MCNP5 CALCULATIONS AND GENETIC ALGORITHM FOR DELAYED NEUTRON FRACTION DETERMINATION

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Abstract

This work is focused on effective delayed neutron fraction (β_{eff}) determination by both calculation using MCNP5 code and measurement by in-pile kinetic method with the use of genetic algorithm for fitting the reactor response function.

1 MCNP5 calculation of β_{eff}

The calculation was realized for the complex MCNP model of training reactor VR-1. The delayed neutron fraction was determined by a prompt method, which

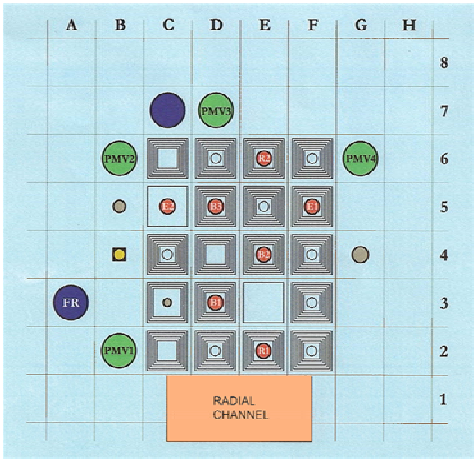

Figure 1.1 VR-1 Reactor core composition C1

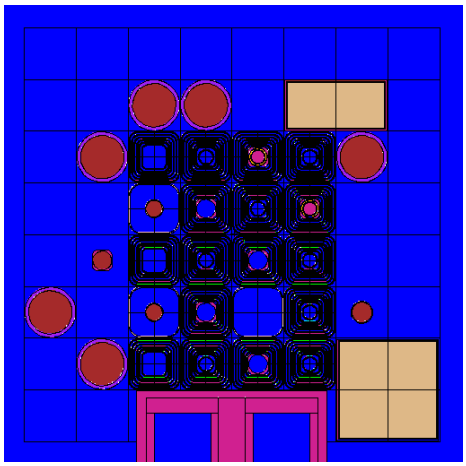

Figure 1.2 MCNP5 plot of VR-1 reactor core

requires two critical calculations. The first calculation in KCODE mode, considering only prompt neutrons, brought the following value of effective multiplication factor for prompt neutrons: k_p = 1.00003±0.00005. In the second calculation, the total number of neutrons was considered and the total effective multiplication factor was calculated as: k_t = 1.00791±0.00005. In both calculations 150000 neutrons per cycle and 2000 neutron generations were set as parameters. The effective delayed neutron fraction was determined from the following formula [1]:

$$\beta_{eff} = 1 - \frac{k_p}{k_t} = 1 - \frac{1.00003 \pm 0.00005}{1.00791 \pm 0.00005} = 0.007818 \pm 0.0001$$

This value of β_{eff} with standard deviation of 0.01% is in relatively good agreement with the theoretical value estimated and used by VR-1 operators. The contemporary used value of β_{eff} was estimated to be 0.00714. The discrepancies between these two values were caused mainly by uncertainties of selected calculation method and considering the simplifications in the MCNP model of the reactor.

Also, the cross-section library selection has a significant impact on the results of MCNP5 criticality calculations. Therefore a comparison of two mostly used libraries was made. The compared libraries were U.S. ENDF/B-VI (B-VI.5, B-VI.6, B-VI.8, LANL/T16) and Japanese JENDL3.3. The calculation parameters, such as number of neutron generations and number of neutrons per cycle were increased continuously to obtain the best result of β_{eff} determined by the prompt method. The difference between these two libraries was calculated as 7.3%. This analysis confirms the fact that the ENDF/B-VI library overpredicts β_{eff} by more than 7% in β_{eff}, β_{eff}/Λ and Λ calculations [2].

2 β_{eff} measurement on training reactor VR-1

Prior to the real measurement, a simulation of VR-1 critical reactor response to periodical reactivity insertion in numerical program Bokin2000, served as an estimation of the β_{eff} value. Using the standard MATLAB identification models, e.g. ARX, ARMAX or PEM, it was not possible to appropriately fit the reactor response function (see Figure 2.1). Applying the Genetic Algorithm [3] included in special MATLAB toolbox developed at our Institute, the fitting precision was increased significantly. The reactor response was fitted by transfer function of 2nd order: $G_0 = \frac{12.86e3s + 5.114e3}{s^2 + 85.62s - 1.829}$ (see Figure 2.2). According to the reactor linearized model [4], the value of β_{eff} was determined to be $\beta_{eff} = 1/|G_0| = 0.006664$.

The discrepancy in the β_{eff} values obtained by MCNP5 calculation and Bokin2000 measurement simulation have to be verified by in-pile kinetic measurement yet to be performed, to assess the theoretically estimated and currently used β_{eff} value of 0.00714.

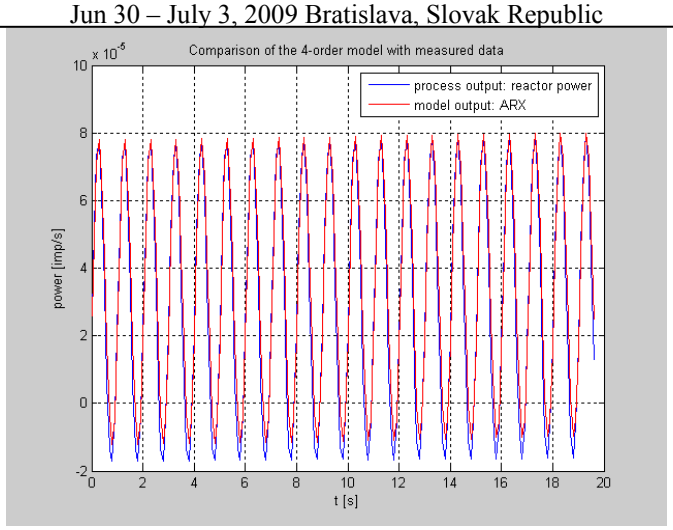

Figure 2.1 Bokin2000 simulation of VR-1 reactor response to low period sinusoidal reactivity insertion of 0.05$ fitted by Matlab, model ARX

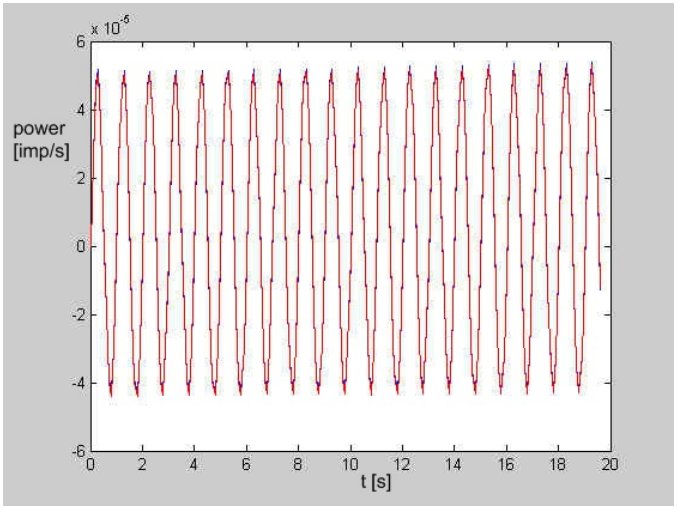

Figure 2.2 Fitting of the Bokin2000 simulation of VR-1 reactor response to low period sinusoidal reactivity insertion of 0.05$ by Genetic Algorithm

References

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