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Contamination Analysis on the Outer Vessel of the KSTAR using MCNP Simulation and Measuring the Neutron Flux with Ni Specimen

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1. Introduction

In fusion reactor, D-D or D-T reactions produce high energy particles which highly contribute to contaminate the structure of reactor. The KSTAR uses D-D reaction which produces high energy neutron of 2.45 MeV. Since the first operation, the plasma performance has been upgraded [1]. Therefore, components inside the KSTAR such as coils, vessels and limiters are activated as a result of nuclear reaction with neutrons and outside of the KSTAR also occurs the same. Therefore, in the decrease of radioactive waste point of view, prediction and evaluation of contamination by high energy neutrons are very necessary in order to estimate the amount of radioactive waste from the KSTAR.

2. Methods and Results

In this section, the analysis of contamination on the outer vessel of the KSTAR due to neutron reaction is described with simulation using MCNP6, FISPACT 2010 code and experiment with Ni specimen.

2.1 MCNP modeling

In this study, considering the symmetric structure of tokamak, the KSTAR was simplified as a cylindrical model with MCNP.

Table 1. Material list of the KSTAR.

Component	Material
Vacuum Vessel	SA240-316LN
Inboard Limiter	Bolted Graphite
Neutral Beam Shinethrough Armor	carbon-fiber-composite SA240-316LN
Poloidal Limiter	
Passive Stabilizer	Graphite carbon-fiber-composite CuCrZrMg
Vacuum Vessel Thermal Shield	Aluminized Kapton carbon-fiber reinforced Plastics

The major materials being used in KSTAR are shown in Table 1 which are adapted to calculate data.

The radioactive specimens made of Ni were installed at the outer vessel of the KSTAR. FENDL3.0 was used to calculate the neutron energy spectrum of Ni specimens to be the input data for FISPACT.

2.2 Inventory Analysis with FISPACT

Radioactivity is calculated with external libraries of reaction cross section, decay constant of relevant nuclides, and operating history. The history of the installed Ni specimens irradiated was 10 days within 2 weeks operation time except holidays. The total irradiation time was approximately 16 minutes and then later specimens were cooled for 2 weeks.

As a result of calculation, major radionuclides produced from Ni specimens were ^{58}Co, ^{63}Ni, ^{55}Fe, ^{59}Ni, ^{58}Ni and ^{58}Co was the most dominant nuclide with the percentage of 98.9 %. Tendency of activity of ^{58}Co is showed in Fig. 1 as time step.

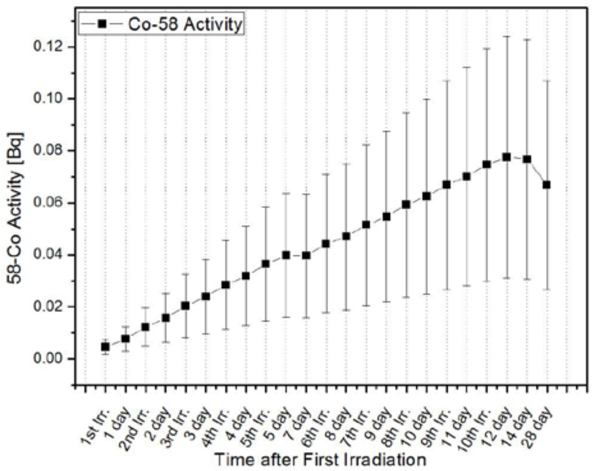


Fig. 1. Activity of ^{58}Co of Ni specimen as time step.

2.3 Ni specimens

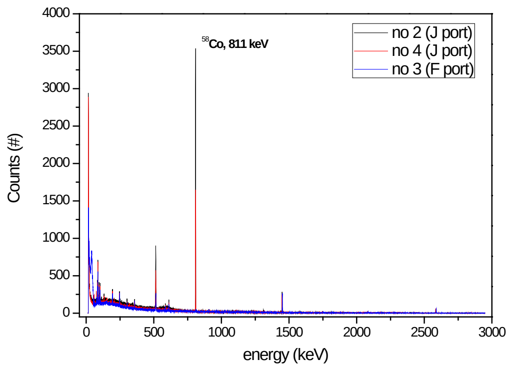
For the experiment of activation with neutron from D-D reaction, selection of specimen is very important. Ni was chosen as a specimen for the reason of n-p reaction which is Ni^{58} (n, p) Co^{58} to monitor the activation of outside of cryostat. The reaction has the half-life of 71 d and Co^{58} emits 0.811 MeV gamma ray [2]. Ni specimen was composed of three isotopes, 68 % of Ni^{58}, 26 % of Ni^{60} and 6 % of Ni^{62}.

