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PRELIMINARY STUDY OF APPLYING SPECTRAL SHIFT CONTROL METHOD FOR VVER-1000 FUEL ASSEMBLY BENCHMARK

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ПРЕДВАРИТЕЛЬНОЕ ИССЛЕДОВАНИЕ ПРИМЕНЕНИЯ СИСТЕМЫ СПЕКТРАЛЬНОГО РЕГУЛИРОВАНИЯ ДЛЯ ТВС РЕАКТОРА ВВЭР-1000

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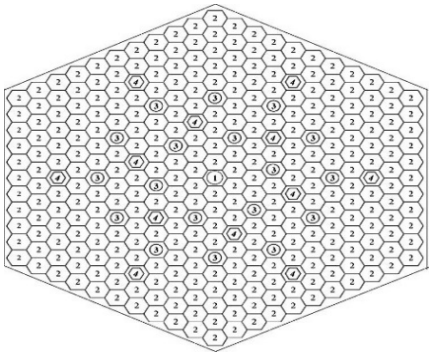
Аннотация. *Повышение топливных характеристик ядерных реакторов за счет применения концепции управления спектральным сдвигом (SSC) вместо традиционных методов, основанных на поглощении, является многообещающим подходом к снижению стоимости топливного цикла и увеличению использования топливных ресурсов (U, Pu). В данной работе было проведено исследование применения химического метода SSC для модели топливной сборки ВВЭР-1000 с низкообогащенным ураном, в которой контроль реактивности осуществляется путем изменения доли D_2O относительно легководного замедлителя (D_2O/H_2O), и сравнение с поглощающими материалами, в которых содержится 600 ppm H_3BO_3 и 4,0 мас.% Gd_2O_3.*

Introduction. For the sake of decreasing the fuel cost and saving fuel resources, significant approaches have been suggested to improve fuel performance in nuclear reactors. One of these approaches relies on using spectral shifting control methods (SSC) rather than conventional poison methods for reactor control. In the chemical SSC method, the reactivity control is carried out by varying the heavy water concentration in a light water moderator (D_2O/H_2O). In the current paper, we have investigated the chemical SSC method for the OECD benchmark model of VVER-1000 with a low enriched uranium fuel assembly. we also compared the SSC method to the standard poison-controlled reactivity method given in the OECD benchmark model. Reactivity conditions (kinf), conversion ratio, and the effect of burnable poisons were evaluated during fuel burnup at different molecular ratios of D_2O/H_2O. The results obtained by Monte-Carlo code Serpent-2 were compared with benchmark mean (BM) values presented in the benchmark specification report.

Research methods. The present analysis of applying the chemical SSC concept for the OECD benchmark model [1] is carried out using a Monte Carlo code Serpent-2 [2] with version 2.1.31 based on ENDF/B-VII nuclear data library. The results have been obtained by simulating 25000 neutrons distributed over 500 cycles with skipping

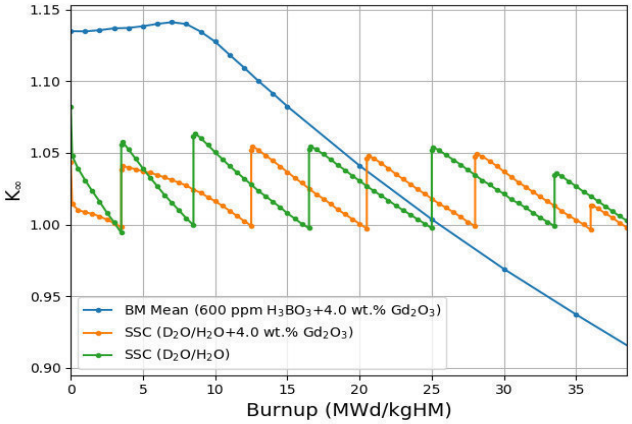
the first 50 cycles. Fig. 1 represents the benchmark model of low enriched uranium (LEU) fuel assembly that has been investigated in this work by the chemical SSC method. According to [1], the LEU fuel assembly has hexagonal geometry with 331 hexagonal unit cells. The elementary cells types included: one central tube, 18 guide tubes, and 312 fuel pins (300 of them with enrichment 3.7 *wt.%* ^{235}U and 12 burnable absorber pins with enrichment of 3.6 *wt.%* ^{235}U and 4.0 *wt.%* Gd_2O_3). The lattice pitch among the fuel rods and fuel assemblies is 1.275 cm and 23.6 cm respectively. The clad and structural materials are composed of a *Zr-Nb* alloy.



