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Influence to The Calculation Result Of Reactor Characteristics By The Simplification Of The ADS Analysis System

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Abstract

INFLUENCE TO THE CALCULATION RESULT OF REACTOR CHARACTERISTICS BY THE SIMPLIFICATION OF THE ADS ANALYSIS SYSTEM. Since Analysis of ADS required a great deal of time, a simple analysis method is proposed with a simple ADS model. The difference between a detail model (a heterogeneous hexagon lattice model) and simple models (a homogeneous hexagon lattice model and a cylindrical model), and the difference between a detail method (the continuous energy Monte Carlo calculations) and a simple method (the diffusion calculation) are investigated. The difference of a fission reaction rate between the models was 10% on average, and the difference of a fission reaction rate between the methods was 5% on average. When the simple method was used, wrong results are obtained for very lower (or higher) density region than the others.

Keywords: *ADS, heterogeneous, homogeneous, cylinder, Monte Carlo calculations, diffusion calculations*

1. Introduction

Today a lot of countries have a great interest in the nuclear reactor because of global warming and increase of energy demand. But there are some problems when we use the nuclear power. One of the most important problems is radioactive waste. We must try to solve the problem as far as we use this power.

Accelerator Driven System (ADS) is proposed as one of the solutions of this problem. ADS is a hybrid system that has a powerful particle accelerator, a spallation target, and a subcritical reactor. The purpose of ADS is to transmute a long life nuclide into a short life or stable nuclide and to produce energy.

Since Analysis of ADS required a great deal of time, a simple analysis method is proposed with a simple ADS model. The difference between a detail model (a heterogeneous hexagon lattice model) and simple models (a homogeneous hexagon lattice model and a cylindrical model), and the difference between a detail method (the continuous energy Monte Carlo calculations) and a simple method (the diffusion calculation) are investigated.

2. Methodology

First, the detail model is compared with the simple models by the detail method. The detail model is a heterogeneous hexagon lattice model (Hetero-Hexa). The simple models are a homogeneous hexagon lattice model (Homo-Hexa) and a cylindrical model (Cylinder). "Cylinder" is the simplest model in this study. Finally, the detail method is compared with the simple method by the simplest model. The detail method is the continuous energy Monte Carlo calculations (Monte Carlo). The simple method is the diffusion calculations (Diffusion).

"Hetero-Hexa" (Figure.1 and 2) is based on the model that is studied by Japan Atomic Energy Agency (JAEA), and fuel regions are heterogeneous hexagon lattices: This region has fuel pin, cladding, coolant, tie rod, and structure. One lattice of fuel region loads with 6 tie rods and 391 fuel pins of 6.47mm (Fuel A), 7.21mm (Fuel B), 7.84mm (Fuel C), and 8.17mm (Fuel D) in diameter arranged in a triangular type lattice with a pitch of 11.48 mm (center-to-center) and an active fuel length of 1000 mm. The other regions are homogeneous hexagon lattices. The every region of "Homo-Hexa" is homogeneous hexagon lattice. "Cylinder" is transformed from "Homo-Hexa" into a cylindrical model at the same volume.

The continuous energy Monte Carlo calculation code [MCNPX2.6c][1] is employed as "Monte Carlo". "HETC" in MCNPX is used for a nucleus spallation reaction calculation, and analysis is performed by the Intra Nuclear Cascade (INC) calculation. Multi-dimensional diffusion calculation code [CITATION] is employed in the comprehensive neutronics calculation code system [SRAC2006][2] with 107-group structure as "Diffusion". In "Diffusion" a beam duct is filled with a one-100th density Pb-Bi since the diffusion calculation can't treat vacuum region. "Diffusion" analysis is performed below 10MeV because SRAC can not treat nuclear data above 10MeV. MCNPX is used above 10MeV, and the data of the neutron that slow down in less than 10MeV are used in CITATION. All data for "Monte Carlo" with "Diffusion" are below 10MeV. Nuclear data library used in MCNPX and CITATION is JENDL-3.3.

