Neutron Beam Evaluation for NRF in AGN-201K Reactor Using MCNP Simulation

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1. Introduction

Neutron radiography facility (NRF), is the non-destructive inspection equipment that use intrinsic matter penetration properties of neutron, in the field of NDT (Non-Destructive Testing) with more advantage as compare to X-ray radiography. Neutron radiography is based on the interaction of neutron with nucleus instead of the electron as in X-ray radiography. Even radioisotopes in the same element can be distinguished by the neutron radiography due to its specific cross-section properties. Namely, the neutron radiography is recognized as a complementary technique to the X-ray radiography. In this paper, although neutron radiography facility is generally installed only at high-flux research reactors, the feasibility of thermal column in AGN-201K was evaluated by using MCNP code. Specially, thermal flux level at the exit of beam line through collimator was evaluated in order to check its feasibility for NRF.

2. Methods and Results

2.1 AGN-201K Reactor

AGN-201K reactor is now on operation at Kyung Hee University mainly for education and training purposes. A licensed maximum thermal power is 10Watt and the maximum thermal neutron flux at this power is about 4.5×10^{8}#/㎠-sec. The graphite thermal column is at the top of reactor core which can be removed for the installation of NRF. Neutron flux level at the bottom of thermal column is about 2.0×10^{7}#/㎠-sec.

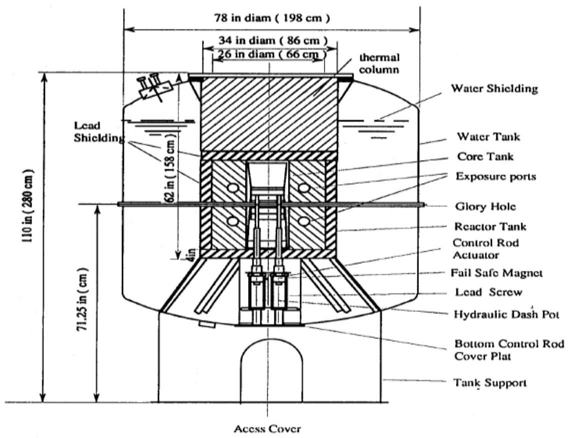


Figure 1. Structure of AGN-201K reactor

2.2 MCNP Modeling

The MCNP code is a Monte Carlo method code verified by NRC and it simulates the behavior of neutrons stochastically. Therefore, solution does not provide the exact value of flux, but an expected probability with standard deviation. The MCNP code can simulate a whole reactor space in 3-D Model. The following figures show an example of geometrical model of AGN-201K reactor including outside space.

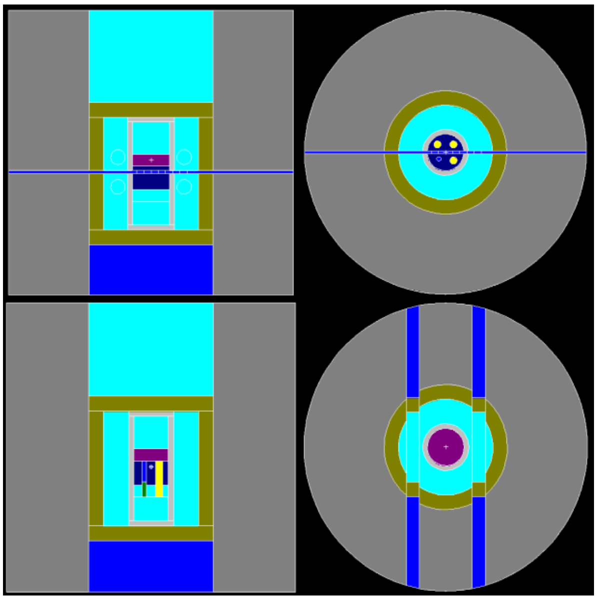
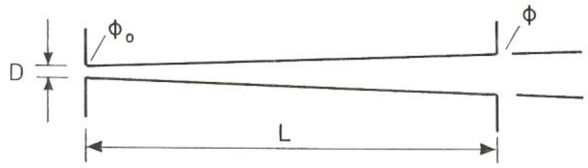


Figure 2. AGN-201K model for MCNP code

In order to evaluate the validity of MCNP code description, experimental data of thermal neutron flux from Glory Hole and Access Port are compared with calculated data from MCNP. The results show that the maximum error is about 20% at the outer boundary.

