USING BURNABLE ABSORBER IN THORIUM REACTOR

D.A. Khrapov, Yu.Yu. Kovalyova

Scientific Supervisor: Ass. Prof, Dr Yu.B. Chertkov

Language Adviser: Yu.Yu. Kovalyova, PhD

National Research Tomsk Polytechnic University, Russia, Tomsk, Lenin str., 30, 634050

E-mail: cheshirskyvolk@mail.ru

ИСПОЛЬЗОВАНИЕ ВЫГОРАЮЩЕГО ПОГЛОТИТЕЛЯ В ТОРИЕВОМ РЕАКТОРЕ

Д.А. Храпов, Ю.Ю. Ковалёва

Научный руководитель: доц., к. ф.-м.н. Ю.Б. Чертков

Языковой консультант: доц., к. п. н. Ю.Ю. Ковалёва

Национальный Исследовательский Томский Политехнический Университет,

Россия, Томск, ул. Ленина 30, 634050

E-mail: cheshirskyvolk@mail.ru

Аннотация. *В качестве выгорающего поглотителя в ториевом реакторе предлагается использовать диборид циркония, напылённый на оболочку твэла. При различной толщине напыления для различного по нуклидному составу топлива были исследованы поведение запаса реактивности, энерговыработка и изменение жёсткости спектра нейтронов в течение кампании.*

Использование выгорающего поглотителя в ториевом реакторе за счет ужесточения спектра нейтронов в топливе приводит к росту наработки вторичного топлива, в связи с чем было проанализировано изменение нуклидного состава топлива в течение времени работы реактора.

There are a few reasons for using thorium into the fuel cycle. Firstly, the world's reserves of thorium are 4–5 times bigger than uranium reserves. Secondly, thorium deposits are more widely spread than uranium ones. This is especially important for the Russian Federation, where uranium resources are said to be enough only for the next 20 years. As for thorium reserves, they are largely concentrated in Siberia, exactly near the cities of Novokuznetsk and Tomsk (Tuganskoe deposit of thorium, titanium, zirconium) [1].

The possible way of using thorium in a high-temperature gas-cooled low power reactor was considered in [2]. Extreme fuel burn-up can be reached with a relatively low reactivity margin at the cost of using thorium-plutonium compositions and microencapsulated fuel, dispergated in graphite matrix. A burnable absorber can significantly decrease reactivity margin of such a type of reactor. The present article introduces a possible way of utilising burnable absorber in a thorium keeping reactor VVER-1000.

Nowadays, the process of improvement of VVER-1000 involves actions of enlarging nuclear fuel burn-up of. High burn-up is determined by an extended fuel cycle. It becomes possible to extend a fuel cycle by enlarging reactivity margin. However, high reactivity margin needs to be balanced at the begining of the campaign. Using a burnable absorber deposited on the fuel cladding allows both balancing excess reactitvity margin and regulating neutron spectrum hardness [3].

Zirconium diboride was used as a burnable absorber deposited on the fuel cladding. By varying the thickness of ZrB_2, energy output, reactitvity margin and changes in neutron spectrum hardness were investigated.

The computational model was represented by an infinitly high elementary cell of VVER-1000 which consisted of a fuel rod and a coolant surrounding the fuel rod. To make computations, a real hexagonal cell was substituted with an equivalent cylindrical one, the cross section area of which was identital to that of the real hexagonal one.

The fuel cladding of VVER-1000 was made of zirconium alloy with the outer diameter of 0.91cm and thickness of 0.65cm. The burnable absorber was deposited on the surface of the fuel cladding. The fuel rod diameter was as of 0.78 cm and the axial bore diameter was as of 0.14 cm. The fuel rods spacing equalled to 1.275 cm.

Neutron-physical computations were performed be means of one-dimentional program WIMS-ANL with a 69-group of neutrons database ANL (WIMSD-5 with database ENDF/B-VI.7).

To implement the thorium fuel cycle, the uranium and plutonium fissile isotopes were used as initial compositions, which lead to the further testing of different fuel compositions [4].

The analysis of reactivity margin dependence on energy output for different compositions allowed us to make very important conclusions. Firstly, the maximum energy output could be reached with the uranium fueled reactor (enrichment 90%). Secondly, the less significant energy output was reached by utilizing a triple composition UO_2+PuO_2+ThO_2 (with uranium enrichment up to 90%). Finally, the composition of PuO_2+ThO_2 would make the alternative with the least significant energy output.

It is more efficient to deposit the burnable absorber on the fuel cladding rather than on the surface of the fuel tablet, since this allows enlarging the mass of the burnable absorber. According to Figure 1, the initial reactivity margin decreases with the increase of the thickness of the burnable absorber in uranium-thorium fuel. Full energy output remains approximately the same for different thickness of ZrB_2 due to boron burning.