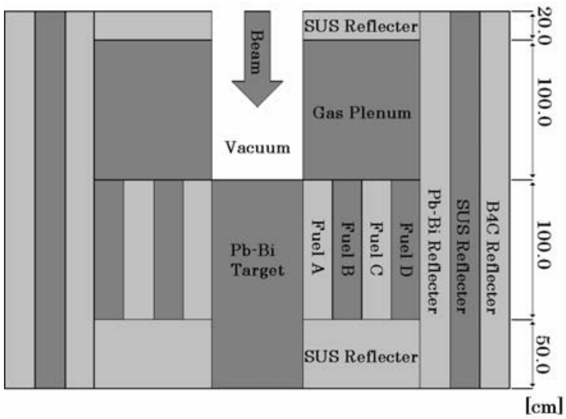

Figure 1. The configuration of detail model (r-z)

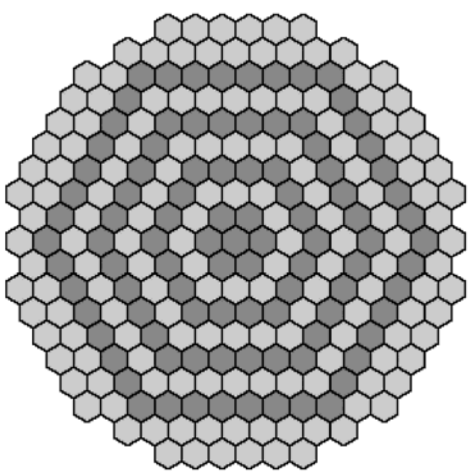

Figure 2. The configuration of detail model (x-y)

3. Results and Discussion (Model)

The detail model is compared with the simple models by the detail method.

First, the effective multiplication factor [k-eff] and the multiplication from neutron source [ks] are evaluated as shown in Fig. 3 to investigate the difference between 3 models without proton beam. "ks" is defined as following expression:

$$ks = \frac{1}{1 - k_{eff}} \quad (3\text{-}1)$$

The difference of "k-eff" between "Hetero-Hexa" and "Homo-Hexa" is approximately 0, so it hardly affects "k-eff" to change a heterogeneous lattice into a homogeneous lattice. The difference of "k-eff" between "Hetero-Hexa" and "Cylinder" is +0.14% and one of "ks" is +4% because a cylindrical model is superior to a hexagon lattice model in neutron economy. But these differences are very small, so it can be considered that "Cylinder" can simulate "Hetero-Hexa" with good precision.

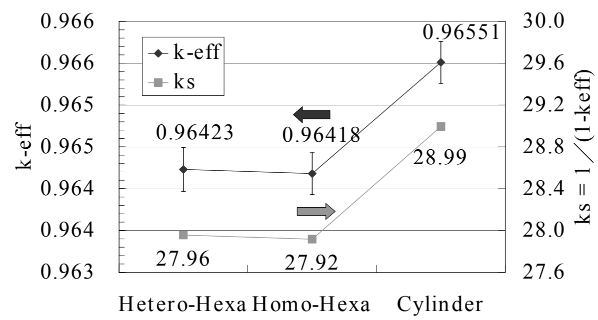

Figure 3. k-eff and ks

Next, the proton beam current [Ib] is estimated as shown in Fig. 4 in order to investigate the difference between 3 models, where thermal output of the reactor is set 800MWth. The difference between "Hetero-Hexa" and "Homo-Hexa" is -1.5% and one between "Hetero-Hexa" and "Cylinder" is -9%.

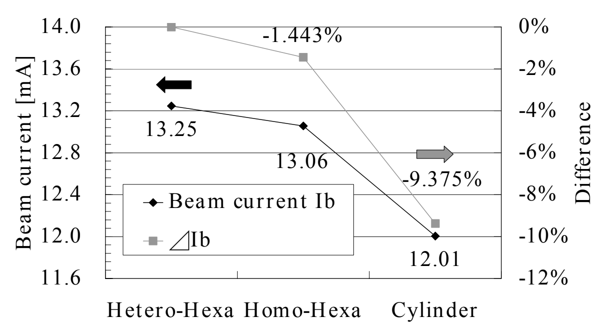

Figure 4. Proton beam current

The neutron energy spectrum and average energy of each fuel region are shown in Figs. 5 and 6. The spectra of "Hetero-Hexa", "Homo-Hexa", and "Cylinder" take almost same shape. The average energy of inner core of "Hetero-Hexa" and "Homo-Hexa" is higher than one of "Cylinder" and the average energy of inner core of "Hetero-Hexa" and

"Homo-Hexa" is lower than one of "Cylinder". These differences are below 1%.

