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T. Elzayat (Египет), Y.B. Chertkov, O. Ashraf
Tomsk Polytechnic University, Russia, Tomsk
Scientific Supervisor: Prof., Dr. Y.B. Chertkov
Ain Shams University, Faculty of Education, Physics Department, Cairo 11341, Egypt

SPECTRAL SHIFT CONTROL CONCEPT FOR OECD VVER-1000 LEU ASSEMBLY COMPUTATIONAL BENCHMARK USING MONTE-CARLO CODE SERPENT

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 (D2O/H2O). 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 (D2O/H2O). 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 (Kalugin et al., 2002) is carried out using a Monte Carlo code Serpent-2 (Leppänen, 2013) 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. According to (Kalugin et al., 2002) Burnup calculations have been studied at operating poisoned state conditions. the fuel has been depleted at a constant power density of 108 MW/m3 up to a burnup of 40 MWD/kgHM. The fuel temperature equals 1027K and the temperature of non-fuel materials equals 575K. the equilibrium concentrations of 135 Xe

and 149Sm was considered. the gadolinium effect during heavy water regulation has been examined by devoting two different study cases of the chemical SSC method. the first case considered the presence of 12 burnable absorber pins (D2O/H2O+4.0 wt.% Gd2O3). whereas in the second case, the regulation process does not incorporate any burnable poisons in the fuel assembly (D2O/H2O). In the first case of the chemical SSC method, the six values of D2O/H2O which have taken during the adjustment process were: 65%, 55%, 42%, 27%, 8%, and 0% during fuel cycle. Whereas, in the second case, the molecular ratios of D2O/H2O have taken: 73 %, 63 %, 50%, 35%, 16%, and 0%.

Results. Fig. 1, and fig. 2, presented the variation of infinite multiplication factor and the conversion ratio for both cases of the SSC method at different six molecular ratios of D2O/H2O relative to benchmark mean (BM) model. As shown in fig. 1, 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 neutrons generated during the fuel burnup compared to the benchmark model. Furthermore in fig.2, the conversion ratio reached up about 0.83 larger than the value that have gotten in the benchmark case (0.47) at the beginning of cycle.

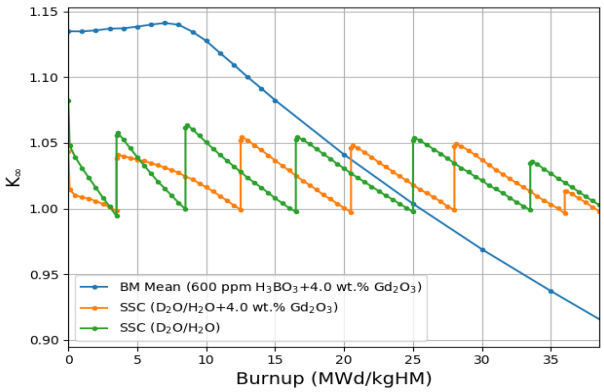

Figure 1. Comparison of Infinite Multiplication Factor during burnup

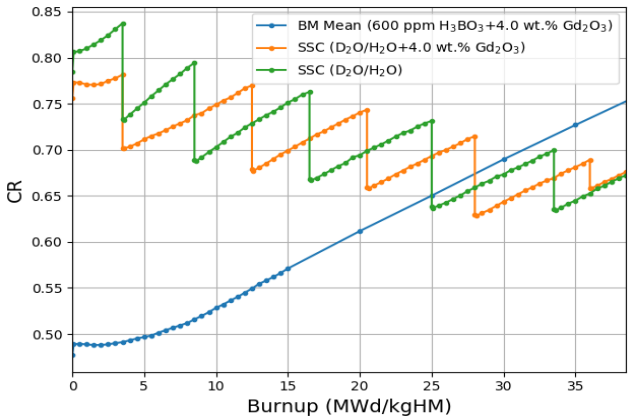

Figure 2. Assembly Conversion Ratio variation during burnup

It's found in the first case of the SSC method, the presence of 12 burnable absorber pins could save the D2O 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 SSC method has the ability to suppress the excess reactivity of fresh fuel, improve reactor conversion ratio and enhance 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 (Martzie, R.A., and F. M. Sider, 1979).

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