The specimens were first polished with 600, 1,200 and 2,000 grit sandpaper for uniform irradiation and encapsulated in polyethylene case to be installed with 3 mm × 3 Φ geometry. Encapsulated specimens were installed at J, F port.

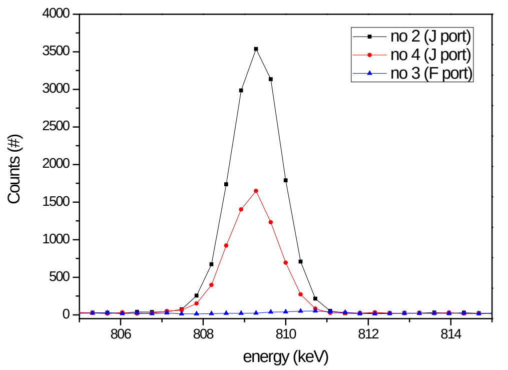
2.4 Activity Experiment

The measurement of activity of installed specimens to monitor the activation was conducted with HPGe for 0.811 MeV gamma ray of Co^{58}. Efficiency calibration was conducted ahead of measurement with a disc source of Mn^{54} which emits 834.8 keV gamma ray and the simulation was conducted with MCNP for comparison. The result of simulation was 4.8 % and relative efficiency is 4.4 %.

Fig. 2 shows the result of activity experiment. The peak of 0.811 MeV from gamma ray of Co^{58} is shown in Fig. 2. Neutron flux calculated from the number of counts of specimen no. 2 which was installed at J port was 8.15×10^{14} #/s. In the case of specimen no. 4, calculated flux was 4.21×10^{14} #/s. Neutron flux of specimen no. 3 which was installed at F port was measured as 1.32×10^{13} #/s.



(a) Range of overall energy



(b) Range of similar energy to ^{58}Co peak

Fig. 2. Counts of gamma ray with HPGe according to energy.

Although no. 2 and no. 4 were installed at the same port of J, the difference in neutron flux is due to the position of specimen no. 2 which is closer to the center.

2.5 Mapping contaminated outside of vessel

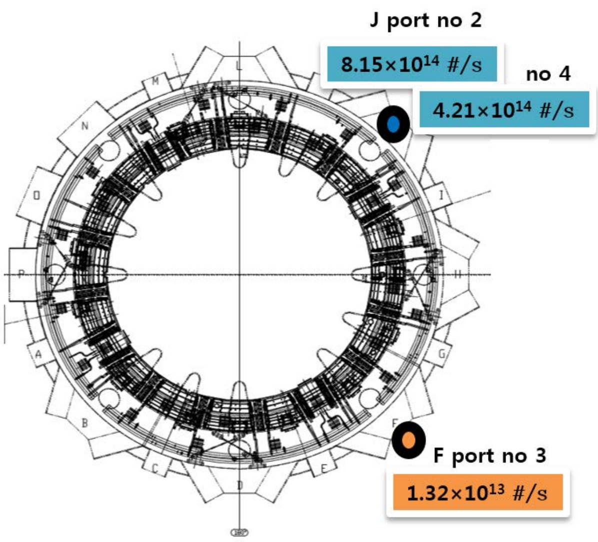


Fig. 3. Mapping of contaminated outside of vessel.

Based on the result of experiment, Fig. 3 shows the flux distribution of outer vessel of the KSTAR. It is needed to update with additional experiments.

3. Conclusions

In this study, the analysis of activation at the outside of KSTAR tokamak was conducted with simulations using MCNP and FISPACT code, and experiment using Ni specimens and HPGe. Inventory of radionuclides from Ni with neutron produced from D-D reaction was calculated in particular operation and cooling time and Co^{58} was the dominant nuclide from Ni specimen. The results of measurement with HPGe for specimen no. 2, no. 4, and no. 3 were 8.15×10^{14} #/s, 4.21×10^{14} #/s and 1.32×10^{13} #/s respectively. Results showed that the contamination by activation influenced by the neutron energy and flux distribution. Therefore, these results can show that contamination rate differs with the position.

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REFERENCES

[1] M. S. Cheon, Y. S. Lee, A.C. England, H. S. Kim, S. Pak, C. R. Seon and H. G. Lee, Diagnostic neutron activation system for KSTAR, Journal of Instrumentation, Volume 7, 2012.
[2] R. Prokopowicz, M. Scholz, A. Szydlowski, S.Popovichev and JET EFDA contributors, Measurements of Neutron Yield from Deuterium Plasmas at JET by Activation Techniques, AIP Conference Proceedings (2008).