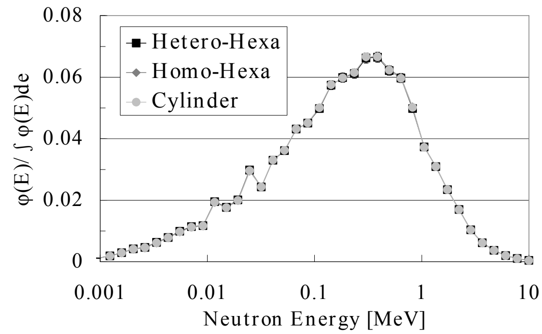

Figure 5. Neutron spectrum

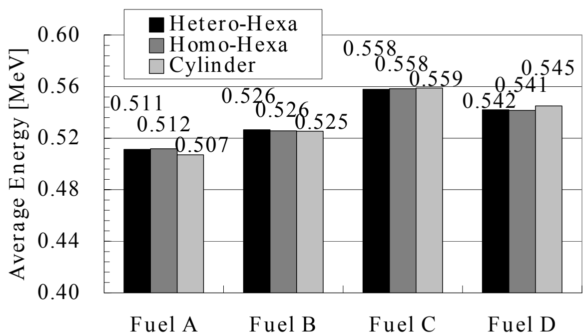

Figure 6. Average energy

Finally, the fission reaction rates are shown in Fig. 7. The difference of the fission reaction rate between "Hetero-Hexa" and "Homo-Hexa" is very small. The difference of the fission reaction rate between "Hetero-Hexa" and "Cylinder" is maximum +12% and minimum +7%.

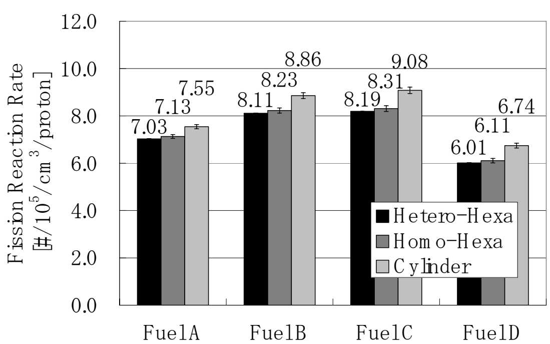

Figure 7. Fission reaction rate

From these results it hardly affects reactor characteristics to change a heterogeneous lattice into a homogeneous lattice. When the hexagon lattice is changed into the cylinder, the fission reaction rate is overestimated and this value of the inner core is different from one of the outer core. When ADS is analyzed by using cylinder model, these differences should be considered.

4. Results and Discussion (Method)

In this chapter the detail method is compared with the simple method for the simplest model.

First, the effective multiplication factor and the multiplication from neutron source are shown in Fig. 8. The difference of "k-eff" between "Monte Carlo" and "Diffusion" is +0.3% and one of "ks" is +10%.

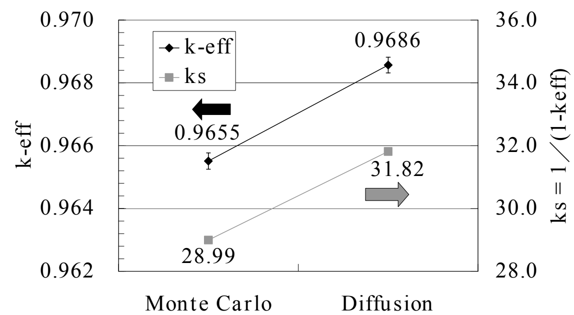

Figure 8. k-eff and ks

The proton beam current is estimated in order to investigate the difference between 2 methods as shown in Fig. 9, where thermal output of the reactor is set 800MWth. The difference of "Ib" between "Monte Carlo" and "Diffusion" is +3.3%. According to result of "ks" the difference of 13% occur between "Monte Carlo" and "Diffusion" by using the proton beam (When "k-eff" of "Diffusion" is higher than one of "Monte Carlo", "Ib" of "Diffusion" is usually lower than one of "Monte Carlo").