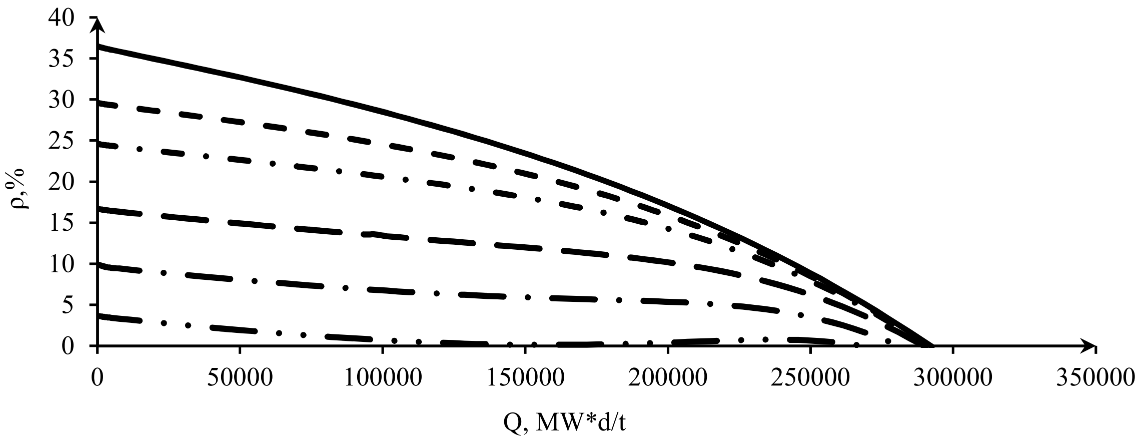

Fig 1. Reactivity margin dependence on energy output for UO_2-ThO_2(1:1) fuel composition with the burnable absorber:

0 μm, 50 μm, 100 μm, 200 μm, 300 μm, 400 μm

Comparative studies with the plutonium-thorium composition were also performed. The findings are presented in Figure 2. To decrease the initial reactivity margin up to 15–17% for PuO_2-ThO_2 fuel, 400-500 μm thickness of deposited ZrB_2 is required. As far as UO_2-ThO_2 fuel is concerned, 400 μm thickness of the deposited burnable absorber is considered to be enough to decrease the initial reactivity margin by 4%.

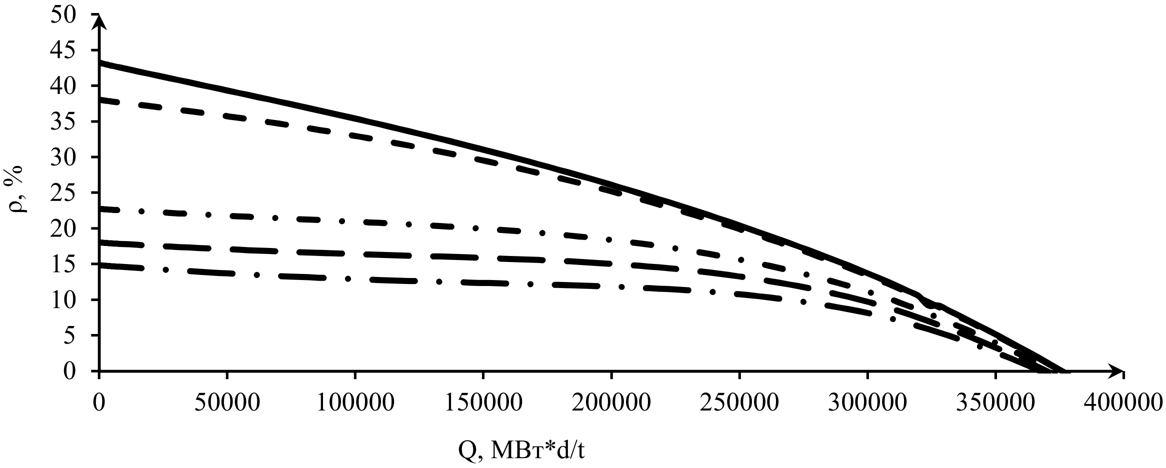

Fig 2. Reactivity margin dependence on energy output for PuO_2-ThO_2 (1:1) fuel composition with the burnable absorber:
0 µm, 50 µm, 300 µm, 400 µm, 500 µm

The application of the burnable absorber in the thorium reactor accompanied by hardening the neutron spectrum contributes to the fertilization growth. Thus, the concentration of Th-232 decreases faster in the presence of the burnable absorber rather than without it. The concentration of Pu-241 increases in time, as well as the concentration of Pu-239. In addition, the rate of Pu-241 accumulation increases in the end of the campaign in the presence of ZrB_2 rather than without it.

It is possible to minimize the decrease of reactivity margin and maintain it within a long period of time by using optimal thickness of the burnable absorber (200 µm for uranium-thorium fuel, 300-500 µm for plutonium-thorium fuel). This period of time will be enough to provide stable work of the nuclear reactor.

A high reactivity margin is required to provide a long-term campaign for the conventional reactor. A long-term campaign for the reactor containing a burnable absorber can be obtained with a low reactivity margin.

Zirconium diboride proved itself as a potentially applicable material for realization of uranium-thorium and plutonium-thorium cycles.

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