Figures 2. As seen from Figure 2, there are some fluctuations like shape of jigsaw in C/Es in the core region. This fluctuation of C/Es might be stemmed from the heterogeneity of pellets stacked along axial direction and the threshold energy of ^{238}U fission chamber. A closed look of experiment data would be found that the abrupt rising of fission distribution was modulated by locating a 90% enrichment pellet and the value drops suddenly as measurement point moves out a bit to the position of 90% enrichment pellet. The threshold energy for ^{238}U fission is so high that fission does not happen if the measurement position moves apart a bit to the position of 90% enrichment pellet because of abrupt slowing down of neutron energy. That would explain why the C/E variations shape large fluctuations that arise up and down so abruptly around the position of 90% enrichment pellet.

To solve this discrepancy, the heterogenous calculation has been performed. Using the super cell method, the calibration factor for the correction of homogenous flux inside the unit cell was calculated. Figure 1 shows the corrected C/Es compared with the previous calculated C/Es. A certain improvement of C/E was observed. The C/E values estimated by the linear curve fitting method were improved by about 5%.

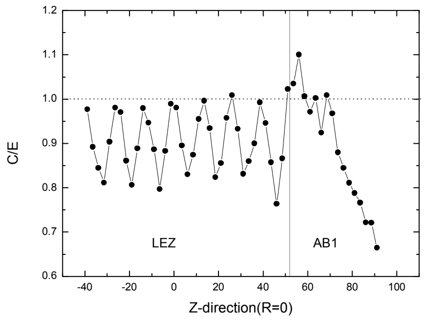

Figure 2. Axial ^{238}U fission rate distribution(C/E)

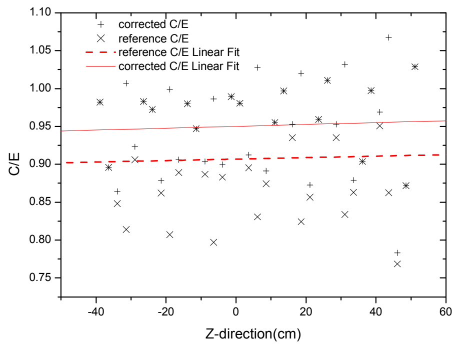

Figure 3. Axial ^{238}U fission rate distribution(corrected C/E)

4. Conclusion

The previous validation calculation showed a lot of C/E discrepancies for fission rate distribution. To improve this discrepancy, the heterogenous treatment has been attempted using the intra flux inside unit cell obtained using the super cell method.

The calculation results show that there is an abrupt flux rising at the point location of 90% enrichment pellet but a more benign rise at around 36% enrichment one in the unit cell. Using the calibration factor obtained from the heterogenous calculation, the corrected C/Es compared with the previous calculated C/Es showed a certain improvement of 5% C/Es. From this calculation, it is expected that a finer treatment of heterogeneity might improve the validation of critical experiment data.

Acknowledgments

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