2.3 Neutron Collimator

One of the most important parts of a neutron radiography facility is the collimator which produce leveled neutron beam. The Collimator characteristics are closely related with resolution and exposure time, that depend on the shape and size of collimator. The idea about the choice of the best shape of the collimator have been changed rapidly with the development of the relatively recent nondestructive technique, as is neutron radiography. In the early years of application of NR, the opinion prevailed that parallel beams of neutrons were needed to obtain an adequate neutron beam flux at the object to be radiographed. However, as in early 1967, Barton concluded that a divergent-beam collimator produced the highest resolution.



$$\frac{\phi_0}{\phi} = 16\left(\frac{L}{D}\right)^2 \qquad \left(\because \quad \phi = \frac{\phi_0 A}{4\pi L^2} \quad A = \frac{\pi D^2}{4} \right) \quad (1)$$

Figure 3. Divergent-Beam Collimator

2.4 Collimator design and evaluation

The minimum thermal neutron flux of object needed in Neutron Radiography, is about 1.0×10^5#/㎠-sec. Based on the formula, the thermal neutron flux is 2.0×10^8#/㎠-sec at the entrance of collimator where the collimator ratio can not exceed more than about 15. In other words, collimator is determined by the length 30cm. Collimator was modeled to be filled with filling gas of helium, after comparison between He and air. For a lining material on the collimator wall was chosen as B_4C (Boron Carbide), after comparison of beam quantity and shape with different material, aluminum, gadolinium and B_4C. The thickness of lining is chosen to be 5mm. Distance from collimator exit to object is 2 cm. Table 1 shows the geometrical design data for collimator and Fig. 4 shows layout of collimator above the core. Fig. 5 shows calculated thermal neutron flux distribution across the object line.

Table 1. Dimensions of Divergent-beam Collimator

Entrance Diameter	20 mm
Exit Diameter	34 mm
Collimator Length	300 mm
Collimator Ratio	15

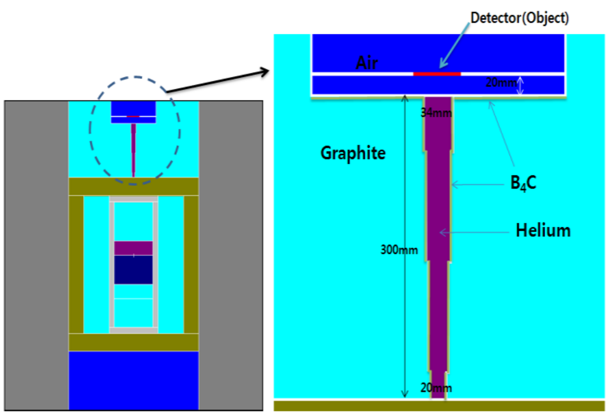


Figure 4. Collimator modeling

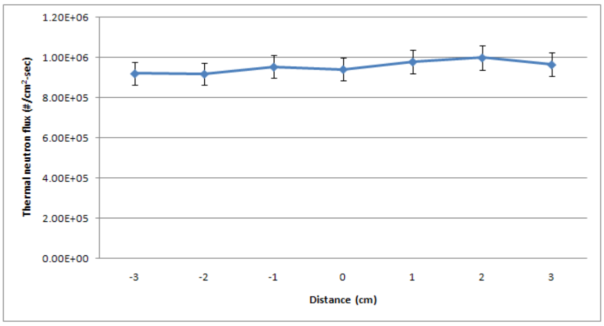


Figure 5. Thermal neutron flux distribution

3. Conclusions

Although neutron radiography facility is generally installed only at high-flux reactors, the feasibility of NRF in AGN-201K can be expected from its small size and accessibility of close contact to core. Calculated thermal flux level was high enough at the object position through collimator line. However, a more detail investigation on beam quality, shielding constraints, camera efficiency and tomography should be followed.

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