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SUPERMC NEUTRON SIMULATION — BURNUP OF DIFFERENT COMPOSITION AND DISTRIBUTION OF BURNABLE POISONS IN VVER-1000 REACTOR

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ВЛИЯНИЕ РАСПРЕДЕЛЕНИЯ ГАДОЛИНИЙ СОДЕРЖАЩИХ ТВЭЛОВ РЕАКТОРА ВВЭР-1000 НА ВЫГОРАНИЕ.

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Аннотация. *Различный состав и пространственное распределение выгорающих поглотителей по-разному влияют на размножающие и теплофизические свойства реактора. В работе создана расчетная 3D модель ТВС реактора с выгорающими поглотителями. В качестве выгорающих поглотителей используются традиционно-применяемые Gd2O3-содержащие твэлы и твэлы с AmO2. Проведенные расчеты позволили исследовать нейтронно-физические свойства реактора и нивелировать, возникающие офсеты энерговыделения в переходных режимах эксплуатации.*

Introduction. In a light water reactor (LWR), burnable poisons (BPs) are usually added in a number of fuel rods of several assemblies for controlling excess reactivity in the early burnup stage of the fresh fuel. As a result, excess reactivity is reduced and power distribution in the core is flattened to avoid a high power peaking factor at fresh fuel assemblies.

In this study, five different fuel consumption situations were analyzed and compared. The size and value of the fuel assembly and the fuel rod cladding are exactly the same, the difference is in the composition and distribution of the burnable poison. In a fuel assembly, there are only 18 fuel rods containing burnable poisons, and the remaining 300 fuel rods are pure *UO2* and 12 guide tubes. The *UO2* enrichment in all fuel rods is 3.7%, only the *AmO2* homogeneous model *UO2* enrichment is 4.95%.

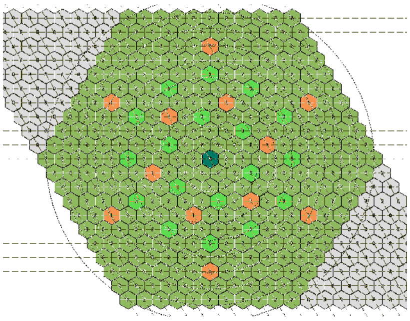

Fig. 1. Cross-sectional view of fuel assembly

The five groups are: homogeneous model 1 (*UO2* 95% + homogeneous *Gd2O3* 5%); heterogeneous model 1 (*UO2* 95% + heterogeneous *Gd2O3* 5%); heterogeneous model 2 (*UO2* 95% + heterogeneous *Gd2O3* 5%); homogeneous model 2 (*UO2* 95% Enrichment + 5% *AmO2*); pure UO2 (no burnable poison).

In this study, SuperMC (Monte Carlo simulation software) was used for neutron simulation to obtain the burn up results of VVER-1000 reactor [1-4].

Research methods. Let's compare the difference between the 5 types of fuel rods in their cross-sections.

1. Homogeneous *Gd2O3* model 1 (*UO2* 95% + homogeneous *Gd2O3* 5%)

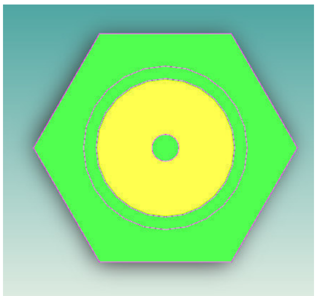

Fig. 2. Cross section *of the fuel rod , the yellow part is the homogenous mixture of Gd2O3 powder and 3.7% UO2*

2.Heterogeneous *Gd2O3* model 1 (*UO2* 95% + heterogeneous *Gd2O3* 5%)

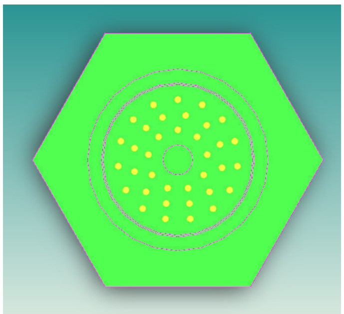

Fig. 3. Gd2O3 part

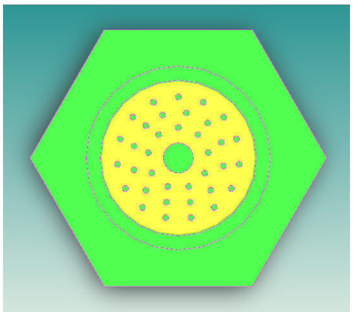

Fig. 4. UO2 part

The first doping method of *Gd2O3* is that 36 *Gd2O3* cylinders with a length of 300 cm and a diameter of 0.015009 cm are embedded in 3.7% *UO2* fuel,and the total volume is 7.643 cm^3.

