Subcriticality Measurement Method for AGN-201 Reactor

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1. Introduction

In order to verify the feasibility and safety of reactor, reactor physics test is performed. The measurement of control rod worth occupies most of period of reactor physics test. For that reason, the new method has been studied for subcriticality measurement to reduce the test period from the economic point of view. Nevertheless, system that can measure or monitor correct subcriticality of nuclear reactor has not been developed yet. If the accurate subcriticality were measured, more efficient of operation would be available and an necessary conservativeness could be removed. In 1980s, the research about subcriticality measurement methodology was performed about subcritical reactor based accelerator, fast breeder reactor and critical experiment reactor. However, study for the Pressurized Water Reactor has been carried on recently. The crucial problem depends on how to correct the spatial effect about signal, neutron source, detector position and measured weak neutron. As the representative measurement methodology, there are Pulse Neutron Source method(PNM), Neutron Noise Analysis, neutron source multiplication method and so on. This paper shows the theoretical analysis of the modified Neutron Source multiplication method (modified NSM method) which is a subcriticality measurement methodology. In the future, measurement of subcriticality will be perform about AGN-201 reactor.

2. Theory

2.1 Basic Theory of NSM Method

Generally, the neutron source multiplication(NSM) method is explained as follows:

$$M = \varepsilon\left(S + kS + k^2 S + \cdots\right) = \frac{\varepsilon S}{1-k}, \qquad (1)$$

where M is the neutron count rates, ε is the detector efficiency of neutron detector, S is the intensity of an neutron source and k is the neutron multiplication factor. This method is measured reactivity through amplification phenomenon of neutron source. However, because neutron source and detector position was not considered, correct measurement of subcriticality is impossible. Therefore, it is necessary to correct spatial effect according to the neutron source and detector position. [1]

2.2 Modified NSM Method

In order to measure of the subcriticality accurately, new neutron source multiplication method was proposed by Hokkaido university in Japan. In this method, fundamental mode solution of neutron flux is calculated in the neutron diffusion equation, and on the basis this solution, the perturbation of neutron importance field and spatial effect was modified by correction factor aim to accurate subcriticality measurement. The modified NSM method was proposed as follows:

$$\rho_l^s = \rho_{ref}^s C_l^{ext} C_l^{im} C_l^{sp} \left(\frac{M_{ref}}{M_l}\right), \qquad (2)$$

where ρ_l^s is the evaluated subcritcality of the specific l-th state, ρ_{ref}^s is the subcriticality of the reference state, M is the neutron count rates and C_l^{ext}, C_l^{im}, C_l^{sp} are correction factors. ρ_{ref}^s is applied to subcriticality calculated neutron activation analysis and MCNP code.

2.3 Correction factors

To estimate the subcriticality exactly, three kinds of correction factors was used to this method. The principle of corrections are (1) C_l^{ext} is corrected fundamental mode extraction ratio of specific state for reference state. (2) C_l^{im} is corrected neutron importance of specific state for reference state. (3) C_l^{sp} is corrected perturbation induced in the distribution of a neutron distribution for reference state. The following three correction factors are expressed as follows:

$$C_l^{im} = \left[\frac{\phi_{1,l}^{*c}, S}{\phi_{1,ref}^{*c}, S}\right], \qquad (3)$$

$$C_l^{sp} = \left[\frac{\int_V W_d(r)\bar{\phi}_{1,l}^{c}(r)dr}{\int_V W_d(r)\bar{\phi}_{1,ref}^{c}(r)dr}\right], \qquad (4)$$

$$C_l^{ext} = \left[\frac{C_{1,ref}}{C_{1,l}}\right], \qquad (5)$$

$$\text{where, } C_{1,x} = \left[\frac{\int_V W_d(r)\bar{\phi}_1^{c}(r)dr}{\int_V W_d(r)\bar{\phi}^{s}(r)dr}\right],$$