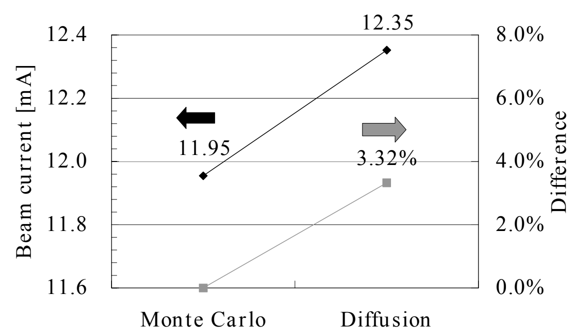

Figure 9. Proton beam current

The fission reaction rates are shown in Fig. 10. The difference of the fission reaction rate between "Monte Carlo" and "Diffusion" is maximum

-6% and minimum -2%. The change of the method from "Monte Carlo" to "Diffusion" makes the fission reaction rate underestimated especially in the inner core.

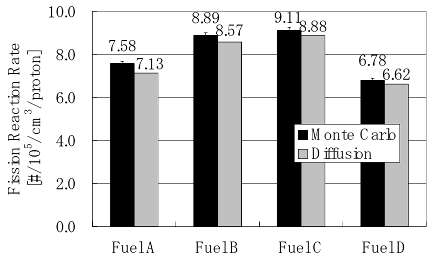

Figure 10. Fission reaction rate

The neutron flux is shown in Fig.11. Each region is expressed by the following method: Inner Target [T1], Outer Target [T2], and Reflector [R]. The "Diffusion" underestimates the flux value especially in the central region. The difference is +13% at "Target" and +7% at "Fuel A". The reason of this difference is that "Diffusion" gives only a very poor estimate in such a non-isotropic neutron field.

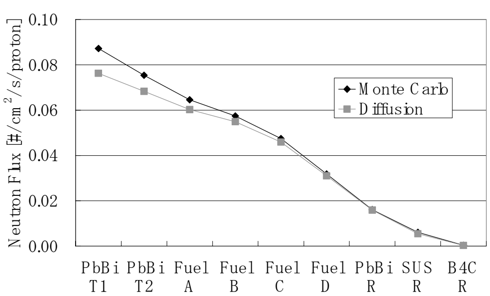

Figure 11. Neutron flux

Effects of the change the Monte Carlo calculations into the diffusion calculations are very big because the diffusion calculations can not treat properly the model that has very lower density region than the others. It is necessary to supplement this part by revision of diffusion term in the diffusion calculations.

4. Conclusion

The core of ADS designed by JAEA has been analyzed for "Hetero-Hexa", "Homo-Hexa" and "Cylinder" models by using "Monte Carlo" and "Diffusion" methods

The difference of the fission reaction rate between "Hetero-Hexa" and "Homo-Hexa" is very small. The "Cylinder" overestimates it by +7%～+12%.

Effects of the change the Monte Carlo calculations into the diffusion calculations are very big. The diffusion calculations can not treat properly the target and its adjacent region. It is necessary to supplement this part by revision of diffusion term in the diffusion calculations.

References

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DISCUSSION

Ruliyanti Pardewi (Question):
What difference between a detail model (using Monte Carlo) and a simple model (using ADS)

Shinya Ishida Answer:
The Monte Carlo is simulation code, like a transportation calculation. This use probably and follow the track of neutron. One calculation per one neutron is done. The simple model (SRAC-CITATION) is to solve diffusion equation. It depend on neutron dencity. The information of vector is none.

Ruliyanti Pardewi:
What difference between a detail model and a simple one.

Shinya Ishida
Detail model is hexagen lattice, and fuel region (Fuel A ▪ D) is complex model. In a calculation, "Fuel pellet", "Clad", and "Coulant" are treated correctly.
Simple model: Homo-Hexa is hexagen lattice, and all region is homogeneus. In the fuel region, all materials are mixed. A fuel region is mixed as one region. Cylinde is cylindrical model

Tagor Sembiring
1. What are the computer codes you used for the analyst of cell and core calculations>
2. How about the accuracy of transport code such as TWOTRAN compare to diffusion code?

Shinya Ishida
1. I use .... and CITATION in Diffusion calculation. But in cell calculation. each region has one material so this get the cross section from JENDL-33
2. I calculated the TWODANT using transport code. But now I don't compare it with other code.
   If I finish it, I send you my data.