Cell types:
1. Central tube cell
2. Fuel cell (3.7 *wt.%* ^{235}U)
3. Guide tube cell
4. Fuel gadolinium cell (3.6 *wt.%* ^{235}U with 4.0 *wt.%* Gd_2O_3)

Fig.1. Benchmark LEU assembly configuration

Burnup calculations have been studied at operating poisoned state conditions. the fuel has been depleted at a constant power density of 108 MW/m^3 up to a burnup of 40 *MWD/kgHM*. the equilibrium concentrations of ^{135}Xe and ^{149}Sm was considered. The fuel temperature equals 1027K and the temperature of non-fuel materials equals 575*K*. the gadolinium effect during heavy water regulation has been investigated by considering two different study cases of the chemical SSC method. the first case included the presence of 12 burnable absorber pins (D_2O/H_2O+4.0 *wt.%* Gd_2O_3). whereas in the second case, the regulation process does not incorporate any burnable poisons in the fuel assembly. In the first case of the chemical SSC method, the six values of D_2O/H_2O which have taken during the adjustment process were: 65%, 55%, 42%, 27%, 8%, and 0%. Whereas, in the second case, the molecular ratios of D_2O/H_2O have taken: 73 %, 63 %, 50%, 35%, 16%, and 0% during fuel cycle.



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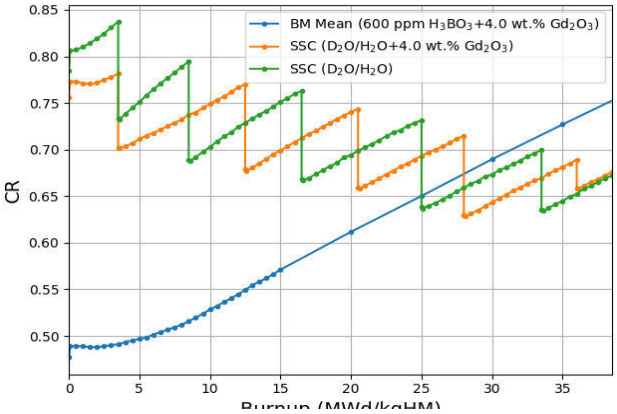
Results. Fig. 2 and Fig. 3 represent the variation of infinite multiplication factor and the conversion ratio for both cases of the SSC method at different six molecular ratios of D_2O/H_2O relative to benchmark mean (BM) model. As shown in Fig. 2 for both cases of the SSC method, the fuel burnup reached up a value of 40 *MWd/KgHM* compared to 25 MWd/KgHM in the benchmark model. As a result of improving the utilizing of excess neutrons during the fuel burnup compared to the benchmark model. As can be seen in Fig. 3, the conversion ratio reached up about 0.83 larger than the value that has gotten in the benchmark case (0.47) at the beginning of the cycle.



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It is found in the first case of the SSC method that the presence of 12 burnable absorber pins could save the D_2O quantity during the adjustment process without influence the obtained discharge burnup. As a result, it could reduce the capital cost of the SSC method.

Conclusion. The chemical spectral shift control (SSC) is a promising approach to reduce the fuel cycle cost and improve the utilization of fuel resources in nuclear reactors. According to the obtained results in the present analysis, the chemical SSC method has the potential to suppress the excess reactivity of fresh fuel, increase the reactor conversion ratio and improve discharge burnup during one batch fuel cycle scheme. Hence, this will make it more applicable for core pattern load to employ a smaller number of batches scheme (i.e., reducing the downtime for refueling thereby raising the capacity factor). On the contrary, according to poison reactivity control methods, this approach of a small number of batches would require incorporating high soluble boron concentrations (with concerns about its positive moderator temperature coefficient) as well as an additional amount of burnable absorbers to control the excess reactivity. Consequently, it would lead to reducing the conversion ratio and further increase in fuel enrichment requirements [3].

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