3. Heterogeneous *Gd2O3* model 2 (*UO2* 95% + heterogeneous *Gd2O3* 5%)

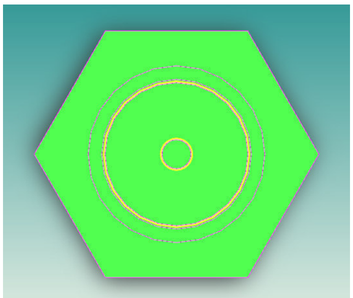

Fig. 5. Gd2O3 part

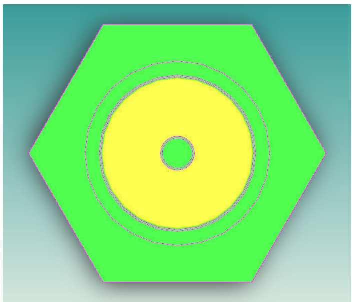

Fig. 6. UO2 part

The second doping method of *Gd2O3* is that *Gd2O3* is transformed into two cylinders and the *3.7% UO2* fuel is wrapped in them. The length of the cylinder is 300 cm, the wall thickness of the cylinder is 0.00336 cm, and the total volume is 7.646 cm^3.

4. Homogeneous *AmO2* model 2 (*UO2* 95% Enrichment + 5% *AmO2*) and Pure *UO2* (no burnable poison)

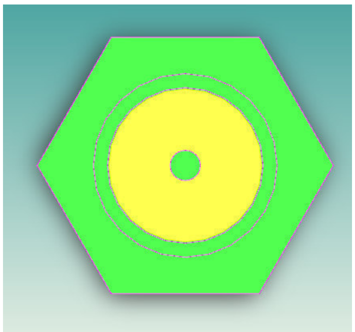

Fig. 7. Cross section *of the fuel rod , the yellow*
yellow part is Pure 3.7% UO2
AmO2 powder

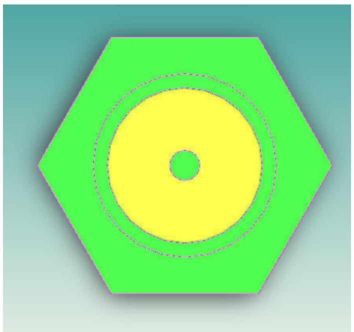

Fig. 8. Cross section *of the* fuel rod , *the*
part is the homogenous mixture of
and 4.95% UO2

Results. The keff value of the burnup result is shown in Fig. 9. :

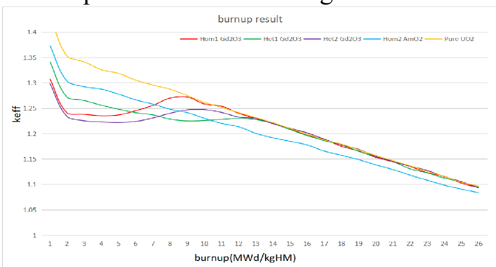

Fig. 9.Comparison of keff in 5 groups

Conclusion. As there is no burnable poison, pure *UO2* has the highest initial keff value, but it drops quickly over time. Comparing the two combustible poisons, *Gd2O3* and *AmO2*, their keff curve has a flat period in the beginning due to the effect of neutron absorption, and then the *keff* begins to decrease with the consumption of *Gd* and *Am*. It can be seen that the *keff* curve of *Gd2O3* has a longer flattening time, indicating that Gd2O3 is more effective as a burnable poison. It can be used to absorb large initial delayed reactivity, deepen the burn up and flatten the distribution of neutron fluence rate.

Comparing the three sets of models of Hom1, Het1 and Het2, it can be seen that when combustible poisons are uniformly applied to the inner and outer sides of the fuel pellet in the form of a cylindrical wall, the trend of the burn up *keff* curve of Hom1 and Het2 is very close. It shows that these two ways of filling burnable poisons are equivalent and can replace each other.

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