$C_{1,x}$ is the extraction factor that was expressed ratio of eigenvalue problem neutron flux to fixed source problem neutron flux. [2]

2.4 Correction of Gamma effect

In the practical reactor, it is necessary to consider about γ-ray background noise was detected by detector for accurate subcriticality measurement. Gamma ray are originated from γ-decay of fission production in bunrt fuels. In this case, the contamination of γ-ray was cut off by using γ correction factor. For correcting γ-ray background noise, the modified NSM method was defined as follows:

$$\rho_l^s = \rho_{ref}^s C_l^{ext} C_l^{im} C_l^{sp} C_l^{\gamma} \left(\frac{M_{ref}}{M_l} \right), \qquad (6)$$

$$where \;\; C_l^{\gamma} = \frac{\dfrac{M_l}{M_{ref}}}{(1+A_{ref})\dfrac{M_l}{M_{ref}} - A_{ref}},$$

$$A_{ref} = \frac{\gamma}{n_{ref}} = gamma \;\; fraction,$$

Through the method above, it is expected that more practical and efficient subcriticality measurement will be possible.[3]

3. Result of calculated flux for AGN-201

AGN-201 is used for experiments of reactor physics related to control rod worth measurement, neutron activation analysis and so on. Therefore it is easy to get the value of neutron flux through the experiments. The theoretical study of subcriticality measurement has been carried on so far. Moreover the neutron flux distribution of AGN-201 using MCNP code has been estimated. In order to apply to modified NSM method, neutron flux was calculated. Figure 1 is neutron flux distribution of AGN-201 reactor.

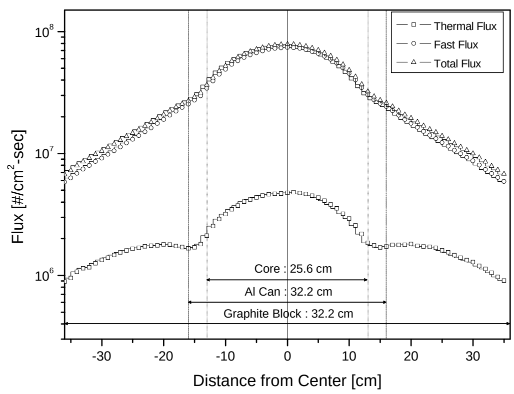

Figure 1. Neutron flux distribution

4. Discussion and Future Work

The modified NSM method is expected to measure subcriticality accurately. In order to evaluate subcriticality, this method is used three correction factors : extraction of the fundamental mode solution, correction of neutron importance field and spatial effect induced by a reactivity change. More over effect of gamma noise was modified. On the foundation of methodology above, it is planed to verify the feasibility of the method for AGN-201 reactor. The Figure 2 is AGN-201 reactor. To estimate the correction factors, neutron flux is necessary. The forward, adjoint and fixed source flux which are solution of eigenvalue and fixed source problem will be estimated using MCNP code. This flux is supposed to apply to modified NSM method. Also it is expected to compare subcriticality of neutron activation analysis to result of MCNP code.

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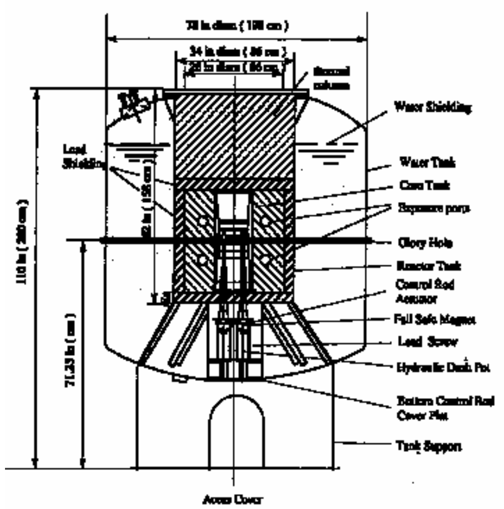

Figure 2. AGN-201 Reactor

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